TECHNICAL DOCUMENTS

IDFS, INC. POWER PROJECT

IN

TEXAS URBAN TRIANGLE

NOTE: This Document is preliminary.

PART ONE: PREAMBLE AND OUTLINE

1. **INTRODUCTION:** The preliminary **Scope Document or Statement** is the listing of the tasks to be done to the required quantity, quality, and variety, in the time and with the resources available and agreed upon, and the modification of those variable constraints by dynamic flexible juggling in the event of changed circumstance called as scope creep.

   This section of the Documentation will consist of the outline of the preliminary **Scope Statement** of the whole project. **Scope statements** can take many forms depending on the type of project being implemented and the nature of the organization. This preliminary scope statement will include details of the project deliverables and describes the major objectives of the overall project.

   This portion of the document will also include a preliminary, but more detailed, outline of the scope of **Phase One** of the **IDFS, INC.** power project. This section will also include some of the scope of the **Green/Sustainable** portions of the Power Project to be built in Matagorda County, Texas.

   Phase One is the creation of an Independent Power Production Company in the State of Texas and the licensing, construction and startup of a 560-600 MWe, Combined Cycle Power plant to be located in the vicinity of Bay City, Matagorda County, Texas.

2. **SUSTAINABILITY:** The **Green/Sustainable** portions of the project shall consist of the following:
   - Design, permit and build one 100 MWe Solar Farms in South Texas on the same property as the Combined-cycle power plant.
   - Design, permit and build one 100 MWe Wind Farms in South Texas on the same property as the Combined-cycle power plant.
   - Developing a synchronization and phase balancing technology to allow more wind and solar energy on the Texas Grid.
   - Research and development of new **carbon Sequestration technologies**
     - **a.** Conversion of Carbon dioxide into syngas using the **Fischer-Trope** process.
     - **b.** Conversion of Carbon Dioxide into limestone

PART TWO: OVERALL SCOPE

1. **Project Definition: IDFS, Inc.,** a Texas Corporation, wholly owned by the Senior Engineer of **AscenTrust,** is the Corporate Entity which will be registered with the **Public Utility Commission** of the State of Texas. We are seeking funding in the amount of **$2,000,000,000.00 (Two Billion Dollars American).** The preliminary **Scope** will be outlined below:
   - **a. Independent Power Production Facility:** The first phase of the project shall consist of the Engineering, Procurement, Construction and start-up of two **FRAME-7FA,** 171 MWe, natural gas fired turbine combined with a single heat recovery unit (**HRSG**) for a combined production of 560-640 MWe of power to be tied to the grid in the vicinity of the **South Texas Nuclear Power Plant.** All of the project documentation, procedures, specifications, contracts and design manuals for

this facility will be re-usable in all sites. We intend to build the first facility as a prototype which can be used to create a power production facility.

b. Renewable Component of the overall project:

- Design, permit and build one 100 MWe Solar Farms in South Texas on the same property as the Combined-cycle power plant.
- Design, permit and build one 100 MWe Wind Farms in South Texas on the same property as the Combined-cycle power plant.
- Developing a synchronization and phase balancing technology to allow more wind and solar energy on the Texas Grid.

c. Grid synchronization and installation of FACTS Controllers: The grid synchronization portion of the project shall consist of the Engineering, Procurement, Construction and installation of a **fiber-optic** communication network interconnecting all of our production facilities with the central dispatch center in **Bay City.** The fiber network will be used to carry the valuable **SCADA** information and control to our monitoring and dispatch center. It should be understood that our dispatch center has to co-ordinate with **ERCOT** for access to the **Texas Urban Triangle** portion of the Grid.

2. Project Owner and EPC Engineering contractor

The corporate entity for which this feasibility study is being prepared is **International Diversified Financial Services, Inc. IDFS, Inc.** will be the single point of ownership for all the Corporate Entities outlined in this document. It will also be the single point of contact of the project with the **Funding Entity.**

The Business planning, Feasibility study, Scope Documents, Front-End Engineering and Design, Project Management, contract Management and construction Management will be provided by **AscenTrust, LLc.**

3. Mission Statement: The mission Statement for this project will be outline presently as we move forward on the production and elucidation of the **Feasibility Study.**

a. The Mission Statement needs to include **Economic Development zone** for R&D research for frequency stability etc.

b. The Mission Statement needs to include eliminating coal-fired power plants in the state of Texas.

c. The Mission Statement needs to include language about Security and monitoring for the **Covid-19 Virus.**

4. Code of Conduct: A preliminary code of conduct has been developed for the employees, vendors and strategic partners of **IDFS, Inc.** This code of Conduct is attached to this document as **Appendix C.**

5. Feasibility Study: The **Feasibility Study will consist of the following Sections:**

SECTION ONE: NOTICE TO INVESTORS

This section will be used to provide mandatory disclosures to the **Funding Entity.** The Funding Entity should make their own investigations and evaluations of the merits and risks involved in this proposed **Energy Project.**

SECTION TWO: EXECUTIVE SUMMARY

This section will contain the **Executive Summary** of the first phase of our Texas Energy Project. **IDFS, INC.** is seeking funding in the amount of **$2,000,000,000.00 (Two Billion Dollars American)** for a total energy production of 800 MWe on a single piece of Property in Matagorda County, Texas.

SECTION THREE: NEEDS ANALYSIS

This section of the **Feasibility Study** will provide the background required The answer to the question (**Why does the Texas Triangle need another Combined-Cycle Power Plant?)** will be formulated first in this feasibility study. The urgent need for additional electrical power production will obviate our need for a detailed marketing plan. Instead we will present the plan which is already in motion to allow **IDFS, INC.** to create an **Independent Power Producer**

This section of the document will begin with a close look at the **Demographics** of the State of Texas and in particular the demographics of The Texas Triangle. The Texas Triangle is composed of the Dallas-Fort Worth Metroplex at the northern tip; Houston at the southeast corner; and Austin-San Antonio at the southwest corner.

The needs analysis will then consider the Energy demands and the growth rate of this demand in the Texas Urban Triangle of Texas. From this growth rate we will see that the Texas Triangle will require an additional two gigawatts of electrical production in the next two years. This requirement does not include any additional requirements from the closure of any operating coal-fired electrical production facilities.

SECTION FOUR: SCOPE DOCUMENT

This section of the document is the **Scope** Document.

SECTION FIVE: STRATEGIC PARTNERS (Utilities)

This section will provide a synopsis of the major Utilities involved in the production and distribution of electrical power in the **Texas Urban Triangle** of the State of Texas. These Utilities will become important to **IDFS** as it acquires access to the grid and becomes a qualified supplier of electricity to the Grid. The Grid in Texas is controlled by **ERCOT** and the **Public Utility Commission** of the State of Texas.

SECTION SIX: REGULATORY AGENCIES WITH JURESDICTION

This section will be used to identify the regulatory Agencies which have Jurisdiction over our projects in the **Texas Urban Triangle** of the State of Texas.

SECTION SEVEN: STANDARDS ORGANIZATION AND STANDARDS TO BE USED

This section will be used to identify the major standards organization which will be mentioned in any of the specific documentation concerning the licensing, project management and construction of these various power production facilities.

SECTION EIGHT: TECHNICAL FEASIBILITY (FRONT END ENGINEERING AND DESIGN)

This section will be used to outline the structure of phase one of the total project: The 560-600 MWe power plant in Matagorda County, Texas

A. System Layout (Turbine-generator physical layout)
B. System Layout (Electrical One-line diagram)
C. System Layout (Computer system, Servers, SCADA system, Security Systems and Corona Virus Mitigation via temperature monitoring.
D. Environmental Report
E. Storm Water Pollution Prevention Plan
F. Site Development Permit
G. Construction Permitting
H. Application to become an **Independent Power Producer** in Texas
I. Application for a Grid Upgrade Survey
J. Application for Environmental Permit for Power Plant.
K. Site and Building Site Survey.
L. Equipment Selection
M. Utility Design
N. Building Plans
O. Application to become our own Utility District (Water and Sewer)
P. Application to Connect to the Existing Natural Gas Pipeline

SECTION NINE: TECHNICAL FEASIBILITY (CONSTRUCTION)

This section will be used to outline the components of the physical construction and to address the Environmental and regulatory risks involved in a power project in Texas. Some of the basic items to be included in this section are:

A. Civil Work.
B. Foundations and underpinning
C. Structural Steel
D. Mechanical Systems
E. Electrical Systems
- a. Upgrade transmission line to STPP Highline
- b. Build Substation at new Power Plant
- c. Underground electrical System from Power Plant to Substation
- d. All commercial and industrial wiring required

F. SCADA Systems (Supervisory Control and Data Acquisition)
G. Water and Sewer Systems
H. Natural Gas Pipeline Interconnect
I. Safety and Environmental Considerations
J. Regulatory Approvals and clearances required to connect to **ERCOT**
K. Application for a Grid Upgrade Survey
L. Preliminary Construction Disbursement Schedule

SECTION TEN: PROJECT MANAGEMENT STRUCTURE OF PROJECT

This section will outline the Project Management structure of the total project within the Corporate boundary. There are two distinct part to the Corporate and Project Management relationships between **IDFS, INC.** and **AscenTrust, LLC.** This section will also provide an outline of the structural relationships between the project Corporate Entities and the regulatory entities of the State of Texas.

SECTION ELEVEN: CORPORATE STRUCTURE AND TEAM FOR IDFS,INC.

This section will be used to outline the Corporate team structure of the total project within the Corporate and regulatory boundaries.

SECTION TWELVE: RESPONSIBILITIES OF ASCENTRUST, LLC.

This section will be used to outline the overall responsibilities of **AscenTrust.** The Engineering staff and Consultants of **AscenTrust** are responsible for the production of this **Feasibility Study** and will manage all aspects of the project initiation which will involve the acquisition of properties, **FEED** (Front End Engineering and Design), licensing and regulatory issues.

SECTION THIRTEEN: MANPOWER REQUIREMENTS

This section will address the overall manpower requirements and the methodology to be used to access the expertise required to bring the multiplicity of projects to a successful end.

SECTION FOURTEEN: FINACIAL DATA AND EXIT STRATEGY

This section will include a summary of the financial data which will be attached to this feasibility study, in **Appendix-Six** of the attached **Appendix.**

SECTION FIFTEEN: APPENDIX

This section is actually an attachment to the **Feasibility Study** but it is included with the document because it contains all the supporting documents required to make our case in the text of the document.

6. Project Plan: The **project plan** is a formal, approved document used to guide both **project execution** and **project control.** The primary uses of the project plan are to document planning assumptions and decisions, facilitate communication among *project stakeholders*, and document approved scope, cost, and schedule *baselines*

The latest edition of the PMBOK (Project Management Book of Knowledge) uses the term *project charter* to refer to the contract that the project sponsor and project manager use to agree on the initial vision of the project (scope, baseline, resources, objectives, etc.) at a high level. In the PMI methodology described in the PMBOK v5, the project charter and the project management plan are the two most important documents for describing a project during the initiation and planning phases.

AscenTrust, LLc. will creates the **project management plan** following input from the project manager of **IDFS, Inc.** team and key project stakeholders. The plan should be agreed and approved by at least the project team and its key stakeholders.

Plan contents: To be a complete project plan according to industry standards such as the PMBOK or PRINCE2, the project plan must also describe the execution, management and control of the project. This information can be provided by referencing other documents that will be produced, such as a procurement plan or construction plan, or it may be detailed in the project plan itself.

The project plan typically covers topics used in the project execution system and includes the following main aspects:

- Scope management
- Requirements management
- Schedule management
- Financial management
- Quality management
- Resource management
- Stakeholder management
- Communications management
- Project change management
- Risk management

In addition to the creation of a complete project plan according to industry standards for each of the production facilities the project plan shall include at a minimum the following specialized plans:

- Change Management Plan
- Communication Management Plan
- Cost Management Plan
- Procurement Management Plan
- Project Scope Management Plan
- Schedule Management Plan
- Quality Management Plan
- Risk Management Plan
- HR/Staffing Management Plan

7. Manuals

a. Design Manuals: A **Design Manual** is a plan or specification for the construction of an object or system or for the implementation of an activity or process, or the result of that plan or specification in the form of a prototype, product or process. The design manual has to provide a set of guidelines and provide boundaries in the form of goals and constraints. The design Manual shall take into account aesthetic, functional, economic, environmental and socio-political considerations. The following is a list of the most important **Design Manuals** which will be incorporated into this **Feasibility Study** as a separate attachment

- Power Plant Design Manual
  - ❖ Combined-Cycle, Natural Gas fired Power Plant Design Manual
  - ❖ Solar Farm Design Manual
  - ❖ Wind Farm Design Manual
- Substation Design Manual
- High Voltage Transmission Line Design Manual
- Land Development Design Manual
- Utilities Design Manual

b. Operational Manual: The **operations manual** is the documentation by which an organization provides guidance for members and employees to perform their functions correctly and reasonably efficiently. It documents the approved standard procedures for performing operations safely to produce goods and provide services. Compliance with the operations manual will generally be considered as activity approved by the persons legally responsible for the organization.

The operations manual is intended to remind employees of how to do their job. The manual is either a book or folder of printed documents containing the standard operating procedures, a description of the organizational hierarchy, contact details for key personnel and emergency procedures. It does not substitute for training, but should be sufficient to allow a trained and competent person to adapt to the organization's specific procedures.[4]

The operations manual helps the members of the organization to reliably and efficiently carry out their tasks with consistent results. A good manual will reduce human error and inform everyone precisely what they need to do, who they are responsible to and who they are responsible for. It is a knowledge base for the organization, and should be available for reference whenever needed. The operations manual is a document that should be periodically reviewed and updated whenever appropriate to ensure that it remains current.

Contents: Content will vary depending on the organization, but some basic structure is fairly universal. Typical sections include:

- Organizational hierarchy
- Job descriptions
- Contact details
- Documented processes and systems
- Occupational health and safety instructions
- Emergency procedures
- Company History
- Products & Services
- Policies and position statements

There are two basic categories of information: Information that is relevant to all people in the organization, and often also to clients and the general public, and information that is relevant to specific positions.

There may be statutory or regulatory requirements for specific content. In some cases the CEO may be required to authorize the operations manual by signature, and this authorization may be required to be present in the document. A version number and date of commencement may be required, and it may be a controlled document.

Bay City and the surrounding areas of Matagorda County are targeted for the first **Combined-cycle Power Plant** and the Global Corporate Office of **IDFS, INC.**

- The Company will design and build an Annex to the existing Wharton Community College to train the employees of the Power Plant and the Molten Metal Syngas production facility.

- The created Corporations will all be resident of the Corporate Office located in the Bay City Wharton Community College Building
- The Company will provide temporary housing for the construction of the Power Plant and the Syngas facilities.
- The company will develop an **Economic Development Plan** with the Bay City official for the re-invigoration of Matagorda County. This project will include downtown redevelopment of Bay City as well as the construction of a substantial number of new homes to accommodate the influx of trained individuals to operate the Research and Development projects and the Power Plant.
- Matagorda County is designated as an **Opportunity Zone:**

  An **Opportunity Zone** is a designation and investment program created by the Tax Cuts and Jobs Act of 2017 allowing for certain investments in lower income areas to have tax advantages. The purpose of this program is to put capital to work that would otherwise be locked up due to the asset holder's unwillingness to trigger a capital gains tax.

  To qualify, the Opportunity Fund must invest more than 90% of its assets in a Qualified Opportunity Zone Property located in an Opportunity Zone. The property must be significantly improved, which means it must be an original use, or the basis of the property must be double the basis of the non-land assets. Capital gain taxes are deferred for investments reinvested into investments in these zones and, if the investment is held for ten years, all capital gains on the new investment are waived. Opportunity zones are census tracts designated by state authorities.

8. COMPUTERS, SERVERS, DATABASES AND IT-INFRASTRUCTURE

a. Computers

A **computer** is a machine that can be instructed to carry out sequences of arithmetic or logical operations automatically via computer programming. Modern computers have the ability to follow generalized sets of operations, called *programs.* These programs enable computers to perform an extremely wide range of tasks. A "complete" computer including the hardware, the operating system (main software), and peripheral equipment required and used for "full" operation can be referred to as a **computer system**.

Computers are used as control systems for a wide variety of industrial and consumer devices. This includes simple special purpose devices like microwave ovens and remote controls, factory devices such as industrial robots and computer-aided design, and also general purpose devices like personal computers and mobile devices such as smartphones. The Internet is run on computers and it connects hundreds of millions of other computers and their users.

The first digital electronic calculating machines were developed during World War II. The first semiconductor transistors in the late 1940s were followed by the silicon-based MOSFET (MOS transistor) and monolithic integrated circuit (IC) chip technologies in the late 1950s, leading to the microprocessor and the microcomputer revolution in the 1970s. The speed, power and versatility of computers have been increasing dramatically ever since then, with MOS transistor counts increasing at a rapid pace (as predicted by Moore's law), leading to the Digital Revolution during the late 20th to early 21st centuries.

Conventionally, a modern computer consists of at least one processing element, typically a central processing unit (CPU) in the form of a metal-oxide-semiconductor (MOS) microprocessor, along with some type of computer memory, typically MOS semiconductor memory chips. The processing element carries out arithmetic and logical operations, and a sequencing and control unit can change the order of operations in response to stored information. Peripheral devices include input devices (keyboards, mice, joystick, etc.), output devices (monitor screens, printers, etc.), and input/output devices that perform both functions (e.g., the 2000s-era touchscreen). Peripheral devices allow information to be retrieved from an external source and they enable the result of operations to be saved and retrieved.

b. Computer Networks: A **computer network** is a group of computers that use a set of common communication protocols over digital interconnections for the purpose of sharing resources located on or provided by the network nodes. The interconnections between nodes are formed from a broad spectrum of telecommunication network technologies, based on physically wired, optical, and wireless radio-frequency methods that may be arranged in a variety of network topologies.

The nodes of a computer network may be classified by many means as personal computers, servers, networking hardware, or general-purpose hosts. They are identified by hostnames and network addresses. Hostnames serve as memorable labels for the nodes, rarely changed after initial assignment. Network addresses serve for locating and identifying the nodes by communication protocols such as the Internet Protocol.

Computer networks may be classified by many criteria, for example, the transmission medium used to carry signals, bandwidth, communications protocols to organize network traffic, the network size, the topology, traffic control mechanism, and organizational intent.

Computer networks support many applications and services, such as access to the World Wide Web, digital video, digital audio, shared use of application and storage servers, printers, and fax machines, and use of email and instant messaging applications.

- **Local Area Network**
  A **local area network** (**LAN**) is a computer network that interconnects computers within a limited area such as a residence, school, laboratory, university campus or office building.[1] By contrast, a wide area network (WAN) not only covers a larger geographic distance, but also generally involves leased telecommunication circuits.

  Ethernet and Wi-Fi are the two most common technologies in use for local area networks.

- **Fiber Optic Synchronization Network**

  Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of infrared light[1] through an optical fiber. The light is a form of carrier wave that is modulated to carry information.[2] Fiber is preferred over electrical cabling when high bandwidth, long distance, or immunity to electromagnetic interference is required.[3] This type of communication can transmit voice, video, and telemetry through local area networks or across long distances.[4]

Optical fiber is used by many telecommunications companies to transmit telephone signals, Internet communication, and cable television signals. Researchers at Bell Labs have reached internet speeds of over 100 petabit × kilometer per second using fiber-optic communication.[5]

Optical fiber is used by telecommunications companies to transmit telephone signals, Internet communication and cable television signals. It is also used in other industries, including medical, defense, government, industrial and commercial. In addition to serving the purposes of telecommunications, it is used as light guides, for imaging tools, lasers, hydrophones for seismic waves, SONAR, and as sensors to measure pressure and temperature.

Due to lower attenuation and interference, optical fiber has advantages over copper wire in long-distance, high-bandwidth applications. However, infrastructure development within cities is relatively difficult and time-consuming, and fiber-optic systems can be complex and expensive to install and operate. Due to these difficulties, early fiber-optic communication systems were primarily installed in long-distance applications, where they can be used to their full transmission capacity, offsetting the increased cost. The prices of fiber-optic communications have dropped considerably since 2000.

The price for rolling out fiber to homes has currently become more cost-effective than that of rolling out a copper-based network. Prices have dropped to $850 per subscriber in the US and lower in countries like The Netherlands, where digging costs are low and housing density is high.

Since 1990, when optical-amplification systems became commercially available, the telecommunications industry has laid a vast network of intercity and transoceanic fiber communication lines. By 2002, an intercontinental network of 250,000 km of submarine communications cable with a capacity of 2.56 Tb/s was completed, and although specific network capacities are privileged information, telecommunications investment reports indicate that network capacity has increased dramatically since 2004.

c. **Servers:** In computing, a **server** is a piece of computer hardware or software (computer program) that provides functionality for other programs or devices, called "clients". This architecture is called the client–server model. Servers can provide various functionalities, often called "services", such as sharing data or resources among multiple clients, or performing computation for a client. A single server can serve multiple clients, and a single client can use multiple servers. A client process may run on the same device or may connect over a network to a server on a different device.[1] Typical servers are database servers, file servers, mail servers, print servers, web servers, game servers, and application servers.

Client–server systems are today most frequently implemented by (and often identified with) the request–response model: a client sends a request to the server, which performs some action and sends a response back to the client, typically with a result or acknowledgment. Designating a computer as "server-class hardware" implies that it is specialized for running servers on it. This often implies that it is more powerful and reliable than standard personal computers, but alternatively, large computing clusters may be composed of many relatively simple, replaceable server components.

d. Databases: A **database** is an organized collection of data, generally stored and accessed electronically from a computer system. Where databases are more complex they are often developed using formal design and modeling techniques.

The database management system (DBMS) is the software that interacts with end users, applications, and the database itself to capture and analyze the data. The DBMS software additionally encompasses the core facilities provided to administer the database. The sum total of the database, the DBMS and the associated applications can be referred to as a "database system". Often the term "database" is also used to loosely refer to any of the DBMS, the database system or an application associated with the database.

Computer scientists may classify database-management systems according to the database models that they support. Relational databases became dominant in the 1980s. These model data as rows and columns in a series of tables, and the vast majority use SQL for writing and querying data. In the 2000s, non-relational databases became popular, referred to as NoSQL because they use different query languages.

e. Content Management System: The creation and maintenance of the Content management system for the **IDFS** Project is one of its most critical components. We intend the content management system to reside on a Linux cluster powered by Dell Server Blades. The **User Interface (UI)** to be used will be a Free Software Foundation **Integrated Software Development (IDE)** environment created by **IBM** in the late nineties called **Eclipse.** Eclipse is a Java powered IDE which is easily extended. Eclipse has been extended to develop code in Fortran, Ada and Lisp. The secure portions of the system will ultimately be carried on optical fiber only without the use of **TCP/IP.**

The content management system, the Project information, the Project Documentation and the CAD files will all be generated under the corporate name of **Advanced Software Development, Inc., (ASD).**

ASD will also develop the Web sites and the communication infrastructure between the various vendors, Manufacturing facilities, Turbineers and Scientists. The protocol for electronic communications between vendors will be XML. We are not going to be interfacing with X25 and the old EDI transaction sets.

f. SCADA/ FACTS Controllers

1. Supervisory control and data acquisition (**SCADA**) is a control system architecture comprising computers, networked data communications and graphical user interfaces (GUI) for high-level process supervisory management, while also comprising other peripheral devices like programmable logic controllers (PLC) and discrete proportional-integralderivative (PID) controllers to interface with process plant or machinery. The use of SCADA has been considered also for management and operations of project-driven-process in construction.

2. A **flexible alternating current transmission system** (**FACTS**) is a system composed of static equipment used for the alternating current (AC) transmission of electrical energy. It is meant to enhance controllability and increase power transfer capability of the network. It is generally a power electronics-based system.

FACTS is defined by the Institute of Electrical and Electronics Turbineers (IEEE) as "a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability".

According to Siemens, "FACTS Increase the reliability of AC grids and reduce power delivery costs. They improve transmission quality and efficiency of power transmission by supplying inductive or reactive power to grid.

9. MANPOWER ORGANIZATION

PART SEVEN: PROPOSED POWER PLANT

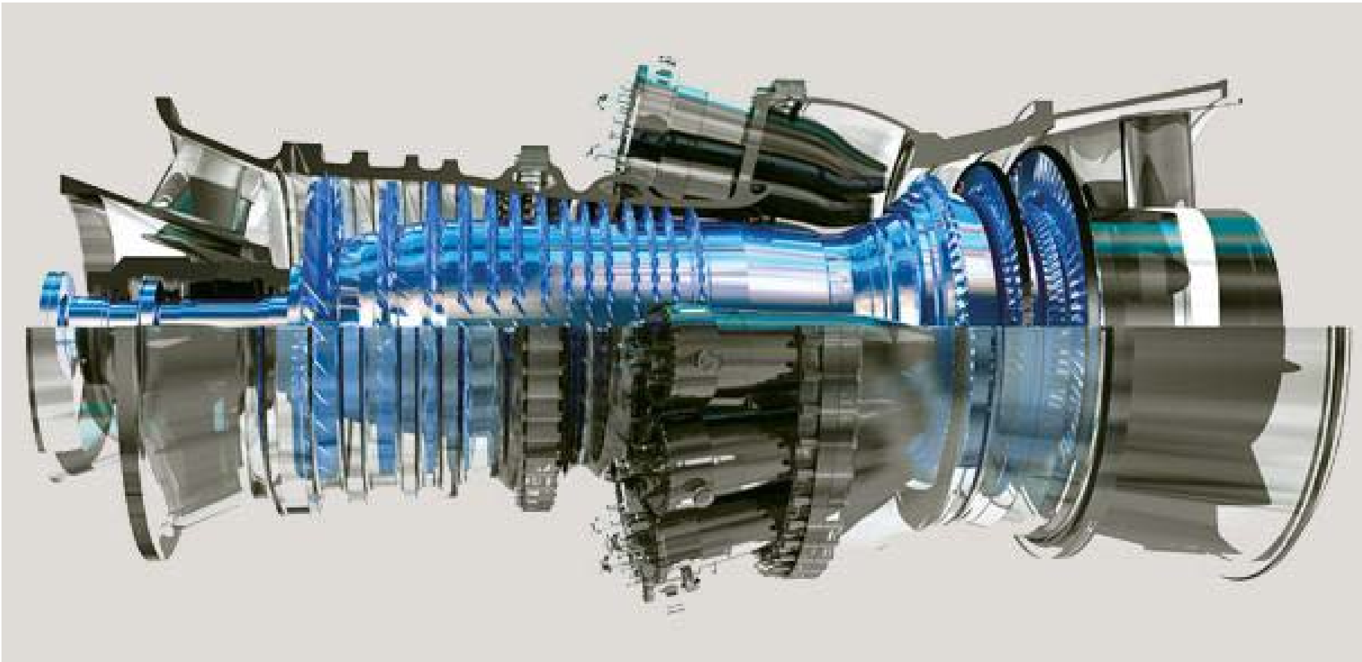
1. The Power Production Facilities: The Company will create an Independent Power Producer in the State of Texas to be Incorporated under the name **Matagorda Power, Inc**.

The Company proposes to build an Electrical Generation Power Plant on a property located in the vicinity of the **South Texas Nuclear Project**, located in Matagorda County Texas. The plant will ultimately consist of two GE Frame 7FA natural gas fired turbine power generating plant capable of producing 342 MWe of electricity. The plant will also incorporate a heat recovery unit for a total production of 560MWe. The heat recovery unit will also include heating elements to be able to increase the electrical production of the steam generation equipment by 40-80 MWe. This additional electrical production will be used for peak shaving.

2. The Turbine-generator Sets: The Power Plant site shall consist of two General Electric Frame 7F-A gas turbine-generator packages. A cross sectional view of the turbine is show below. The combustion turbines will be fired on natural gas. Power will be exported into the high voltage transmission system coming out of the **South Texas Nuclear Project**.

- **System Duty Cycle**. The Plant will be designed for baseload service, which means it will be designed to operating in continuous duty (i.e., 720 hours/month).

CROSS-SECTION OF GENERAL ELECTRIC FRAME 7F-A, NATURAL GAS TURINE



GAS TURBINE EQUIPMENT:

- Foam suppression fire protection system.
- Evaporative cooler on the gas turbine air inlets.
- Diesel starter systems.
- Black start capability if required
- Water injection.
- New blade coatings.
- Standard combustion.
- Minimum of 5 years of service before the next major overhaul.
- Four-stage turbine for moderate stage loading
- Low NOX combustion system for reduced environmental impacts
- Cold end generator drive for increased efficiency
- Two-bearing rotor for simplified rotor alignment
- Variable inlet guide vanes for improved efficiency
- All blades removable with rotor in place for easy maintenance and shorter outages

The GE FRAME 7F-A standard package comes with:

- Lube oil cooler
- Enclosure air outlet
- Combustion air inlet
- Enclosure air inlet
- Fire and gas system
- On-package controls
- Core engine
- Combustion exhaust
- AC generator

3. Heat Recovery Steam Generator:

RENDERING OF A HEAT RECOVERY STEAM GENERATOR WITH INLINE FIRING

The **heat recovery steam generator (HRSG)** is an energy recovery heat exchanger that recovers heat from the hot gas stream which forms the exhaust from the two Natural Gas Turbines. The steam created from this exhaust heat is used to drive a steam turbine (combined cycle).

The HRSGs consist of four major components: the economizer, evaporator, superheater and water preheater. The different components are put together to meet the operating requirements of the unit.

The **HRSG** shall include supplemental, or duct firing. These additional burners provide additional energy to the HRSG, which produces more steam and hence increases the output of the steam turbine. Generally, duct firing provides electrical output at lower capital cost. It is therefore often utilized for peaking operations.

4. **Switchyard.** The gas turbines will operate at 13,800VAC, 60Hz, 3 phase. The Company will purchase and install three new or used generator step up transformers (GSUs) to meet **ERCOT** power delivery requirements, which are assumed to be 34.5 kV. It should be noted that this assumption is subject to change based on feedback from **ERCOT** after The Company submits its application for interconnection and an interconnect study has been completed.

TYPICAL 13.8kv TO 34.5kv TRANSFORMING SUBSTATION

5. **INTERCONNECT:** Picture below is of a medium voltage (34.5kv) transmission line to bring our generated power to the **South Texas Nuclear Project,** high voltage transmission node.

6. **INTERCONNECT:** Picture below is the high lines leaving the **South Texas Nuclear Project**

7. **Natural gas interconnection.** The existing pipelines on the production facility site will be interconnected to provide the required natural gas to only be up-graded if required by the **OEM.**

8. **Emissions to air.** The Plant will generate emissions to air, including nitrogen oxides (NOx), carbon monoxide (CO) and volatile organic compounds (VOC). Since the Plants will not be located in the Houston-Galveston-Brazoria ozone non-attainment area, it will not be subject to a stringent level of air quality regulatory oversight relating to NOx, CO, and VOC emissions. The Company still intends to limit these emissions to "minor source" levels, which are:

   - **a.** NOx: <25 tons per year
   - **b.** CO: <100 tons per year
   - **c.** VOC: <25 tons per year

9. **Water requirements**. Since there will be a constant loss of cycle water for one reason or another, it will be necessary to have a continual source of incoming water. The Company estimates its water requirements will be approximately 50 gpm. The Company will purchase a new or used makeup water treatment system sized at [65] gpm to serve the Market of the power plant. The Company will purchase the required water from Entergy Texas.

10. **Wastewater discharge system**. The Company estimates that wastewater discharges from plant operations will be approximately 4 gpm.

16. SCOPE OF: Grid synchronization and FACTS Controllers

A. Definitions:

a. Synchronization: In an alternating current electric power system, **synchronization** is the process of matching the speed and frequency of a generator or other source to a running network. An AC generator cannot deliver power to an electrical grid unless it is running at the same frequency as the network. If two segments of a grid are disconnected, they cannot exchange AC power again until they are brought back into exact synchronization. An AC generator must match both the amplitude and the timing of the network voltage, which requires both speed and excitation to be systematically controlled for synchronization.

b. FACTS Controllers: FACTS is defined by the Institute of Electrical and Electronics Turbineers (IEEE) as "a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability".

B. Synchronization

a. Conditions: There are five conditions that must be met before the synchronization process takes place. The source (generator or sub-network) must have equal line voltage, frequency, phase sequence, phase angle, and waveform to that of the system to which it is being synchronized..

Waveform and phase sequence are fixed by the construction of the generator and its connections to the system. During installation of a generator, careful checks are made to ensure the generator terminals and all control wiring is correct so that the order of phases (phase sequence) matches the system. Connecting a generator with the wrong phase sequence will result in a short circuit as the system voltages are opposite to those of the generator terminal voltages.

The voltage, frequency and phase angle must be controlled each time a generator is to be connected to a grid.

Generating units for connection to a power grid have an inherent droop speed control that allows them to share load proportional to their rating. Some generator units, especially in isolated systems, operate with isochronous frequency control, maintaining constant system frequency independent of load.

b. Process: The sequence of events is similar for manual or automatic synchronization. The generator is brought up to approximate synchronous speed by supplying more energy to its shaft - for example, opening the valves on a steam turbine, opening the gates on a hydraulic turbine, or increasing the fuel rack setting on a diesel turbine. The field of the generator is energized and the voltage at the terminals of the generator is observed and compared with the system. The voltage magnitude must be the same as the system voltage.

If one machine is slightly out of phase it will pull into step with the others but, if the phase difference is large, there will be heavy cross-currents which can cause voltage fluctuations and, in extreme cases, damage to the machines.

c. **Scope of Synchronization:** The scope of the synchronization portion of the project will have long range impact on the stability of the grid in the **Texas Urban Triangle** of Texas. The preliminary scope is to interconnect the two Nuclear Power production facilities in the Urban Triangle via optical fiber. This will allow us to synchronize the two power production facilities to one part in 10^3.

C. **FACTS Controllers:**

a. **Introduction:** A **flexible alternating current transmission system** (**FACTS**) is a system composed of static equipment used for the alternating current (AC) transmission of electrical energy. It is meant to enhance controllability and increase power transfer capability of the network. It is generally a power electronics-based system.

FACTS is defined by the Institute of Electrical and Electronics Turbineers (IEEE) as "a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability".

According to Siemens, "FACTS Increase the reliability of AC grids and reduce power delivery costs. They improve transmission quality and efficiency of power transmission by supplying inductive or reactive power to grid.

b. **Shunt compensation:** In shunt compensation, power system is connected in shunt (parallel) with the FACTS. It works as a controllable current source. Shunt compensation is of two types:

1. **Shunt capacitive compensation:** This method is used to improve the power factor. Whenever an inductive load is connected to the transmission line, power factor lags because of lagging load current. To compensate, a shunt capacitor is connected which draws the current leading the source voltage. The net result is improvement in power factor.
2. **Shunt inductive compensation**: This method is used either when charging the transmission line, or, when there is very low load at the receiving end. Due to very low, or no load & nbsp;– very low current flows through the transmission line. Shunt capacitance in the transmission line causes voltage amplification (Ferranti effect). The receiving end voltage may become double the sending end voltage (generally in case of very long transmission lines). To compensate, shunt inductors are connected across the transmission line. The power transfer capability is thereby increased depending upon the power equation

PART THREE: SCOPE OF FIRST DESIGN-BUILD PROJECT

SUB-PART ONE: GENERAL

1. International Diversified Financial Systems (IDFS) will sign a Design-Build Power Plant Building and Facilities from a contractor and/or professional consulting and Engineering firm with experience in Design (including Architectural & Engineering) and Build (constructing) Diesel Generating Power Plants and related facilities. The New Power Plant Building and related facilities will be situated next to the old Bay City Power Plant location as designated by the land area outlined in the map and diagrams in the Exhibits section.

2. The selected EPC Contractor will develop detailed design from a pre-designed conceptual layout of 23 MW diesel turbine power plant building which consists of seven (7) each GE16V250GSU Diesel generators & all associated auxiliary equipments, two (2) each, black start generators, 480V, 13.2 kV switchgears, distribution to feeders of 13.2 kV power grid system with a centralized control room and related facilities for the smooth operation of the plant. All local and federal required Permits for Design and Construction of the 23 MW Power Plant and its ancillary structures, cable trenches/runs between the power plant and the existing distribution grid for underground transmission, and distribution lines must be complied with and be included. The Generator, Switchgear, and Auxiliary equipment information and layout will be provided to the EPC contractor.

3. The selected EPC Contractor will construct the Bay City Power Plant Electrical Earth/Ground Grid System as per design specification for Generators, Switchgear & Auxiliaries as listed in Exhibit 7 page 4.

4. The proposed design for construction will have detailed layouts, descriptions, project schedule and costs estimates. The proposed plan will address location, size, parking, landscape, utilities, ingress and egress within the Bay City Power Plant IDFS Compound as related to the new building.

5. The Design and Build Contractor will survey, design and perform any required construction for the best cable route and layout for duct work, conduit runs, and cable runs to interconnect with the Bay City Power plant with the Bay City Medium Voltage and Low Voltage substation, and distribution grid system for all 13.2 kV Feeders.

6. The selected Design and Build Contractor will be responsible for the final detail architectural design & Engineering of the New Power Plant Building, Facility and Facility grounds to include Bulk Fuel Storage Tanks, Waste Liquid Storage Tanks, runoff water separator, etc. If required by IDFS, the Design and Build Contractor shall prepare all bid documents for the purpose of issuing the request for bid for the construction of the New Power Plant Building. All Engineering & design, selected materials and equipment are required to be submitted to IDFS project manager for final approval before actual construction.

7. The selected Design and Build Contractor will be tasked with coordinating all work with the IDFS Project Manager, and work with IDFS technical team, Generators & Switchgear supply contractor for timely completion of project as per standard best work practices with the Building Construction Contractor. The scheduled timeline for this project is part of the evaluation criteria.

8. The selected Design and Build Contractor will design the new Power Plant Building to include Noise Attenuation for the surrounding residential area. Noise level must be 65 dB or lower, measured at 10 meters from the corners of the power plant. Other design criteria should also be applied to further reduce the noise level of the plant from the residential homes nearby, such as trees/plants or other natural or man made barriers.

9. The new power plant and entire power plant facility shall include security & boundary fencing, security guard post, and security lighting.

SUB-PART TWO: SCOPE OF WORK FOR NEW POWER PLANT BUILDING

1. The EPC Contractor will be required to design the new power plant building on the proposed IDFS Bay City site, outside of the VE Zone in accordance with the map in Exhibit 2.

2. The EPC Contractor will be required to plan and design the new Bay City power plant to meet the most current industrial and local building codes as well as regulations established by Federal and local government (See page 23, Section II, Code and Design Criteria). The Bay City Power Plant design must meet all required environmental regulations and local permits.

3. The EPC Contractor shall perform the required work for site survey, soil testing, Geotech and site mapping.

4. The EPC Contractor will prepare a site layout and building design for the new Power Plant building and facility as shown in the layout provided in Exhibit 3 and Exhibit 7, page 3 for the Generators, Switchgear & Auxiliaries.

5. The Building will be designed to withstand wind loads up to 150 mph , and accommodate all the generating units, switchgears, auxiliaries, operator controller room, support staff facility, integrated with fuel, lube oil and other ancillary components, fixed overhead crane for maintenance of generators, and connections to support utilities such as water, wastewater and station service.

6. The EPC Contractor shall design the new building per Equipment Contractor's (EC) conceptual design with some modification per IDFS requirements. The EPC Contractor will design building layout with EC's recommended spacing and equipment layout, to house the following major equipment components:

- Seven (7) 3.5MW, 13.2kV, 60Hz Generators
- Two (2) 500 kW, 480 V, 60Hz Emergency Generators
- Electrical Maintenance Overhead Crane – 10 Ton
- 34.5KV & 13.2 kV and 480V Switchgear
- Motor Control Centers (MCC) for each Generator
- Earth Resistors, DC Supply and Battery system and other auxiliaries
- Other components as required for the Generators, Switchgear & Auxiliaries in conceptual drawings in Exhibit 3

7. The new Power Plant Building shall incorporate energy efficient designs and plans for electric, water and waste water utilities with out sacrificing the artistic design of the building.

8. Apart from the Generator Bay, the new Power Plant Building shall be designed into two story or floors for the control room, offices, workshops, restrooms, etc. with a basement or Ground floor for cable room for all cable runs. All offices, meeting rooms and kitchen shall be fully furnished with appropriate furnishing and appliances – desks, chairs, sinks, refrigerator, etc. The New Power Plant building floors shall be designed to accommodate the following minimum requirements (EPC contractor may also propose alternate design that is equivalent or better than IDFS's requirement – to be approved by IDFS):

   A. Ground Floor or Basement: Cabling room for HV/MV/LV; Control; LAN/FIBER & SCADA; Telephone etc.

   B. First Floor:

      a. Turbine Room: Seven (7) –GEV16250GSU, 3.5MW, 13.2 kV Gensets with generator LCPs
      - Two (2) Cummins, 500 kW, 480 V Emergency Gensets Overhead Crane – 10 tons
      - MCC Panels/CB
      - Air ventilation and circulation system for proper cooling of the power plant (ventilation intake openings should be elevated as part of flood proofing)
      - Flood proofing doorways and entry ways – entire plant building will be designed to withstand flooding and water inundation of turbine room and vital equipment rooms
      - All Entrance/Exit ways should be water tight when closed in case of flooding, but also allow for containment of any spills within the power plant

      b. Switchgear Room - located next to the Turbine floor
      - 480V Switchgear/CB
      - 13.2 kV Switchgear/CB
      - 34.5 kV Switchgear/CB
      - Auxiliaries – MCC boards, Battery chargers, Environmental Control (Air conditioning and dehumidifiers) AC, DC panels.
      - Battery Room

      c. Restroom Lockers and Showers- located next to the Turbine floor

      d. Maintenance crew room (Electrical and Mechanics) - located next to the Turbine floor

      e. Material Storage/Warehouse & Tool Room - located next to the Turbine floor

   B. Second Floor:
      a. Operator Control Room
      b. Office Room – Mgr/Supervisor
      c. Meeting Room
      d. Rest Room
      e. Kitchen

f. Public Entrance/Reception Area

C. Generator Bay viewing platform/cat walk with stairway to first floor

D. For general lighting inside and outside, the latest energy efficient lighting shall be used (for example: LED lightings)
E. Air-conditioning for the Control Room and High/Low Voltage Switchgear Room
F. Security surveillance control & monitoring with back up power supply located inside the Operator control room to monitor the entire facility
G. Building and entire facility will be located near the ocean, therefore it must be designed to withstand corrosion and tropical climate
H. Fire detection, Fire suppression system or sprinkler system and emergency exit doors
I. Americans with Disability Act (ADA) compliance where required
J. Rain water harvesting system with adequate storage tank(s) from roof drainage of the building that serves a second purpose of minimizing any runoff within the compound
K. The Operator Controller room shall have windows to allow view of the entire turbine bay. A viewing platform along the length of the second floor with stairs shall also be included outside the controller room. The Noise level inside the control room and offices shall not exceed 55dB.
L. Floors shall have adequate space to accommodate moving of desks and equipment between the first and second floor (wide & tall doorways for control room and other critical operational space).
M. A roof platform with railings with easy access for roof and ventilation maintenance.

SUB-PART THREE: FACILITIES PLAN LAYOUT

The successful EPC Contractor will also design and provide a compound plan layout and location for other support facilities for the new Power Plant Project activities to include but not limited to the following:

1. Two (2) each, 50,000 Gallon Bulk Storage Fuel Tank system with Off-loading Refueling Rack Facility; to include mass flow fuel metering, fuel management system, valves, pipe work, spill prevention, fire fighting & detection system, and all associated equipment and materials.

2. Waterlines and Wastewater Installations, including back up Water Storage Tank system for turbine cooling water, and Sludge & Waste Oil Storage Tanks with spill prevention (containment structure)

3. Station services transformers – located outside of the Power plant building; to include containment to prevent oil spills

4. Perimeter Concrete & Rock Wall

5. Oil & Water Separator System for treatment of all run-off water from power plant grounds (USEPA and US Coast Guard compliant). The new Power Plant Building and power plant grounds should have adequate containment in case of oil or fuel leak inside the power plant facility.

6. Design the Layout and install for the entire compound the lighting electrical system
7. Re-route Existing Drainage System and Construct Drainage system where required
8. Internal/External Drainage System for Fuel and Oil Spill Prevention and Runoff
9. Fuel and Lube Oil Storage & Secondary Containment Facilities
10. Parking Space with handicap parking, Security Building, and Machine Shop
11. Drainage shall be designed and constructed properly to avoid flooding of power plant building during heavy rain storms. Building foundation should be high enough to prevent flooding from runoff and heavy rains

SUB-PART FOUR: GENERATION EQUIPMENT, SWITCHGEAR, AND AUXILIARIES

1. The Successful EPC Contractor will be coordinating the New Power Plant building Design with the Equipment Contractor (EC) for the new Bay City power plant.
2. The Successful EPC Contractor will work with the EC group for any needed civil structure detail layout for the design of the generator foundation and any other required equipment foundation.
3. The Successful EPC Contractor will assist and work with the IDFS technical Staff to completely address all schedules and plans for completion of the tasks which are specified in EC's scope of work (SOW) for the Base Load Generators, Switchgear & Auxiliaries specifications as required by IDFS.

SUB-PART FIVE: DETAIL ARCHITECTURE AND DESIGN

1. The EPC Contractor shall arrange and conduct a series of meetings with the IDFS technical team during the scope design phase of the project to fully understand the specific project elements and to define the basic requirements for each of the project scope elements.
2. The EPC Contractor and IDFS shall arrange and conduct a series of meeting with the contractor for the Generator, Switchgear & Auxiliaries layout and installation.
3. The EPC Contractor shall be required to develop a comprehensive set of safe and constructible plans and specifications for the construction of the Project. The EPC Contractor is required to ensure that these are in full compliance with all Federal, State and the IDFS codes, regulations and ordinances. The EPC Contractor shall be responsible for development of all details for any feature or function that is not covered by applicable standards. All design, construction materials and its specification require pre-approval from IDFS before actual construction.
4. The design and construction of this project is to be achieved in the shortest time period, at the most economical cost, and with minimal disruption to IDFS daily operation and minimal inconvenience to IDFS customers. Therefore, all work during design and construction must be staged so as to maintain IDFS operation and minimize traffic impacts and disruptions to the surrounding areas. The EPC Contractor shall develop staging and phasing plans which will ensure that the construction can be accomplished in this manner.
5. The EPC Contractor shall be responsible for developing constructible contract documents that

are sufficiently clear and complete, so that they can be easily interpreted and competitively bid out. The EPC Contractor shall anticipate the need to develop construction documents in accordance with local and federal law.

6. The EPC Contractor shall develop all necessary submissions as required by Federal and Local government, and IDFS. Submissions shall include, but not be limited to, sketch plans, phasing plans, zoning plans, and permit applications. Further, the EPC Contractor shall attend and participate in all meetings necessary to satisfy the Federal and Local governments and IDFS requirements.
7. The EPC Contractor is required to satisfy all Federal, Local, and IDFS ordinances, statutes and other stipulations. If required, the EPC Contractor shall obtain any and all approvals and/or obtain all zoning variances necessary to acquire approval from the relevant agency.
8. Whether or not it is expressly stated, the EPC Contractor shall be responsible for the performance of any work that is either incidental to, or a prerequisite for, any of the tasks or services identified herein. Furthermore, the EPC Contractor shall be responsible for performing tasks and services that may not be specifically identified herein, but are clearly included in the intent of this section. Wherever in this section a task is described, without specifically stating who is responsible for performing said task, it shall be implicit that the responsibility for the completion of the work is that of the EPC Contractor. Sub- Contractor may perform portions of the work subject to the conditions of this Contract with review and supervision by the EPC Contractor.

SUB-PART SIX: TASK PHASING

The work comprises distinctive design and construction phases as described below:

1. **PHASE 1: TURBINE ENGINERING & DESIGN**

   A. Collection of information and data (IDFS & EC; the Generator and Switchgear Supplier)
   B. Establishment of design requirements
   C. Design development
   D. Preparation and delivery of construction documents, inclusive of technical specifications and drawings.

   Phase 1 will include Scope Definition (30%), 45%, 90% and 100% design submittals and Bid Documents. The formal design submission review meeting(s) shall be held at a minimum of fifteen (15) calendar days after the design presentation meeting for the 45%, 90%, and 100% stage submittals.

   IDFS stresses the significance of the design review and discussion of the details presented during the 45% design submittal. The 45% design submittal provides the focal point for critical decision making with respect to the project budget and design direction. IDFS will “freeze” the design at the completion and acceptance of the 45% submittal, preventing any fundamental changes in the design unless directed and deemed necessary by IDFS. Changes in design beyond the 45% milestone shall be incorporated at no added cost should the design element revision in question be determined to be the result of errors or omissions.

2. FURNISHED INFORMATION & DATA

A. References: The references listed below were used in compiling this Request for Proposal and are available for review. Additional information as it is available will be provided upon request.

TOPOGRAPHIC MAP OF THE IDFS BAY CITY COMPOUND

IDFS BAY CITY – LAND DEED/LEASE AGREEMENT BETWEEN IDFS AND THE ASG – FOR PERMITTING PROCESS

UTILITIES MAPS AND LAYOUTS – (ELECTRIC, SEWER, WATER.)

EXISTING FOOTING AND FOUNDATION DESIGN OF EXISTING FREEZER SLAB

EPA ASSESSMENT OF PROJECT SITE AND ADJACENT SITE

B. IDFS will provide the EPC Contractor with topographical map in electronic data format. IDFS will also conduct the route survey and provide ground elevations, coordinates, and related data required for preparation of the plan and profile design sheets for the facilities to be designed under this RFP.

C. IDFS can provide field survey work if requested by the EPC Contractor if more data is required for the project site.

3. ADMINISTRATION

A. The EPC Contractor shall provide administrative project management. Administration shall include, but is not limited to, quality control / quality assurance, design procedures and criteria, coordination of the design team and project elements, monitoring schedules, document control, submittal review, submitting of design deliverables, organizing and conducting progress meetings, monitoring the progress of work, and oversight of value Engineering implementation and construction estimates.

B. The EPC Contractor shall be expected to coordinate the documentation for all design disciplines; including that of the sub-contractors, so that the initial project research and the resulting contract documentation is complete, concise, and without omission, contradiction, or ambiguity.

4. SITE EVALUATION & INVESTIGATION

The EPC Contractor shall conduct all research and perform all investigations necessary to develop the design documents for the project. This shall include but not be limited to surveys, geotechnical research, hydraulic and hydrological studies, drainage investigations, environmental research, hazardous materials research and assessments of existing conditions.

A. EXISTING CONDITIONS

Comprehensive Code Review - The EPC Contractor shall research and identify all codes, requirements, guidelines and standards pertaining to the work for inclusion in the Design Manual. If requirements are unclear or contradictory, the EPC Contractor shall obtain clarifications from code enforcing bodies and the Equipment Contractor (EC). Existing Information Review - The EPC Contractor shall review all existing information. This effort shall be used to verify information regarding the site, and to augment or revise it as the existing conditions warrant.

B. IDFS EXISTING FACILITIES

- IDFS and EPC Contractor shall work together to locate and identify existing condition plan of all IDFS facilities, both above and below ground that are within the vicinity of the Project.
- These facilities shall include, but are not limited to power transmission lines and poles, power systems, waterline, sewer line, cable TV, and communications systems.
- This effort must also include details regarding proposed facilities, including types and locations.
- In addition, IDFS and the EPC Contractor shall work together to identify other utilities (Telecommunication & Cable TV) infrastructures/facilities that will require relocation or adjustment, temporary or permanent, for this project.

C. SURVEY REVIEW

IDFS shall provide a survey of the site with the following information:

- Conventional topographical field property survey that determines the condition, nature, dimensions, elevations, grades and locations of all necessary, existing natural and physical features and facilities within the limits of the proposed work or adjacent areas needed to address changes to the tract, signals, communication, and other systems.
- Boundary land survey, as required by local statutes and ordinances, for all parcels that are within a minimum of 500 feet of the limits (but not less than that required by governing entities) of the proposed work. All boundaries of the identified parcels have been verified through an independent title search.
- Surface and known subsurface features shown within the limits of the project area.

The survey control points have been performed by IDFS surveyors and Public Works surveyors with adequate details to establish horizontal and vertical control with offset ties for recovery and maintenance of all control points.

- The EPC Contractor will review and confirm that the surveys have been performed in adequate detail for their preparation of design documents.
- The EPC Contractor shall provide a fully dimensioned existing condition plan based on the survey. The plan must show all utilities, property boundaries, set back requirements, and other existing features accurately including, but not limited to, the location, size and type of all structures, roadways, and other salient features that are within the limits of the project and those features which may affect or be affected by the project including all

aerial and underground utilities within ten (10) feet of the project limits.

- The EPC Contractor shall provide a list of potentially affected property and utilities including telephone, storm water drains, water and sewer, communication tower

5. INFRASTRUCTURE INVESTIGATION

The EPC Contractor shall be responsible for performing a detailed investigation of the infrastructure at and surrounding the project area. This infrastructure investigation shall include all items necessary to develop the design documents for the project. This effort shall include, but is not limited to, the following items:

A. Levels of Service: The EPC Contractor shall evaluate the level of service provided by other utility that will provide basic services to this facility. If the service is deemed to be inadequate for use in this building, the EPC Contractor must develop a design for providing adequate service levels to the facility. Any additional services shall be part of contractor responsibilities.

B. Oil & Water Separator System: The EPC Contractor shall investigate and identify all applicable regulatory requirements (e.g. USEPA and US Coast Guard compliant) for treatment of all run-off water from power plant grounds.

C. Storm water Management: The EPC Contractor will identify all applicable regulatory requirements and develop a Storm water run off Management Plan for the site.

D. Existing Storm Water: The EPC Contractor shall investigate the existing storm water drainage that will require relocation or adjustment, temporary or permanent for this project. The EPC Contractor shall identify if the Army Corp of Engineers 404 section 10 is required.

6. GEOTECHNICAL ANALYSIS

A. Subsurface Conditions: The Contractor shall investigate the subsurface conditions in the area of the project. Substantial effort must be made to minimize the potential for unforeseen conditions. This investigation shall study all affected areas, potentially including, but not limited to, platforms areas, foundations, yard areas and areas requiring slope stabilization. The subsurface investigations shall include digging test pits and/or taking soil borings in numbers and locations necessary to develop an accurate profile of the soil conditions in all areas where construction operation will take place and is appropriate for the planned work.

B. Soil Borings: The EPC Contractor shall conduct soil borings as required at the area of the proposed work. Test pits may be substituted where deep (four feet +/-1 or greater) foundations are not needed, (e.g., in areas to be paved only). The borings shall be developed to refusal depth, with approximately 33% to include rock sampling. Rock sampling shall be a minimum of 10 feet into rock. A minimum of 20 additional borings shall be taken at areas specified by the IDFS Project Manager and analyzed to provide data and to confirm assertions and assumptions regarding subsurface conditions. The borings delineated above are considered a minimum. If the EPC Contractor determines that it is in their best interest to further the quality of the design, i.e., that additional borings are required, they shall be provided.

C. Soil Boring Analysis: Soil borings are to be coordinated so as to provide samples for environmental evaluation and to expose such subsurface conditions for analysis.

D. **Soils Report:** The EPC Contractor shall provide a full conditions report on the subsurface conditions. The report shall identify subsurface soil layers, including soil type and pertinent soil properties for each layer, identify underground utility locations, including depth, as well as any other important subsurface locations and items. The report shall also include the soil boring logs and soil design criteria. The EPC Contractor shall provide a plan locating all soil borings. The drawing shall have the proposed foundation system projected on it as a reference overlay. The subsurface report, including geotechnical Engineering data and plot of the subsurface conditions shall be produced in paper and electronic forms suitable for review by IDFS PM and technical team and compatible with IDFS's current software.

7. ENVIRONMENTAL CLEARANCE

A. **Environmental Site Assessment (ESA):** The EPC Contractor has to commence a Phase 1 ESA. The EPC Contractor shall incorporate the "recommendations for further action" of the ESA in the final contract documents.

B. **Environmental Assessment (EA)**: The EPC Contractor has to commence an Environmental Assessment including Section 106 of the National Historic Preservation Act.

The EPC Contractor shall address the findings of the EA in the final contract documents:

a. **Subsoil Evaluation**: The EPC Contractor shall report the results of soil sampling, including sampling done in conjunction with structural soil borings, and incorporate necessary environmental remediation efforts into the final contract documents.

b. **Permit Applications:** Applications for all applicable federal and local permits will be prepared and submitted to respective agencies upon determination of the appropriate action to pursue in order to satisfy NEPA requirements. The A/E pre-design plan shall provide sufficient and adequate environmental data for preparation of permit applications.

c. **Compliance to Environmental Assessment:** The EPC Contractor must comply with all aspects of the EA.

SUB-PART SEVEN: SITE DEVELOPMENT

The EPC Contractor shall refine the master development plan and prepare detailed design drawings. The drawings shall include, but not be limited to, plans for the building, parking, pedestrian crossing, and other infrastructure improvements such as roadway and sidewalk improvements.

If additional data are required to meet and comply with the recommendations resulting from the Design Engineering efforts that were accepted by IDFS, the EPC Contractor shall conduct the surveys, studies, investigations, inspections, and research necessary to obtain this data and use it in modeling their design.

SUB-PART EIGHT: STRUCTURAL

Building - The EPC Contractor shall design a two-story building with office facilities for the ground floor and Power Plant main functions for the second floor.

Building Wall should be reinforced concrete, Doorways should be water tight, ventilation openings should be elevated, all pipe and ductwork entry into the plant building should be sealed to withstand water intrusion against flooding force from a tsunami wave or storm surge.

Architectural Site Plan - This plan will include the site area generally within the IDFS Bay City compound. The plan will show the proposed location of the Power Generation Building, the parking configuration, side walks, and surrounding roadway improvements.

Schematic Floor Plans - These drawings include the ground floor plan with all the IDFS requirements; ADA compliant bathroom, waiting area, new stairs, new ADA elevators (if required), etc. The drawings will also include schematic plans for upper levels that will be used for office space.

SUB-PART NINE: SCHEMATIC SECTIONS OF BUILDING STRUCTURE

Based on the results of the geotechnical investigation, the EPC Contractor shall review and compare alternative foundation systems for the building that will also meet the Turbine footprint and foundation requirement and Over Head (OH) crane requirement. The EPC Contractor shall develop cost comparisons for the alternatives. The advantages and disadvantages of each scheme must be noted with respect to construction cost, life cycle cost, constructability and future maintenance.

The EPC Contractor will be responsible for the design of retaining structures necessary to stabilize and support elements of the project.

The EPC Contractor will be responsible for the proper design structures necessary to support the overhead crane rated at 10 tons.

The EPC Contractor shall provide calculations in support of all elements of the building site design with regard to sizing, loads, volumes, area, flows, controls, consumption levels and capacities. All calculations shall reference the specific code, requirement or criteria that are the subject of the calculations.

1. **Turbine Foundation - Design Consideration:**

   The foundation will have the required mass and base area, assuming installation on firm soil and the use of high quality concrete. Before final details of the foundation design are established by the designer, the bearing capacity and suitability of the soil on which the foundation will rest will be determined. Modification of the manufacturer's recommended foundation may be required to meet special requirements of local conditions. Modifications required may include:

   A. Use of a reinforced mat under the regular foundation.

   B. Support of the foundation on piles.

   C. Piling may require bracing against horizontal displacement

   D. The Adjustment of the mass.

E. Additional reinforcing steel.

F. The turbine foundation may extend below the footings of the building and the foundation will be completely isolated from the walls and floors of the building. The foundation block will be cast in a single, continuous pour. If a base mat is used, it will be cast in a separate continuous pour and be provided with vertical re-bars extending up into the foundation block.

G. Generator foundation shall be designed to avoid transfer of vibration to adjacent area (generator foundation is to be isolated from power plant floor).

b.

2. Generator Bay Ventilation

A. Heat from the turbine is radiated to the surrounding air. It is essential that provision be made for removal of this heat. Turbine room temperature rise should be limited as much as possible.

B. Contractor must provide in any calculations and design plans to provide adequate ventilation of the Generator Bay

C. The selected design ventilation system should also help lower parasitic loads.

D. Ventilation cool air shall be drawn in, and allow for natural air movement to force hot air out through vent openings in the roof. There shall be adequate ventilation openings with noise attenuation to allow hot/exhaust air out and to keep the ambient air inside the building cool

E. Intake Ventilation shall be elevated or mounted on top – to avoid flooding from future storm surge or tsunami, and fresh air drawn in shall be ducted to bottom of turbine room

3. ARCHITECTURAL

The EPC Contractor shall develop the architectural designs provided by their own Design Architect for the Building and parking. The design of the building, compound layout and parking must be consistent with the use of the building. The EPC Contractor shall incorporate changes as requested and approved by the IDFS Project Manager and technical team. The review and coordination process will apply for the design of all elements.

The architectural design shall ensure that the spaces are sized properly, have appropriate correspondence and are suitably finished and conditioned for all users and programmed functions, including mechanical, electrical and building systems without sacrificing aesthetics and general appearance.

4. ELECTRICAL

The EPC Contractor shall provide the necessary details for all electrical systems necessary for the proposed New Power Plant Building and illustrate all electrical spaces with full dimensions. Drawings will show the development of panels and circuits for all electrical systems. Electrical elements comprise all items associated with electrical service and distribution, including but is not limited to, conduits, telephone service, fire alarm systems, cable, emergency back-up power, radio and telephone communications, lighting, and CCTV and/or security systems.

A. All electrical systems and distribution shall meet all applicable local, state, and federal codes, requirements and guidelines.

B. All services shall be distributed from centrally located panels.

C. Connections between systems designed by the EPC Contractor shall be specifically noted and detailed such that the systems are properly and fully integrated, fully functional as intended, with specific directions provided as to who is responsible for making the connections.

D. The lighting design must conform to IDFS standards. Lighting shall be provided with emergency back-up systems. The EPC Contractor shall incorporate an energy management system and Energy Efficient Design (LEED) components into the lighting design.

E. The Building Electrical system should be designed and linked to the Emergency Supply system provided in the EC Electrical switchgear.

F. The EPC Contractor shall ensure the Building Emergency Equipment and Critical electrical Load is connect to the EC's Emergency back up circuit on the Switchboard.

G. Emergency wiring for the emergency systems must be entirely independent of the wiring used for normal lightning and other circuits, also in separate ducts/cable trays, cables and boxes.

H. All of the New Power plant building Electrical wirings must be labeled and color coded.

I. Electrical wiring and cable material selection shall comply with the latest industrial standards.

5. ACCESSIBILITY

A. The EPC Contractor shall provide for ADA compliant access into and through the Building facility where ADA access is required.

B. For all ramps and platforms, the EPC Contractor shall be responsible for developing all related aspects of the design of these elements including, but not limited to, lighting, signage, warning strips, tactile edging, and railings.

6. MECHANICAL

A. The EPC Contractor shall design and prepare drawings, details, specifications and calculations for all mechanical systems for the Building.

B. Mechanical design shall include, but not be limited to, all items associated with the plumbing, water supply, waste water disposal, garage, storm/rain water collection, heating, air conditioning and ventilation.

C. The EPC Contractor shall prepare a Life Cycle Cost Analysis for major mechanical systems (e.g. heating, cooling, and ADA elevators if required).

7. DESIGN DOCUMENTATION

A. The EPC Contractor shall design the necessary elements and prepare complete and coordinated Engineering drawings, specifications and calculations for anything related to construction of the Power Plant Building and Facility.

B. The Power Plant Building and Facility is to be constructed in accordance with the latest standards and guidelines including any other supporting documents provided in the Existing Information, Data, Code & Design Criteria.

8. CONSTRUCTION DOCUMENTS

A. The EPC Contractor shall develop construction drawings to depict all the details, layout, configuration, notes, schedules, and dimensions necessary to enable accurate and reliable estimates of the quantities, quality, character, and costs of the labor, materials and equipment required to furnish and install the work in a skillful and well executed manner.

B. The EPC Contractor shall prepare the specifications to enable accurate and reliable estimates of the quantities, quality, character, and costs of the labor, materials and equipment required to furnish and install the work in a skillful and well executed manner.

C. The EPC Contractor shall prepare the final documents in electronic format, in addition, three (3) sets of hard copies and a copy in reproducible CD in word and PDF format shall be submitted to IDFS.

9. DESIGN MANUAL

A. The EPC Contractor shall document all codes, requirements, guidelines and standards pertaining to the work. If requirements are unclear or contradictory, the EPC Contractor shall obtain clarifications from code enforcing bodies.

B. The Design Manual shall incorporate approved resolutions to Value Engineering comments.

C. The Design Manual shall incorporate all prior comments and their resolutions, including documented references to correspondence, meeting minutes, telephone conferences, emails, memos or other documents supporting the resolution of the comments or specific directions in the Manual.

D. The Design Manual shall include the data and Engineering systems criteria for civil, architectural, structural, electrical, mechanical, communications and other Engineering disciplines, which may have a potential impact on the project.

E. In addition, this manual shall clearly, concisely and logically compile pertinent information regarding the size, capacity, layout, spacing, quantity, style, type, location, etc. for all material elements of the design, including structures, hardware, finishes, furnishings, amenities, graphics, signage, and specialty items.

F. The final approved Design Manual shall be considered the basis on which the EPC Contractor shall proceed with their final design efforts. Should the EPC Contractor not be able to progress their design or proceed in accordance with the information contained in the final approved Design Manual, the EPC Contractor shall bring the non- compliant issues to IDFS's attention for resolution. IDFS's decisions on these matters shall be final and binding on the EPC Contractor. Subsequent design work by the EPC Contractor shall be based on IDFS's decisions.

G. No requests for additional compensation by the EPC Contractor will be entertained by IDFS for items that either were not found or were not able to be completed based on the final approved Design Manual.

10. AGENCY COORDINATION & PERMITTING

A. The EPC Contractor shall list all regulatory authorities, agencies, utilities and jurisdictions that may have regulations relevant to the project.

B. The EPC Contractor shall also provide a detailed written report of all regulatory requirements, approvals and variances for which compliance may be necessary based on the defined scope of the project. The report will also identify permits required for construction.

C. The EPC Contractor shall be responsible for all coordination with relevant agencies that have jurisdiction over the intended work, and to obtain necessary approvals and permits. Requests for modifications or out-of-scope work must be approved by the IDFS Project Manager. In particular, the EPC Contractor shall satisfy all land development requirements and obtain site plan approval from IDFS.

D. The EPC Contractor shall contact in writing all affected utility companies and private property owners or entities to determine their requirements for protection, relocation or replacement of their facilities as necessitated by the design. The EPC Contractor shall schedule and conduct any necessary meetings between IDFS and the affected utilities and private entities to obtain the necessary approvals or develop the necessary agreements so that the work may progress.

E. The EPC Contractor shall confirm the necessity for any utility relocations or special maintenance provisions with the affected utilities and determine if the utilities will accomplish the relocations or maintenance provisions with their own Force Account personnel or request/allow one construction contractors to perform the work.

F. The EPC Contractor shall coordinate all traffic, vehicular, and pedestrian related activities with other agencies that might be affected during or as a result of this project. The EPC Contractor shall also prepare application(s) for, and obtain, all required permits from American Samoa Department of Public Works (DPW) and American Samoa Department of Public Safety (DPS) such as curb-cuts for ingress and egress , street closures or traffic detours at locations under their respective jurisdictions.

G. The EPC Contractor shall engage an ADA compliance specialist that is independent from the design process and that is acceptable to IDFS to review the construction documents for compliance with ADA regulations. The ADA specialist must submit to IDFS, prior to the start of the ADA review, credentials attesting to his experience and knowledge.

11. CONSTRUCTION PHASING

A. The EPC Contractor shall provide a comprehensive phasing plan that indicates all construction sequencing necessary to minimize impacts to Operational, adjacent properties and roadways.

B. Preliminary construction phasing plans shall be included with each submittal package. Final phasing plans shall have been submitted and approved by the requisite authorities and agencies.

C. The construction phasing plans will detail the limits of work, the specific work elements, and the duration of the phases to meet other related requirements as stated in this scope of work. These phasing plans shall be in accordance with IDFS and other agency requirements and guidelines.

D. The EPC Contractor shall keep their construction phasing efforts current with IDFS throughout their entire design effort.

E. The EPC Contractor shall identify means of minimizing disruptions to existing IDFS parking, as well as locations and methods of providing temporary and contractor parking during construction. The EPC Contractor shall develop and finalize plans for alternate parking to be used by IDFS customers, IDFS fleet vehicles and IDFS employees displaced during phased construction.

F. The EPC Contractor shall identify all temporary construction required to maintain safety and Operational; provide details of how new construction will be coordinated with temporary Operational measures.

G. The EPC Contractor will be responsible for the design of all temporary work necessary to stabilize and suitably support any element affected by the scope of the project.

H. Construction access, including access for material loading, unloading and storage, shall be developed and maintained so as to minimize the interference with businesses, adjacent properties, pedestrian flow, and vehicular flow. Construction access shall be coordinated with the phasing of the project.

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APPENDIX

TECHNICAL PORTION

(GE POWER PLANT BEST PRACTICES)

PROPOSED POWER PROJECTS

IN THE ERCOT AREAS OF TEXAS

GE Power & Water

Combined Cycle Power Plant

Best Practices 2015

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Contents

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Combined Cycle Power Plant Best Practices 2015

Introduction

What It Is

This is a single source document that describes GE's best practices in the configuration and execution of combined cycle power plants (CCPPs). These best practices reflect GE's involvement in hundreds of CCPPs built around the globe over the past 60+ years for all types of customers by numerous Engineering, Procurement and Construction companies (EPCs).

Why It Matters

The purpose of capturing these best practices in a single location is to ensure that customers, Owner's Engineers, EPCs and developers understand how to extract the most value from GE-supplied equipment when designing and building a CCPP. This document is intended to document the benefits and impacts of these features on key customer imperatives.

How to Use This Document

The best practices developed by GE are grouped into the following six major categories:

- Layout
- Schedule
- Simplification
- Performance
- Operability
- Controls/User Experience (UX)

There is an introduction at the beginning of each of the six major categories that provides an overview of the overall benefit of that group of features. Within each category are chapters summarizing the benefits and application of each feature.

Each chapter is divided into sections that describe what the feature is, why it matters and what its key enablers are. The objective is to describe how this feature differs from legacy industry practices and the quantifiable benefit it brings to customer plant imperatives. Needs and limitations with respect to plant requirements and constraints are provided along with plant system impacts and critical engineering requirements. Implementation effects are also discussed.

Key Enablers

Each feature has a section that describes one or more technology enablers that make it possible. These critical attributes are described in this section.

Plant Systems-Based Structure

The GE Power Generation Products (PGP) systems-based structure has been utilized to describe each feature. This structure is broken into three top level categories called dimensions:

- Requirements & Constraints
- Function
- Physical Implementation

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Together the plant location, interface needs and mission and goals define the requirements and constraints for the power plant. The various plant systems satisfy these requirements and constraints while accounting for physical implementation needs. Each feature contains a separate paragraph that discusses each of the three high-level dimensions. Within each dimension, the feature limitations, interactions and impacts are discussed in more detail.

Requirements & Constraints

This section considers the plant mission and goals and how they influence the infrastructure and location-based constraints. These are broken down into six categories:

- Operations
- Site
- Fuel
- Grid
- Environmental
- Schedule

The purpose of this dimension is to capture the requirements and constraints that drive the product configuration.

Plant Systems or Functions: Interactions & Engineering Requirements

The primary goal of the system interaction section is to describe which functions of the power plant are affected by the particular feature. The functions of the plant are split into five primary systems. Along with defining the functionality of the power plant, it also provides the common language or system breakdown structure (SBS) for use across the GE Power Generation Products team. Functional system engineering balances physical implementation needs with the plant requirements and constraints.

The five primary systems are:

Topping Cycle

The gas turbine and its dedicated systems.

Bottoming Cycle

The steam turbine, HRSG, condensate, feed water and associated systems.

Heat Rejection

Systems that reject heat to the environment.

Electrical

Systems that export power to the grid or supply power to plant equipment.

Plant Integration

Systems that support the power train equipment in converting fuel to electrical power.

Appendix B provides a detailed list of the 96 systems.

Physical Implementation

Physical Implementation of the plant considers how the plant is built, operated and maintained. The implementation methods also address the functional needs of the plant along with plant requirements and constraints. Physical implementation of the plant should be adaptable to meet requirements and constraints such as manpower availability and logistical issues. Impacts of each feature are described in this section.

A detailed breakdown and discussion of these attributes are in Appendix C.

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Combined Cycle Plant Configurations

There are two main CCPP configurations, single-shaft (SS) and multi-shaft (MS). The defining characteristic of the SS configuration is that the steam turbine, generator and gas turbine are connected together and share one shaft. The defining characteristic of the MS configuration is that a steam turbine and its associated generator are separate from one or more gas turbine(s) and generator shaft lines. In a MS, the steam turbine and generator are designated the ST island. The gas turbine, its generator and associated Heat Recovery Steam Generator (HRSG) are designated the GT-HRSG island. Each main configuration has variations that impact the plant and power train layout. Because of the significant differences in these two configurations, this guide often treats them separately. Chapter 2 elaborates on these differences and the applicability of various GE best practices.

Feedback

GE appreciates the time you've taken to familiarize yourself with these best practices. In order to continuously improve this document and all of our power generation products, we would be grateful to receive your suggestions for additional best practices or feedback from experience that differs from GE's. Please contact your GE Account Manager with any feedback and they will ensure it is transmitted to the GE PGP Product Management team responsible for this document.

Figure 1 – Single-Shaft Configuration

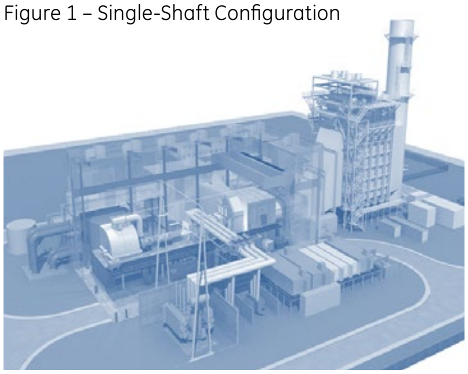


Figure 2 – Multi-Shaft Configuration

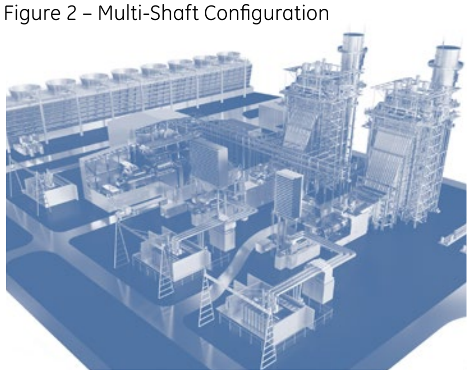
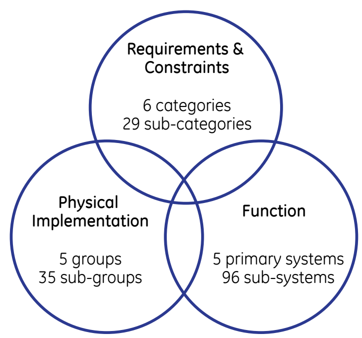


Figure 3 – Plant System – Based Structure



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Combined Cycle Power Plant Best Practices 2015

1.0 Layout

There are two main combined cycle plant configurations, single-shaft (SS) and multi-shaft (MS). Each of these configurations has its own specific plant and power train layout. These are described in the first two chapters of this section. In 1x1 configurations, both SS and MS layout configurations are possible. The Single-Shaft vs. 1x1 Multi-Shaft chapter discusses which of these configurations is the best choice considering plant requirements and constraints as well as customer needs. Within each main configuration (SS or MS), the steam turbine last stage bucket selection (single flow, double flow or four flow) affects the layout details in the steam turbine area. The Preferred Steam Turbine Exhaust Direction chapter provides configuration requirements for these bucket selections. The MS layout is offered with both outdoor and indoor GT configurations. The Compact Gas Turbine Building chapter provides recommendations for the indoor GT configuration. All of the layouts have features that are critical to the construction schedule, total installed cost and maintainability of the plant. GE recommends utilizing these features unless prohibited by the customer or site requirements and constraints.

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Combined Cycle Power Plant Best Practices 2015

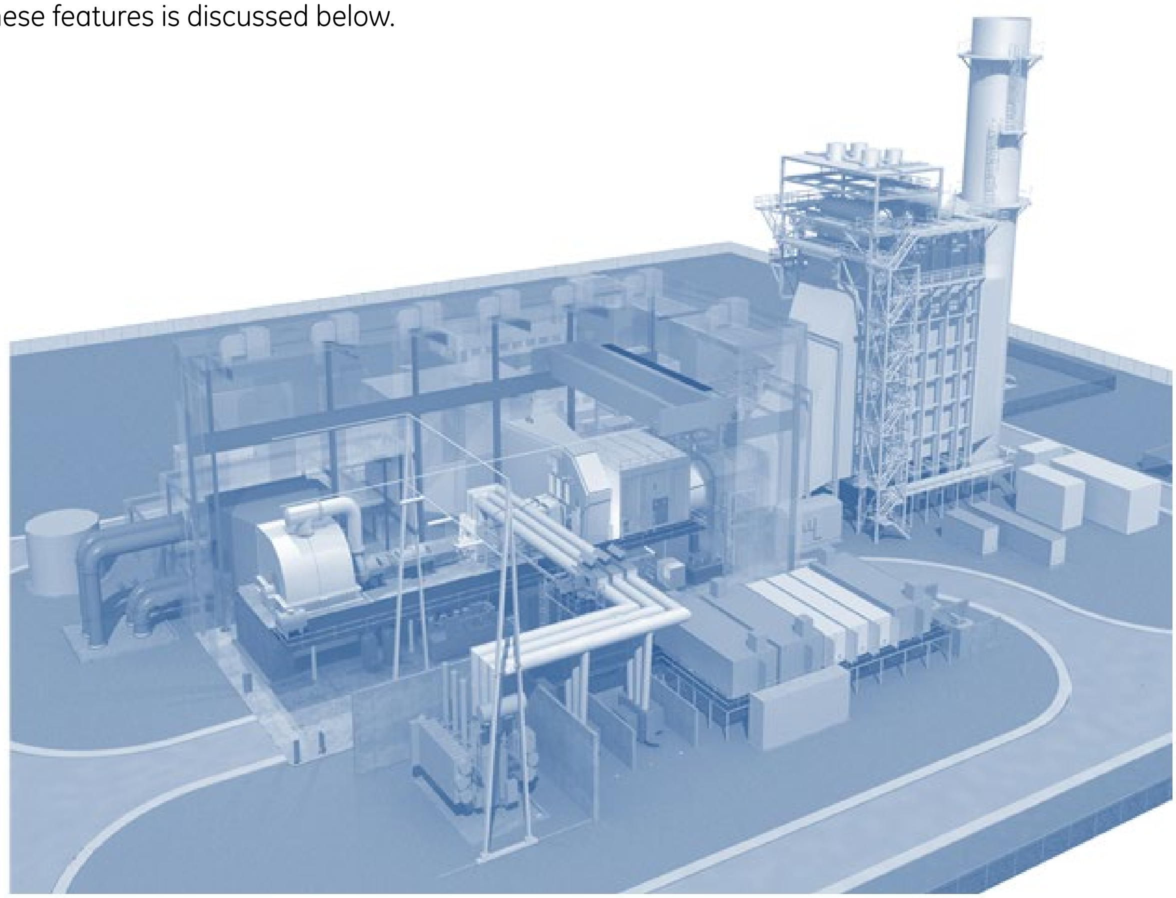
1.1 Layout for Single-Shaft Plants

What It Is

The Single-Shaft (SS) Combined Cycle Plant layout has features that are very important to the construction schedule, total installed cost and maintainability. These features include low power train centerline height, side access roadway, pier foundations, generator in the center of the rotor train and segregation of construction disciplines. Each of these features is discussed below.

Reduced Building Height

- Mechanical Discipline Scope Concentration
- Low Bay for Condenser
- Generator in the Center
- Low Centerline Height
- Pier Foundation
- Electrical Discipline Scope Concentration
- Side Access Roadway



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1.1.1 Low Centerline Height

Why It Matters

The low power train centerline height (relative to previous configurations) results in lower cost for equipment foundations, reduced building height and enhanced installation/maintenance access. The chapter "Preferred ST Exhaust Direction" provides the details of the benefits associated with the lower centerline height.

Key Enablers

A single side or axial exhaust steam turbine is required to achieve the low centerline height. Refer to the Chapter "Preferred ST Exhaust Direction" for additional detail on when this configuration can be offered. In general, every two flow ST is available with a side exhaust. An axial exhaust ST can be used when the exhaust area is met with a single flow low pressure section.

Requirements & Constraints

Schedule and total installed cost are the biggest factors affected by centerline height. Any increase in centerline height impacts civil costs in unit foundations, building size and unit interconnects. Increasing the civil work also adds additional schedule risk due to more complex foundation requirements involving more formwork and pours. Low centerline can help reduce unit installation schedule risk with simplified heavy lifts, lift height for all components and fewer scaffolding requirements. Lower lift heights typically reduce the crane capacity required for a given lift. Lower capacity cranes have improved availability. These advantages translate directly to improved maintenance outage predictability.

System Interactions & Engineering Requirements

Low centerline height impacts:

P90 Structures

Low centerline impacts unit interconnect structures set by centerline height. These include GT inlet, GT exhaust, generator bus and neutral connections, control valves and steam turbine stop.

P91 Foundations

Lower centerline results in less complex and less costly foundations.

P92 Buildings

The turbine hall height is determined by rotor lifting requirements.

P93 Cranes

The lower building height requires smaller cable drum sizing for lifts to the deck.

P70 HVAC

The resulting smaller building size will require less ventilation.

T40 GT Exhaust

The lower centerline results in reduced need for GT exhaust support.

T50 GT Inlet

The lower centerline will decrease GT inlet structural requirements.

E20 Electrical Evacuation

The lower centerline will decrease generator Isolated Phase Bus (IPB) duct length and structural requirements.

Physical Implementation

Interfaces

Impacts all unit accessories connections.

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1.1.2 Side Access Roadway

Why It Matters

The side access road has multiple functions. It creates a flow-through material delivery path. This is especially important for movement-intensive construction and maintenance activities such as centerline equipment installation, piping disassembly, and GT compartment breakdown.

The roadway also provides enough laydown space in the building for GT or ST maintenance-critical parts while allowing deliveries at the opposite end bay.

The roadway creates the footprint necessary to take advantage of low centerline side heavy lift options for major equipment like the GT, ST and generator. This is a significant schedule risk reduction feature. It takes these heavy lifts from a series to a possible parallel schedule if needed due to delivery delays.

The roadway also allows easy access to some of the most critical auxiliary systems such as lube/seal oil, stator cooling water and the GT compartment itself.

Key Enablers

The key enablers to achieve these benefits are a building sized for the roadway, low centerline height, generator interconnect via isolated phase bus (IPB) bridge, and accessories modularization/location.

Requirements & Constraints

Site considerations often require adapting reference layouts. In the case of very narrow plant footprints, serious consideration should be given to relocating other balance of plant equipment in lieu of eliminating the side access roadway. Maintenance and construction schedules are the largest requirements affected by the side access roadways. Changing these features will require alternative planning or designs to maintain the same schedules.

System Interactions & Engineering Requirements

The side roadway impacts:

P90 Structures

Unit interconnect structures and generator IPB bridge.

P91 Foundations

Loading on roadway to allow rotor laydown and heavy lift delivery.

P92 Buildings

Turbine hall width to accommodate roadway.

P93 Cranes

Longer crane trolley to span roadway.

P70 HVAC

Larger building size will require extra ventilation.

Physical Implementation

Layout

When customizing the layout for project needs, keep the roadway clear of permanent equipment. Ensure interface changes don't encroach on the roadway. Ensure IPB duct bridge height remains at sufficient elevation to allow truck passage through the building.

Lifting Capability/Availability Heavy Haul Gantry

Provide sufficient side footprint for loading of GT, ST and generator to foundation.

Material Handling

Speeds material handling operations by limiting travel distance needed for crane hook. Also facilitates the option for additional rubber tire lifting equipment to supplement building crane and further expedite installation and maintenance.

Maintenance Laydown

Provide indoor laydown for critical equipment.

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Maintenance

The GE suggested layout provides access to critical equipment and accessories.

Maintenance Predictivity

Schedules assume short travel of building crane from equipment centerline to roadway. Roadway also offers the option of adding rubber tire cranes to improve outage schedule.

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1.1.3 Pier Foundations

Why It Matters

ST and generator pier foundations reduce the complexity and cost of the unit foundations. There is significant reduction in concrete volume, formwork and installation hours. Savings are elaborated later in the chapter titled "Preferred Steam Turbine Exhaust Direction." Additionally, the pier foundations open space for unit close-in piping and lube oil connections when compared to traditional table top foundation configurations. A table top foundation consists of a large slab of reinforced concrete joining multiple piers together. It resembles a table with legs. The standard table top foundation makes close coupling ST stop/ control valves highly impractical because of the amount of table top concrete close to the ST shell.

Key Enablers

A side exhaust or axial exhaust steam turbine is required to implement pier foundations. The low centerline height eliminates the need to tie the piers together in a table top configuration or increase the pier dimensions to a size that makes the pier configuration impractical.

Requirements & Constraints

Location-Geologic-Seismic Zone

The standard plant pier configuration is based on a moderate seismic zone and can be used for most sites. It is expected only minor modifications to the pier configuration are needed for higher degree seismic locations.

Schedule – Predictability

Pier construction, with its single concrete pours, can be accomplished in less time than a table top foundation. It also provides better access and less interference during remaining construction activities.

Engineering Cycles

Pier configuration has no special conditions to extend engineering cycles.

System Interactions & Engineering Requirements

Due to their less intrusive shape, pier foundations have less interference with unit piping and require no special tooling or methods for installation.

The pier foundations will impact:

P91 Foundations

Design loads on roadway must allow rotor laydown and heavy lift (example assembled GT and generator) delivery.

B31 Steam Turbine Unit

High pressure (HP) and intermediate pressure (IP) steam turbine standards are engineered considering pier foundation interface requirements.

E10 Generator

Generator is engineered for four point pier type support.

Accessory system engineering must consider locations of piers in equipment layout and connection routing. To avoid construction interferences, field connections are made a sufficient distance from the pier to allow access for assembly.

Physical Implementation

Construction and Operation & Maintenance (O&M)

Construction accessibility is improved due to elimination of the concrete table top. In a similar manner, O&M activities also benefit from improved accessibility.

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1.1.4 Generator in the Center

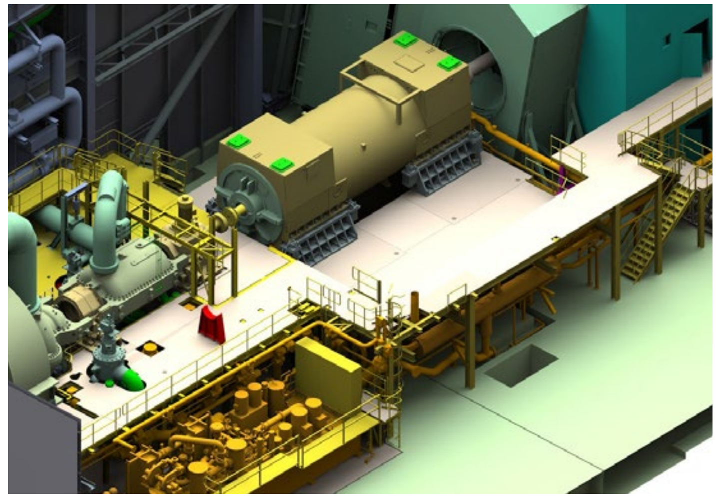
Why It Matters

Generator in the center allows multiple single-shaft configuration options without major changes in the GT-Gen configuration. These include incorporation of a clutch between the ST and generator, axial and side exhaust ST configurations, and district heating provisions.

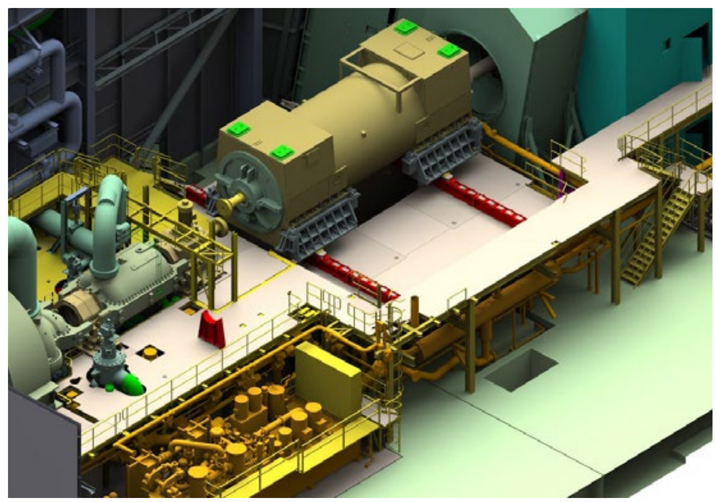
During shutdowns, the clutch facilitates rapid access to the gas turbine for maintenance. The GT cools down faster than the ST. An open clutch allows the ST to cool down on its separate turning gear. This provides access to the GT for maintenance up to three days earlier compared to a direct coupled unit. Further discussion on the clutch is provided later in this document.

Key Enablers

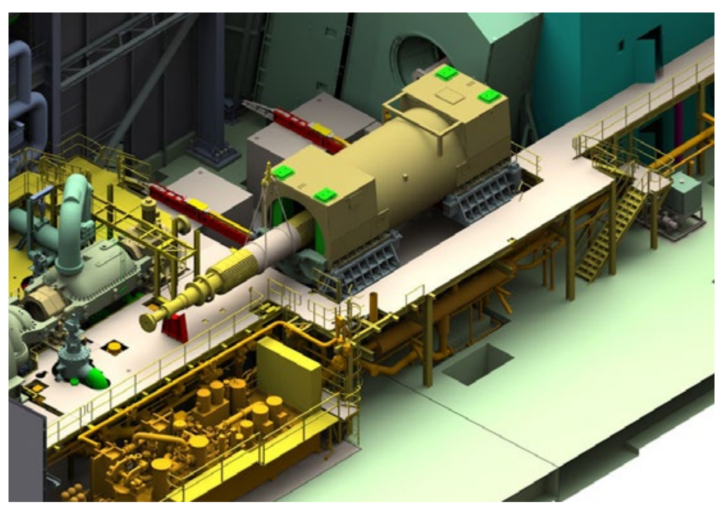
The key enabler to achieve the benefit of the generator in the center is one-piece frame construction for four point support. Other factors are generator leg structures for jack and slide maintenance provisions, removable generator connections to support jack and slide and plant civil engineering to support jack and slide provisions. In addition, the generator is capable of receiving steam turbine torque from the collector end.



Generator in Position



Generator Jacked with Sliding Beams Installed



Generator Slid to Side for Maintenance

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Requirements & Constraints

Availability

The jack and slide provisions for the generator shorten generator outages. As previously described, GT outage durations are shorter than solid coupled single-shaft units because the clutch allows access to the GT for maintenance up to 3 days earlier.

Grid Connection

The center-mounted generator requires a slightly longer path to the grid interconnect vs. the end-mounted generator.

System Interactions & Engineering Requirements

GENERATOR IN THE CENTER IMPACTS:

P90 Structures

Unit interconnect structures and generator IPB bridge.

P91 Foundations

Foundation designs with jack and slide provisions for generator maintenance.

B30 Steam Turbine Unit

Front standard with clutch.

E10 Generator

Generator requires one piece frame for 4 point jack and slide foundation application.

E20 Electrical Evacuation

ISO-phase bus shifted to center of building compared to generator on end design.

Physical Implementation

Construction

With the incorporation jack and slide provisions, the erector has the option of threading the generator rotor (when required) outside the building or in the maintenance position prior to setting on the foundation. This may be advantageous at locations where lay down space is not available.

Maintenance Special Tooling

The GE standard offer utilizes jack and slide tooling for generator maintenance. Alternatively, other provisions can be requested, such as maintenance heavy lift gantry plan or a building crane capable of lifting the generator with the stator installed.

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1.1.5 Segregation of Construction Disciplines and Layout Considerations for Construction Scheduling

Why It Matters

By segregating the majority of mechanical and electrical BOP components, the contractor has less interference during the execution of the installation scope. This segregation and scope planning allows for a more centralized work focus for the individual trades and limits work area interferences and delays due to readiness for trade handover. Generally the order of trade installation is Civil, Structural, Mechanical, Electrical, and Controls. Segregating the majority of the electrical and mechanical scope allows prioritization of civil structural work needed to support early mechanical installation. That in turn enables a high level of parallel electrical installation to take place. GE's preferred layouts consider these construction sequencing and equipment segregation attributes. These layout attributes are key contributors to improving the notice to proceed (NTP) to commercial operating date (COD) schedule.

This work split also simplifies planning for constructors who have adopted Work Face Planning. By enhancing the layout for schedule, the customer benefits from reduced project overhead and lower total installed cost for the project.

Key Enablers

GE's layout segregates mechanical and electrical disciplines. This segregation delivers a balanced approach to equipment positioning, interconnection methods, scheduling and material quantities to reduce total installed cost.

GE-preferred layouts support shorter installation schedules by utilizing preformed/modular components such as the consolidated plant electrical room described later in this document. The layouts also reduce complex site installation activities and consider the overall schedule when specifying configuration elements. An example of this is avoiding the routing of drains or services under main circulating water (MCW) piping. MCW piping is normally the first underground system installed. Installing drains under MCW requires either early engineering of the system or extra excavation later in the schedule to install the drains. This adds interference in the work areas for the deep excavation, risk to MCW installation and complicates what should be a very simple work phase. GE's preferred layouts avoid many of these complex system intersections and scheduling issues.

Requirements & Constraints

Site considerations often require adapting reference layouts. In the case of constricted plant footprints, consideration should be given to relocating other balance of plant equipment in lieu of modifying the power island layout. Construction schedules significantly benefit from the layout. Changes to this layout concept could increase construction and maintenance schedules or require alternate features and perhaps cost to maintain these schedules.

System Interactions & Engineering Requirements

Because this plant layout governs the placement of almost all plant power island equipment, the engineering of almost all systems are affected. Each system must consider the interface needs to integrate with other equipment in the layout drawing.

Physical Implementation

The GE suggested layout provides significant benefits to multiple physical implementation attributes across the construction, commissioning and O&M areas. Examples include opportunities for parallel work efforts, commissioning simplification and maintenance access.

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1.2 Layout for Multi-Shaft Configuration

What It Is

The Multi-Shaft (MS) Combined Cycle Plant layout has many features which support schedule, total installed cost and maintainability needs. Each feature will be discussed in more detail in their individual chapters. They are:

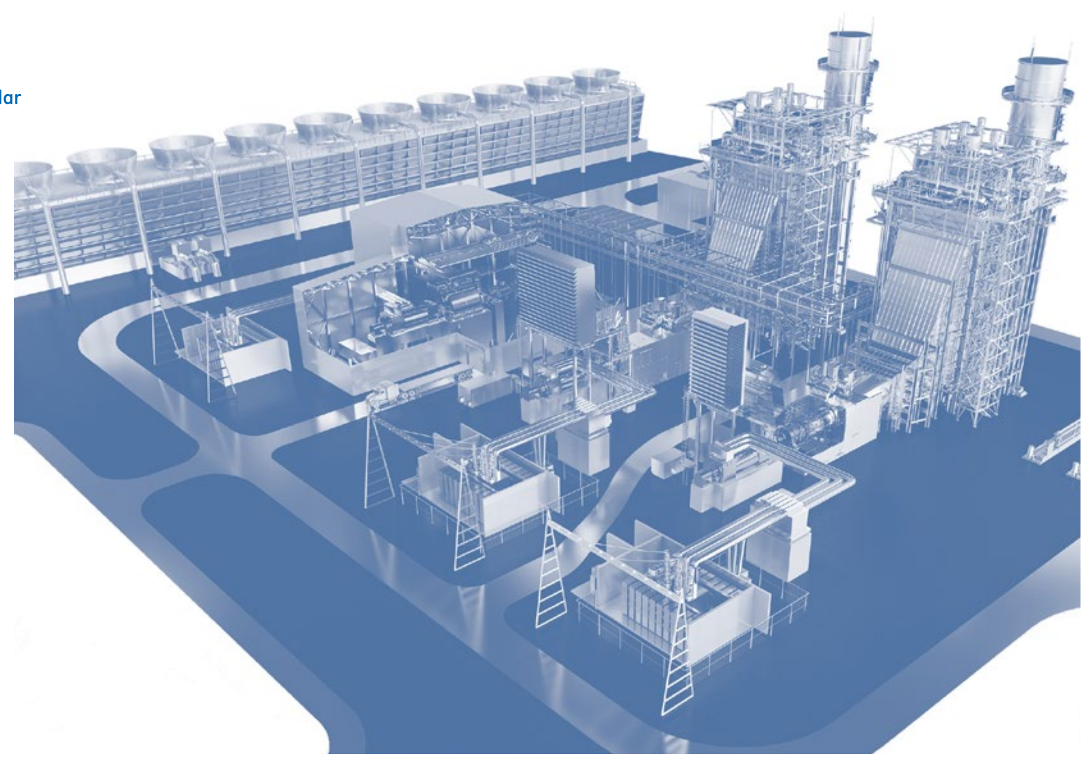
- Side exhaust steam turbine (ST)
- Modularized gas turbine (GT) compartment
- MS side exhaust steam turbine generator in low bay
- Enhanced GT building for MS configurations
- MS Electrical Room (E-Room)
- Low ST centerline height

The enhanced layout includes additional attributes:

- A separate turbine hall or space allocation for a maintenance gantry crane to support gas turbine servicing
- Segregated electrical discipline scope including MS E-Room
- Truck access and crane planning for gas turbine maintenance
- Low bays utilized for generators and BOP equipment
- Heat Recovery Steam Generator (HRSG) feed pumps located outboard (for large HRSGs) to relieve piping congestion and improve construction access

Compact GT Power Island based on Modular GT Compartment with GE Engineered Interconnecting Systems

- Lower Bays Utilized for Generators and BOP Equipment
- For Large HRSGs Locate HRSG Feed Pumps Outboard to Relieve Piping Congestion and Improve Construction Access Between HRSGs
- Gas Turbine Separate Turbine Hall or External Maintenance Gantry Crane
- Truck Access and Crane Planning for Gas Turbine Maintenance
- Segregate Electrical Discipline Scope Including Optional MS E-Room
- Roadway for Construction and Maintenance Access



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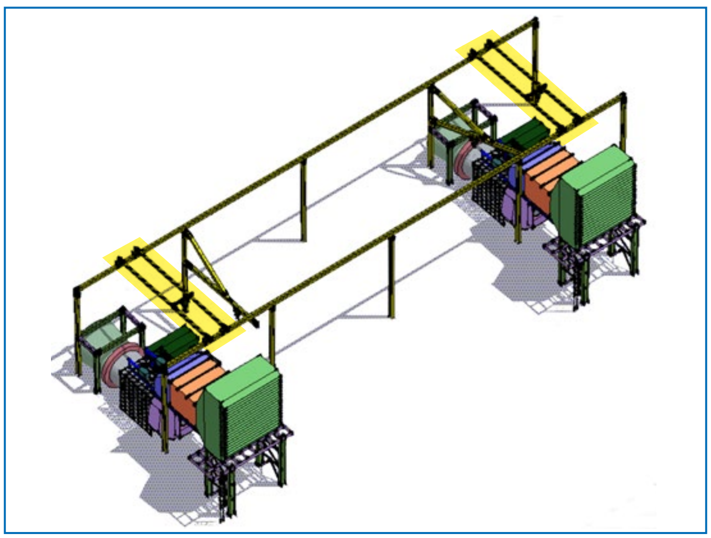
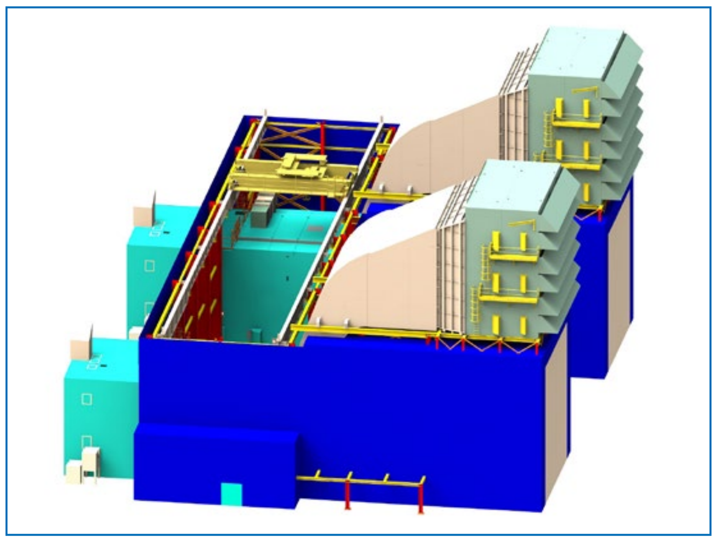
1.2.1 Layout Provision for Gas Turbine Hall or Maintenance Gantry

Why It Matters

As the GT units are growing in output, size and weight, the mobile cranes needed to perform maintenance activities are becoming more difficult to obtain, schedule and erect on site, especially in small footprint sites. GE-preferred layouts allocate space for an optional gas turbine hall or gantry crane. The hall design includes a crane sized to support GT rotor removal. For plants with outdoor gas turbines, the layout includes space reserved for gantry support columns. This supports the option to install a gantry crane to span both GT units. A permanent gantry crane will reduce outage schedule risk by being immediately available for planned or unplanned outage events.



Outdoor Gas Turbines with External Maintenance Crane



Gas Turbine Hall with Integrated Crane

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Key Enablers

The gas turbine power island layout includes spacing provisions for columns adjacent to the GT compartment to support a maintenance gantry, and access roadway space for lift and laydown zones under the crane's rails. An angled GT air inlet reduces the crane rail height.

Requirements & Constraints

Availability requirements may require a permanent maintenance crane or a GT building to reduce outage durations. The main constraints for the crane/building design are seismic, wind and snow loads for local code compliance.

System Interactions & Engineering Requirements

The turbine hall or external maintenance crane options for GT maintenance impacts these major systems:

P90 Structures

Additional crane structure and interfaces with adjacent equipment.

P91 Foundations

Outdoor units – consider column footings in original configuration for lowest capital expenditure (CAPEX) retrofit.

P92 Buildings

Additional hall (building) for the GT with turbine hall option.

P93 Cranes

Additional crane(s) for GT installation and servicing.

P70 HVAC

Additional HVAC for GT hall option.

T40 GT Exhaust

Interface with turbine hall.

T50 GT Inlet

Interface with turbine hall.

Physical Implementation

Construction

Material handling and laydown.

Operations & Maintenance

Maintenance predictivity, laydown and lifting needs.

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1.2.2 Access Roadways and Crane Planning

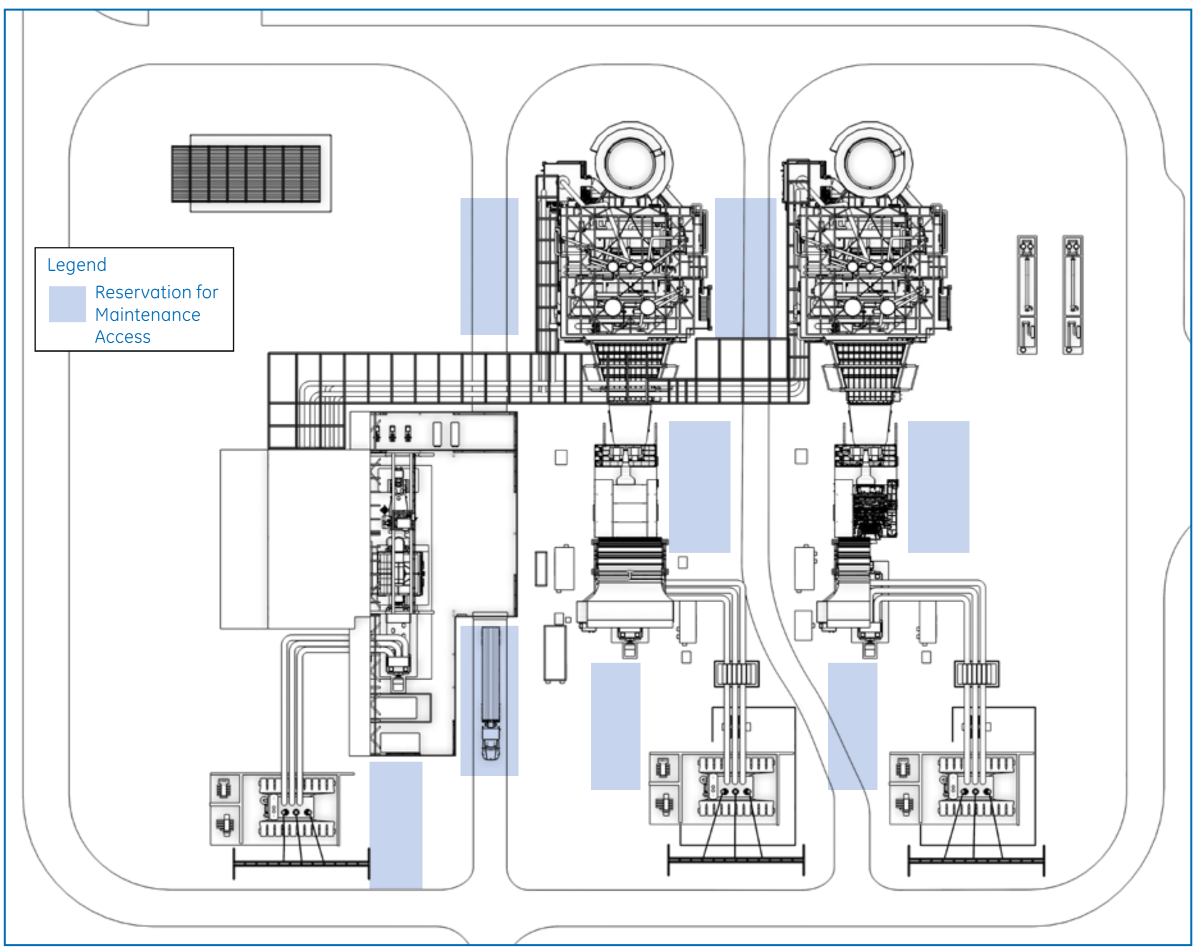
Why It Matters

Access roadways with the necessary gas turbine centerline spacing have multiple functions.

The roadways (shown in gray below) create a flow through the material delivery path. This is important for movement-intensive construction and maintenance activities such as GT installation, maintenance piping disassembly and GT compartment breakdown. They also provide laydown space for critical parts while allowing access for deliveries.

The roadways offer the footprint necessary to take advantage of side load, heavy lift options for major equipment like the gas turbine, generator and ST inlet and exhaust. This is a significant schedule risk reduction feature that takes these heavy lifts from a sequential series to a possible parallel schedule to accommodate delivery delays.

The roadways also provide easy access to some of the most critical auxiliary systems including lube/seal oil, HRSG feed pumps and power evacuation equipment.



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Key Enablers

The key enablers to achieve these benefits are GT centerline spacing to allow roadways, layout reservations for crane placement, and suitable placement of auxiliary equipment.

Requirements & Constraints

Site considerations often require adapting reference layouts. In the case of very narrow plant footprints, serious consideration should be given to relocating other balance of plant equipment in lieu of eliminating the side access roadway. Maintenance and construction schedules are the primary requirements affected by the side access roadways and crane placement recommendations. Changing these features will require alternative planning or designs to maintain the same schedules. Alternative configurations require review for impact.

System Interactions & Engineering Requirements

The side roadway and crane placement reservations impact:

P90 Structures

Unit centerline spacing.

P91 Foundations

Loading on roadway to allow rotor laydown and heavy lift delivery.

P92 Buildings

For units with a gas turbine hall, sufficient width between gas turbines to accommodate roadway.

P93 Cranes

Longer crane trolley needed to span roadway.

Physical Implementation

Layout

When customizing the layout for project needs, keep roadway locations clear of permanent equipment. Ensure interface changes don't encroach on the roadway.

Lifting Capability/Availability Heavy Haul Gantry

Provide sufficient footprint along side shaft line for loading of GT generator, GT inlet and GT exhaust to foundation.

Material Handling

Speeds material handling operations by limiting the travel distance for the crane hook and facilitates the option for additional rubber tire lifting equipment to supplement the building crane to expedite installation and maintenance.

Maintenance Laydown

For units with a gas turbine hall, indoor laydown is provided for critical equipment.

Maintenance

The GE-suggested layout provides access to critical unit and accessories.

Maintenance Predictivity

Schedules assume short crane travel from equipment centerline to roadway. The roadway also offers the option of adding rubber tire cranes to improve outage schedules.

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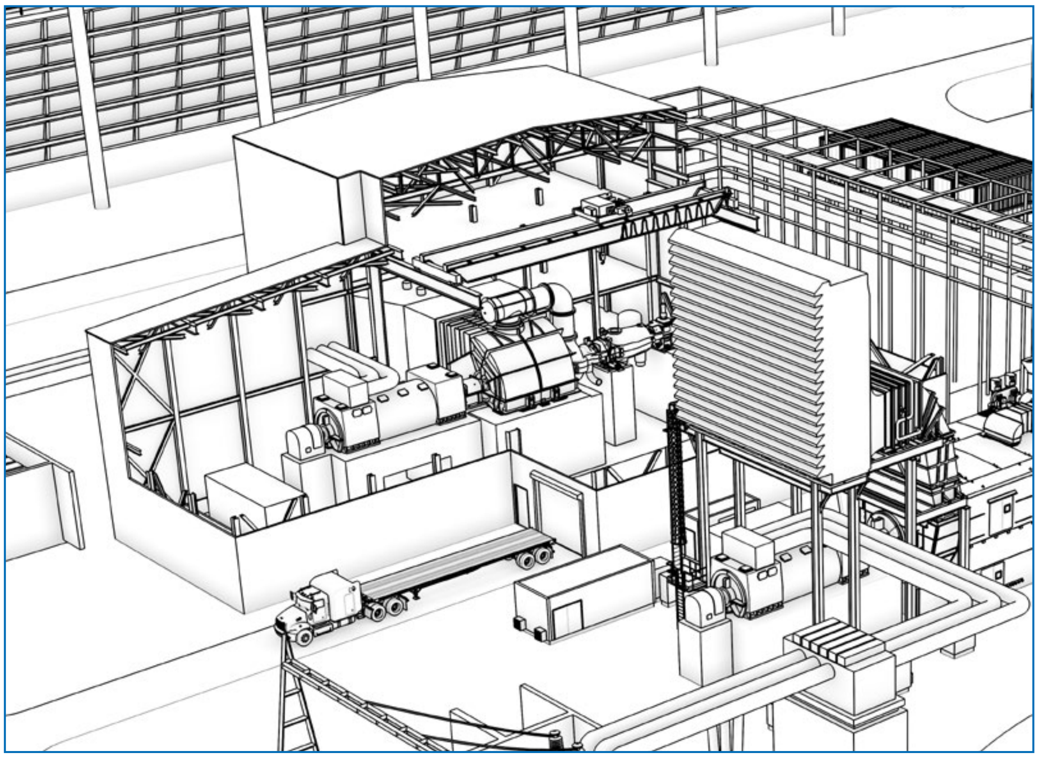
1.2.3 Low Bays Utilized for Generators and BOP Equipment

Why It Matters

Equipment that has to be enclosed but doesn't need a building crane can be housed in a low bay building to achieve significant cost savings (see MS, ST, generator sections). Use of low bays for these portions of the layout can reduce both total installed cost and schedule risk.

- Low Bay Over Condensate Pumps
- Low Bay Over Condenser
- Low Bay Over Generator For ST
- Low Bay Over Generator For GT



NOTE: If the gas turbines are in a building there would be an additional low bay over the GT lube oil module

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Key Enablers

- A side exhaust or axial steam turbine to allow low centerline height. Raising centerline height makes generator servicing unmanageable from the ground level. That means the building crane and large operating deck space would be needed for generator rotor removal.
- Removable low bay roof panels and other mobile crane access points for major component replacement. Examples would be condensate pumps, generator rotor transport and condenser water boxes for tube pull.
- A generator rotor removal system that does not require a permanent crane. Examples are a portable lift or rail system with low capacity trolley hoists at the generator end covers.

Requirements & Constraints

The building configuration and features must support the installation and maintenance requirements of components in these areas. The CAPEX savings from the low bays should be balanced against any special maintenance or installation needs for the site. The low bays in this ST building design reduce initial cost, even when special features like removable roof panels are incorporated.

Location Geologic-Seismic Zone

The standard plant pier configuration is based on a moderate seismic zone. Minor modifications are required to accommodate higher seismic locations.

Availability

Equipment maintenance requirements.

System Interactions & Engineering Requirements

Due to their smaller size, low bays and their related systems have reduced material quantities compared to high bay sections.

P91 Foundations

Low bay foundations have smaller dimensions due to reduced load.

P92 Buildings

A smaller building structure is required.

P93 Cranes

Lower travel distance requirements for building crane.

P74 HVAC

Lower building volume reduces the HVAC system size.

Physical Implementation

- Normal construction methods
- Maintenance lifting and access needs

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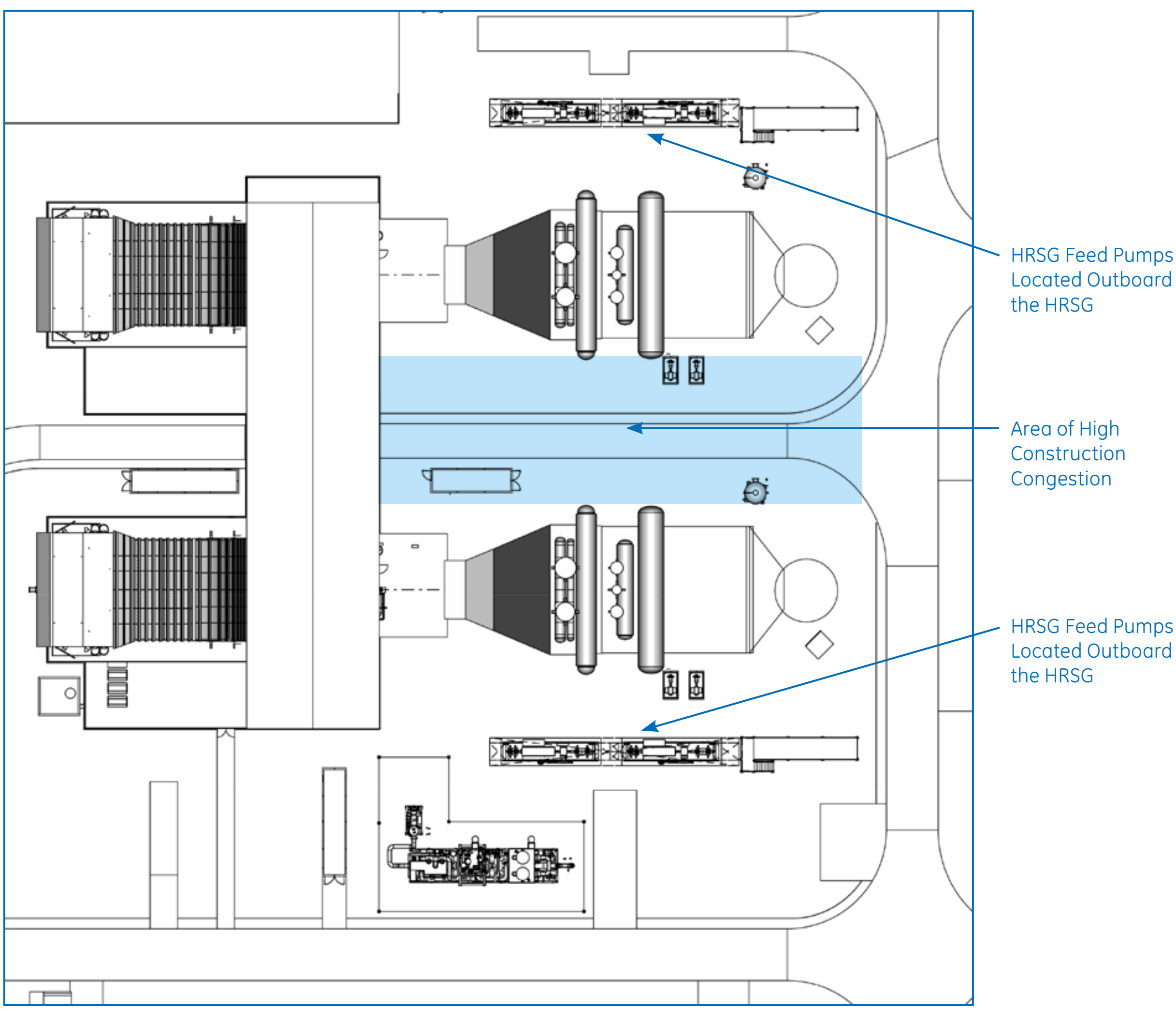
1.2.4 Outboard HRSG Feed Pumps for Large HRSGs to Relieve Piping Congestion and Improve Construction Access

Why It Matters

For multi-shaft gas turbine combined cycle (CC) plants under construction or in maintenance mode, the area between the HRSGs and the main steam pipe rack can be extremely congested. It is one of the critical construction pinch points and interference zones due to the high density of activities later in the project cycle. There is a lot of competition for mission-critical equipment such as cranes and scaffolding. Locating the feed pumps outboard of the HRSGs removes a portion of the pipework and electrical scope to reduce congestion. Additional benefits include better feed pump maintenance access, room for an access roadway and more space for the central crane needed for HRSG erection.



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Key Enablers

To achieve the benefits of an outboard feed pump, an HRSG with low pressure (LP) drum downcomers with economizer connections mirrored to outboard is needed.

Requirements & Constraints

Schedule Predictability

Reduced interference and scope loading in the HRSG "valley" area.

Availability

Improved access to feed pumps for installation and maintenance.

System Interactions & Engineering Requirements

OUTBOARD HRSG FEED PUMPS IMPACT:

TP90 Structures

Pipe Rack.

B10 Feedwater

Routing to outboard of HRSG.

B20 HRSG

LP drum and economizer connections.

P91 Foundations

Foundations feed pump and pipe rack.

P95 Roads

Enables access roadway.

Physical Implementation

Interfaces

HRSG LP drum and economizer connections mirrored.

Lifting/cranes

More space for cranes in HRSG "valley".

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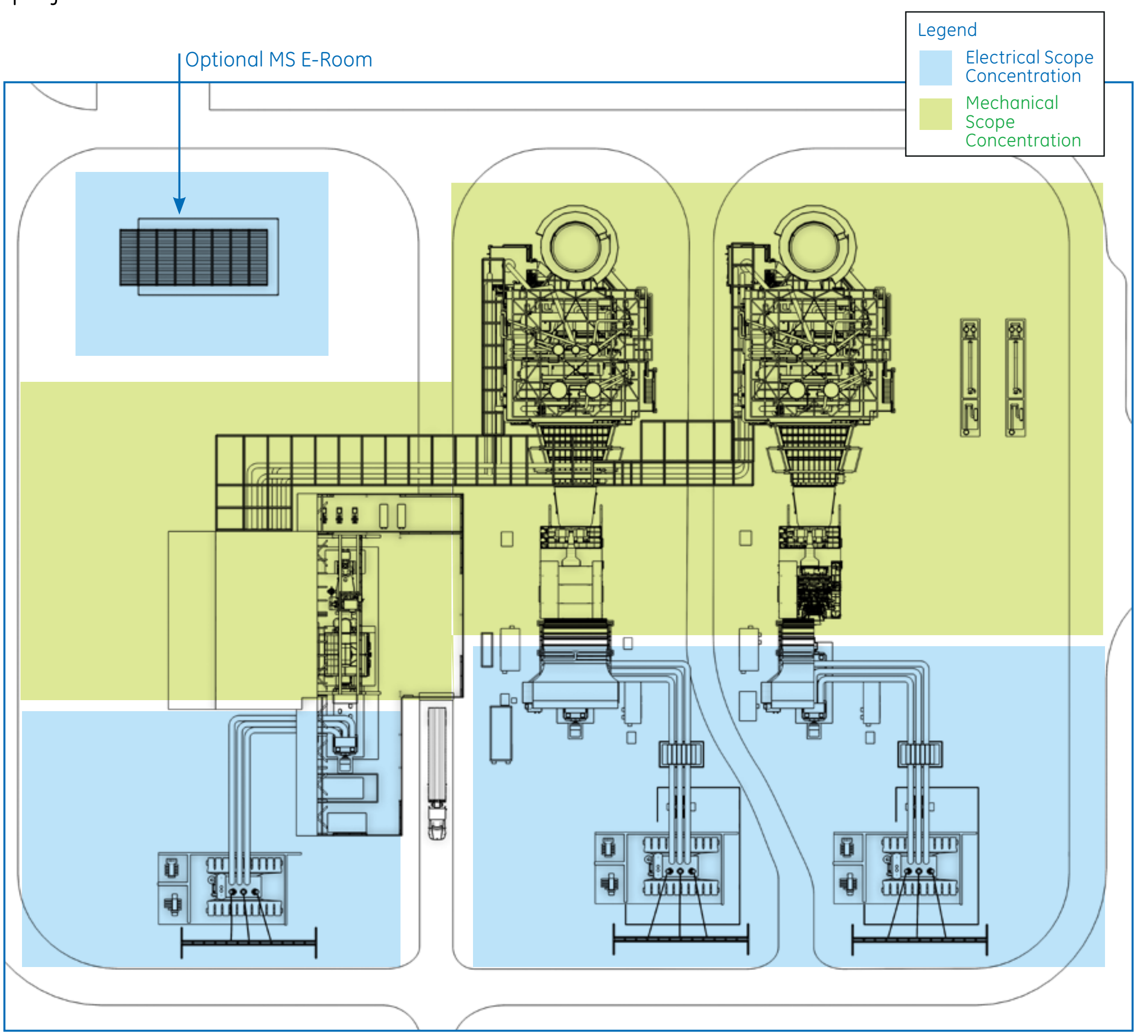
1.2.5 Segregation of Mechanical and Electrical Disciplines and Layout for Installation Schedule

Why It Matters

By segregating the majority of mechanical and electrical Balance of Plant components, the contractor experiences less interference in the execution of the installation. It allows for a more centralized scope of work for the individual trades and limits work area interferences and delays due to trade handover issues. Generally the order of trade installation is Civil, Structural, Mechanical, Electrical, and Controls. Segregating the majority of the electrical and mechanical scope allows prioritization of civil structural work to support early mechanical installation. That in turn enables a high level of parallel electrical installation. GE's preferred layouts consider these construction sequencing and equipment segregation attributes. These layout attributes are key contributors to improving the construction schedule. This work split also simplifies planning for constructors who have adopted Work Face Planning. By enhancing the layout for schedule, the customer benefits from reduced project overhead and lower total installed cost for the project.



Key Enablers

The segregation of mechanical and electrical disciplines delivers a balanced approach to equipment positioning, interconnection methods, scheduling and material quantities to reduce total installed cost.

GE-preferred layouts support shorter installation schedules by utilizing preformed/modular components such as the consolidated plant electrical room described later in this document. The layouts also reduce complex site installation activities and consider overall schedule when specifying configuration elements. An example of this is avoiding the routing of drains or services under main circulating water (MCW) piping. The MCW piping is normally the first underground system installed. Installing drains under the MCW piping requires either early engineering of the system or extra excavation later in the schedule to install the drains.

This adds interference in the work areas for the deep excavation, risk to MCW installation and complicates what should be a very simple work phase. GE's preferred layouts avoid many of these complex system intersections and scheduling issues.

Requirements & Constraints

Site considerations often require adapting reference layouts. In the case of constricted plant footprints, consideration should be given to relocating other balance of plant equipment in lieu of modifying the power island layout. Construction schedules significantly benefit from the layout. Changes to this layout concept could increase construction and maintenance schedules or require alternate features and perhaps additional cost to maintain these schedules.

System Interactions & Engineering Requirements

Because this plant layout governs the placement of almost all plant power island equipment, the engineering of almost all systems is affected. Each system must consider the interface needs to integrate with other equipment in the layout drawing.

Physical Implementation

The GE-preferred plant layout provides significant benefits to multiple physical implementation attributes across the construction, commissioning and O&M areas. Examples include opportunities for parallel work efforts, commissioning simplification and maintenance access.

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1.3 Single-Shaft vs. 1x1 Multi-Shaft

What It Is

Single-Shaft (SS) denotes the power island configuration where the gas turbine and steam turbine share one generator and are connected on one shaft. Multi-shaft (MS) refers to power island configurations where the gas turbine(s) and generator(s) are separate from the steam turbine and its generator. 1x1 denotes that there is one gas turbine supplying steam energy to one steam turbine.

Why It Matters

For power generation and most cogeneration applications, a single-shaft is typically the lowest cost integrated solution when compared to a 1x1 Multi-shaft configuration. The primary driver to lower cost is the need to purchase and install one less generator, associated electrical bus, step up transformer, high yard connection, power train foundation and building.

Occasionally, plant requirements and constraints may not support applying the single-shaft solution. These exceptions are noted in the Requirements & Constraints section below.

Key Enablers

The key enablers of a 1x1 single-shaft configuration are:

1. An integrated rotating power train of gas turbine, steam turbine and generator. A key effort is ensuring acceptable rotor dynamics with all equipment connected under all operating conditions.
2. Where the generator is placed between the steam turbine and gas turbine, the generator must be capable of receiving steam turbine torque from the collector end.
3. A combined lube oil system (gas and steam turbine plus generator) prevents inadvertent operation and attendant machine damage due to an isolated lube oil supply.

Requirements & Constraints

For most Combined Cycle offers, the plant requirements and constraints can be met with the GE single-shaft configuration. The few exceptions are discussed below.

In some cases, plant output and peak output demands exceed single-shaft capabilities. Output demand covers

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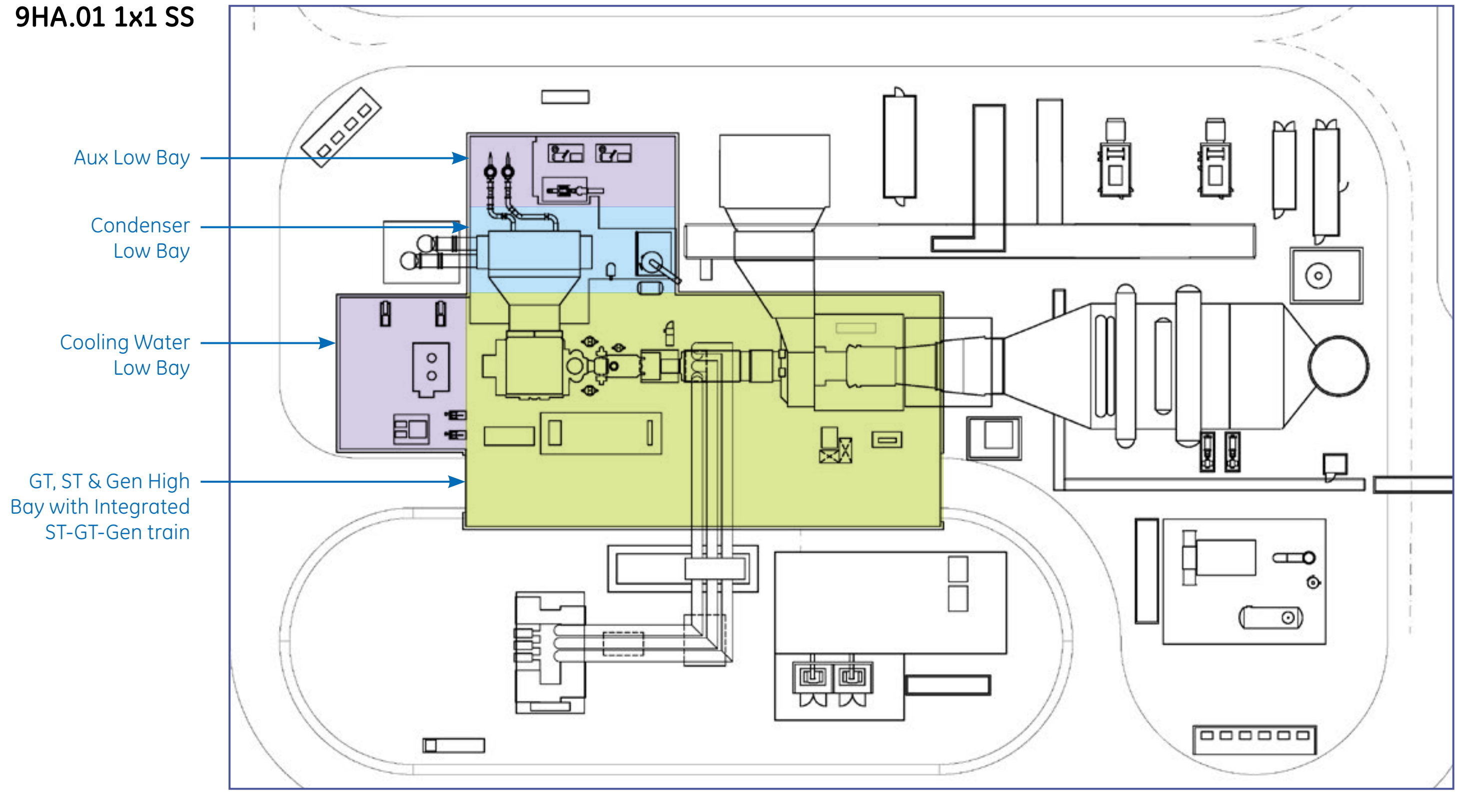
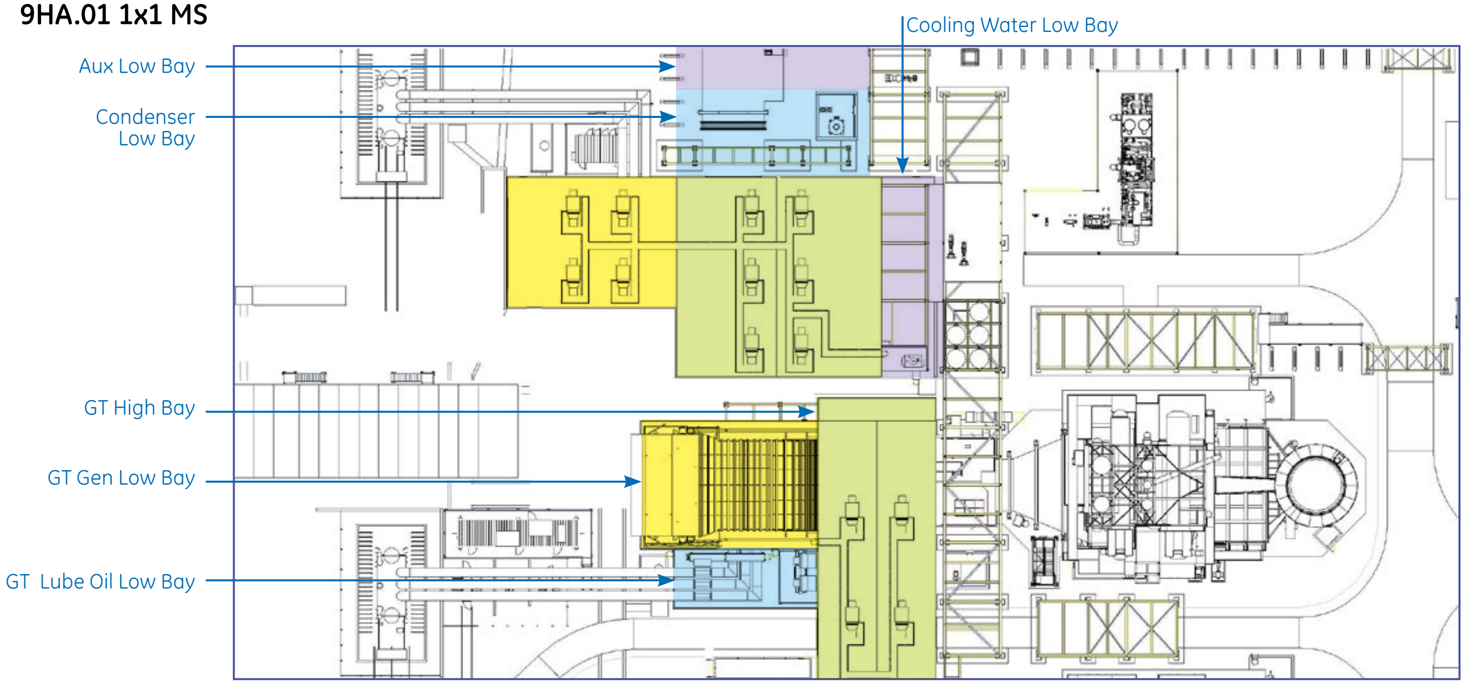
9HA.01 1x1 SS



9HA.01 1x1 MS



both electrical and process steam. These output limits are typically process steam extraction leaving at least 10% ST exhaust flow, supplemental firing up to 10% of unfired combined cycle output or ST output greater than 300 MW. Consult with engineering specialists when needs are within +/-5% of these levels to see if a single-shaft is still possible. When process steam demand requires all steam to be extracted prior to the condenser, a clutch is applied to allow the low pressure (LP) ST to be shut down. In this case, a multi-shaft configuration will be offered due to the complex interaction of train dynamics and control when the LP section is not spinning (clutch disengaged). When the supplemental firing need exceeds single generator or steam turbine-to-generator connection (clutch and collector end drive) capabilities, a multi-shaft configuration will be offered.

Customers may require the ability to perform major steam turbine service with the GT operational. In these cases, major is defined as any service requiring the opening of the steam turbine pressure boundary. The challenges of isolating lube oil and hydraulic systems, along with performing work in close proximity to operating equipment with hydrogen-cooled generators, effectively prevent this operation on a single-shaft unit. Instead, a multi-shaft configuration with a bypass stack between the GT exhaust and Heat Recovery Steam Generator (HRSG) is offered. A blanking plate is installed to ensure isolation of the HRSG steam cycle from the exhaust. The location of the steam turbine and its generator in a separate area with a dedicated lube oil and hydraulic system allow major steam turbine maintenance while the gas turbine continues to run.

Customers may require early gas turbine installation to generate power while the bottoming cycle is still under construction or part of a longer range add-on. This is known as phased installation. Single-shaft units typically require hydrogen generators due to their high output. Many phases of bottoming cycle construction call for either the hydrogen generator to be shut down or effectively isolated from construction work to allow hot work near hydrogen systems. Also, the lower lube oil system demand during gas turbine-only operation must be accommodated. Significant gas turbine downtime is needed to finish construction of integrated systems such as lube oil. Due to these issues, multi-shafts are generally specified for phased installations.

From a schedule perspective, both single-shaft and multi-shaft side exhaust configurations are capable of a 24-month Notice To Proceed (NTP) to Commercial Operation Date (COD) schedule. However, the MS activity detail between over-the-bolts major equipment like the GT, ST and generator(s) installation to first fire is different due to the two shaft lines and accessory details.

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System Interactions & Engineering Requirements

In power generation applications, 25 of the 96 Systems (26%) are impacted in some way when comparing Single-Shaft to Multi-Shaft. The comparison table below highlights the significant cost drivers.

Major Quantities Comparison

Item	1x1 9HA.01 SS	1x1 9HA.01 MS	Delta (MS-SS)
Generator	1 – 600MW	1 – 400MW, 1 – 200MW	+1 Generator & related accessories
General Station Unit Transformer	1 – 750MVA	1 – 500MVA, 1 – 250MVA	+1 GSUT
Bus Duct Length	3x58m=174m	GT: 3x60m ST: 3x51m = 333m	+159m (91%)
Lube Oil Tanks	1	2 total, 1 for GT and 1 for ST	+1 Lube oil tank
Steam Pipe & Rack	Base	+10 m each HP, HRH, CRH & LP Steam	X Tons
High Bay Buildings	57.5x26.5x20.2(m) Vol: 30,780m^3	GT: 28.75x13x19(m) Vol: 7,100m^3 ST: 26.5x24x19(m) Vol: 12,080m^3	-11,600m^3 (-38%)
Generator Low Bays	Generator in high bay	ST Gen: 22x15x19(m) Vol: 6,270m^3 GT Gen:23.7x15x14.5(m) Vol: 5,150m^3	+11,420m^3
Condenser Low Bay	26.3x11.7x19(m) Vol: 5,850m^3	26.5x11.7x19(m) Vol: 5,890m^3	+40m^3 (1%)
Aux Low Bay	26.3x7.65x5(m) Vol: 1,010m^3	GT LO: 19.1x7.75x7.8(m) Vol: 1,150m^3 Condenser aux: 26.5x7.3x5(m) Vol: 970m	+1110m^3 (1%)
Cooling Water Low Bay	17.7x15.7x5(m) Vol: 1,390m^3	24x7.2x 7(m) Vol: 1,210m^3	-180m^3 (14%)
Power Island Footprint	143x91m=13,013m^2	172x91m=15,652m^2	+2639m^2 (20%)
Excitation (Ex) Compartments & Transformers	1	1 LCI/Ex compartment & transformer for GT 1 Ex compartment & 1 transformer for ST	+1 Excitation compartment

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There are numerous differences across the plant systems. The table below describes the impacts to each system.

System	SS	1x1 MS
T50 GT Inlet	Side inlet	Located up and over generator
B31 ST Unit	Integrated with GT and Generator, Clutch between ST and Generator	Separate unit
E11 Generator	Single generator sized for combined output of GT and ST, hydrogen cooled, larger units water cooled	Two separate generators. Hydrogen or air cooled (size limited)
E12 (Generator) Gas Cooling	Hydrogen	Air (size limited) or hydrogen
E13 Excitation	One system	Two systems, one for each generator
E14 (Generator) Protection	One system	Two systems, one for each generator
E20 Electrical Evacuation	Generator step up (GSU) transformer rated for single-shaft combined generator size. Iso-phase bus duct for one generator	Separate GSU transformer for each generator for a total of two. No circuit breaker for ST generator. Iso-phase bus ducts for two generators.
E21 Voltage Conversion	One step up transformer	Two step-up transformers, one per generator
E22 High Voltage	High side connections to one step up transformer	High side connections to two step-up transformers
E322 Low Voltage	Cabling and switchgear to single lube oil and hydraulic system	Cabling and switchgear to two lube oil and sometime two hydraulic systems (when GT has hydraulics)
P11 GT Control	No lube oil & generator control. Lube oil & generator control by P12 ST control system	Lube oil & GT generator control.
P12 ST Control	Lube oil & generator control for GT and ST	Lube oil & generator control for ST
P13 Power Island Control	Logic and controls for integrated shaft line & system starting, operation and shutdown.	Logic and controls for separate shaft line & system starting, operation and shutdown
P31 Hydraulic Oil/ Lift	Integrated system for ST and GT	Separate systems for GT and ST
P32 Seal Oil	One system	If two hydrogen cooled generators, two systems. No seal oil for air cooled Generator(s)
P33 Lube Oil	Combined GT, ST, gen lube oil system. Lube oil supplied to clutch.	Separate systems for GT-gen and ST-gen units. Clutch lube oil needed only on clutched LP designs
P41 H_2, CO_2, N_2 Storage and Distribution	Single connection for E12 gas cooling system for H_2 and CO_2	Each hydrogen cooled generator (up to two) connects to S E12 gas cooling system for H_2 and CO_2. No connections for air cooled generators.
P70 HVAC	Shared HVAC for main building	Separate building for GT and ST need separate HVAC systems
P81 Service Air	Shared service for main building	Separate building for GT and ST need separate Service air systems
P82 Instrument Air	Single-shaft configuration equipment locations & tubing runs	Multi-shaft configuration equipment locations & tubing runs
P91 Foundations	Combined GT, ST, gen foundation, combined building foundation, combined lube oil and hydraulic foundation	Separate foundations for GT-gen and ST-gen, their building and lube oil and hydraulic systems
P92 Buildings	Combined GT,ST, gen building for indoor units	Separate building for GT-gen and ST-gen when indoors
P93 Cranes	Shared high capacity crane for GT, ST, gen capable of lifting ST rotor, generator rotor, GT rotor	When equipment located indoors, separate high capacity cranes for GT-gen and ST-gen capable of lifting GT rotor and ST rotor respectively. Generator rotors not accessible by building crane.
P94 Duct Banks	Compatible to single-shaft layout	Compatible with MS layout
P95 Roads	Compatible to single-shaft layout	Compatible with MS layout

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Physical Implementation

For power generation applications, the following table summarizes the physical implementation attribute differences between single-shaft and 1x1 multi-shaft (MS) configurations. Overall, 15 of 35 (43%) of the attributes are affected.

Attribute	SS	1x1 MS
Location	Single train	Two separate power trains, side by side parallel shaft lines
(Construction) Interfaces	Common lube oil, seal oil and hydraulic system. Lube oil supplied to clutch.	Separate lube oil, seal oil (hydrogen cooled generators) and hydraulic systems. Clutch lube oil needed only on clutched LP designs
(Construction) Interferences	Layout specific (example air inlet duct must be maneuvered side-ways into building)	Layout specific (example: congestion occurs when installing GT air inlet over generator while in parallel installing generator and gas turbine installation)
Modularity	Modular GT compartment engineered for single-shaft. Single lube oil, seal oil and hydraulic module	Modular GT compartment engineered for multi-shaft. Two separate lube oil, seal oil and hydraulic modules
Cranes	Indoor, single high capacity crane capable of lifting ST rotor, generator rotor, GT rotor. High capacity mobile crane required for HRSG erection	Each unit located indoors (ST and/or GT) have separate high capacity cranes capable of removing ST rotor and GT rotor respectively. Generator rotors not accessible by building crane. High capacity mobile crane required for HRSG erection and outdoor GT & ST unit erection
Gantry	Construction heavy lift gantry needed for GT and generator, optional for ST LP turbine	Construction heavy lift gantry needed for GT and generators, optional for ST LP turbine. Must be moved between GT and ST unit buildings
(Construction) Laydown	Single-shaft layout specific	Multi-shaft layout specific
Cleaning	Single lube oil system	Two lube oil systems
System Tuning	Single generator systems	Two set of generator systems
(Construction) Spares	Single generator, lube oil, seal oil & hydraulic and step-up transformer spares. Clutch spares	Two sets of generator, lube oil, seal oil (if present) hydraulic (if present on GT) system spares
Maintenance	One generator to maintain. Clutch to maintain	Two generators to maintain
(Maintenance) Spares	Single generator, lube oil, seal oil & hydraulic and step-up transformer spares. Clutch spares	Two sets of generator, lube oil, seal oil (if present) hydraulic (if present on GT) system spares
(Maintenance) Laydown	Single-shaft layout specific. See layout discussion for detail	Multi-shaft layout specific. See layout discussion for detail.
(Maintenance) Lifting Needs/ Availability	Single generator, lube oil, seal oil & hydraulic systems. Generator rotor pulled with building crane. Clutch	Two different size/models generator, lube oil, seal oil (if present) hydraulic (if present on GT) systems. Generator pull of GT and ST generators with temporary equipment.
(Maintenance) Assembly Disassembly	Generator disconnected from ST and GT, slide sideways to pull rotor	Generator rotor pulled without moving generator

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1.4 Preferred Steam Turbine Exhaust Direction (When to Bid Down vs. Single Side vs. Axial)

What It Is

Two-flow low pressure steam turbines can exhaust to condensers either in the down direction or to the side. Side exhaust steam turbines can exhaust to one side (single side) or both sides. Axial flow low pressure steam turbines can exhaust to a condenser either in the down or axial direction. Four flow low pressure configurations exhaust to condensers only in the down direction.

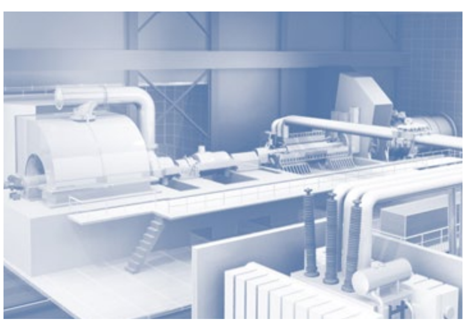
Why It Matters

Choosing the right steam turbine exhaust direction for two-flow and axial-flow pressure steam turbine configurations provides significant plant cost savings. An axial or single side exhaust steam turbine (ST) retains the performance of a down exhaust steam turbine (of the same capacity) in a smaller building volume. As shown in the figures below, lowering the centerline from ~12-13 meters to ~5.5-6.5 meters for both single-shaft and multi-shaft configurations generally requires less concrete and a less expensive building.

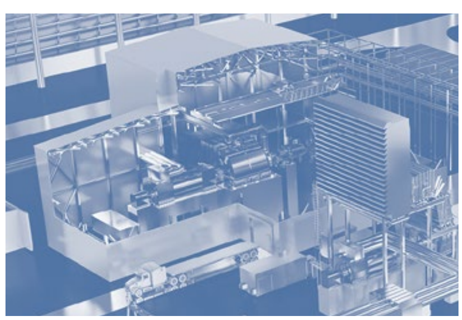
Additionally, the use of a low bay configuration over the ST generator and condenser in a multi-shaft configuration means that the building columns for this part of the structure only need to be engineered for environmental conditions, not to handle the crane loads associated with steam turbine maintenance.

The figures below elaborate on the major benefits of a side exhaust. In a typical installation, balance of plant savings are approximately $7.1M for single-shaft and $6.3M for multi-shaft configurations.

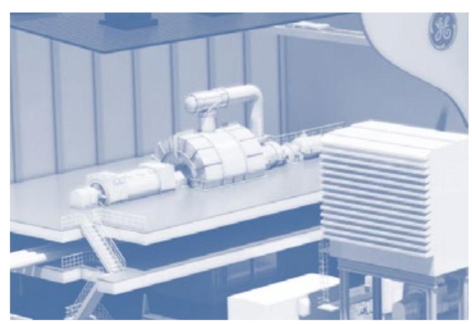
SS Side Exhaust (5.5m CL Height)



MS Side Exhaust (6.5m CL Height)



Down Exhaust (12-13m CL Height)



MS Side Exhaust Has 1m Higher Elevation to Accommodate Bigger ST Valves and Piping.

Quantity Comparison – Indoor with ST building

7HA SS	Down	Side	Delta
Concrete* (yds^3)	7,777	6,336	-1,441 (-15%)
Steel (MT)	950	725	-221 (-24%)

9HA 2x1 MS	Down	Side	Delta
Concrete* (yds^3)	5,692	4,694	-998 (18%)
Steel (MT)	951	660	-291 (-31%)

*Equipment + Building Foundation

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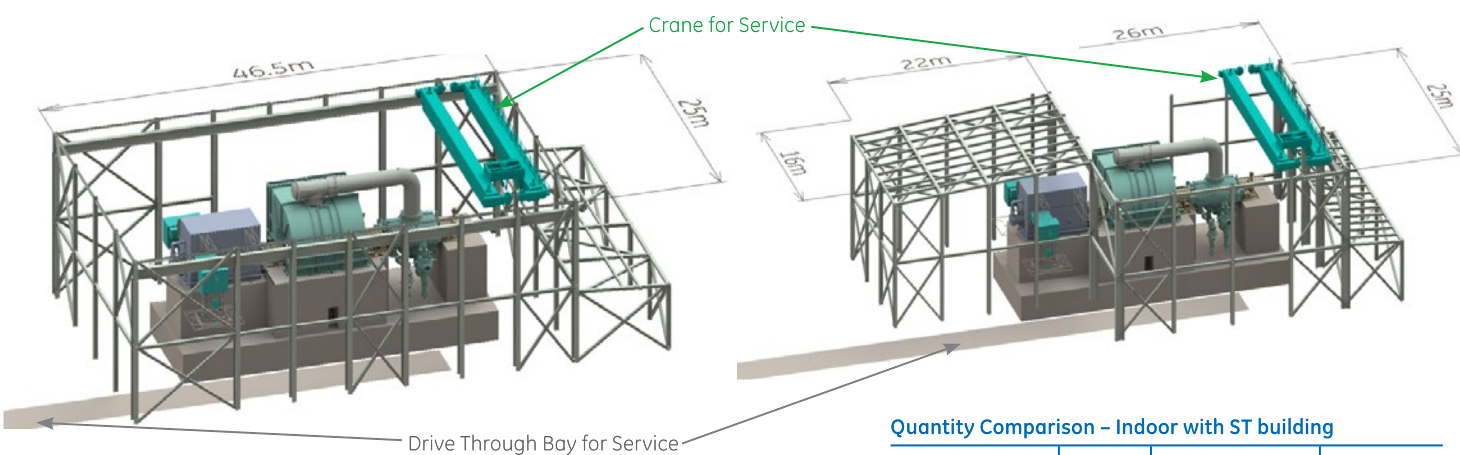
Legacy Practice | State-of-the-Art



Quantity Comparison – Indoor with ST building

9HA 2x1	Legacy	State-of-the-Art	Delta
Concrete (yds³)	4,694	4,219	-475 (-10%)
Steel (MT)	660	580	-80T (-12%)

Key Enablers

A side exhaust steam turbine requires a semi-rigid connection between the low pressure (LP) hood and condenser to allow differential settlement of the major foundation structures without overstressing the LP hood or impacting clearance control inside the steam turbine. The semi-rigid connection also allows support of the condenser from the bottom of the structure, not at the level of the turbine centerline (5.5 m), reducing the complexity of the condenser foundation.

In multi-shaft configurations, hydraulic jacks are used to remove the generator rotor from the stator. This eliminates the need for a heavy lift crane over the generator, permitting a low bay structure in this area. In a single-shaft plant where the generator does not have a "free end," hydraulic equipment is used to first pull the entire generator out of the shaft centerline. But since it is still located inside the crane rails used for GT and ST maintenance, the crane is used to remove the rotor from the stator.

A leads up generator on single-shaft units allows the generator to be pulled sideways to clear the shaft centerline for rotor removal. In the case of a multi-shaft unit, a leads up generator simplifies constructability and minimizes the length of isophase bus duct from the generator to the step-up transformer.

Requirements & Constraints

Site conditions combined with water supply capabilities and grid connection electrical output capacity will drive the selection of the gas and steam turbine configuration. The resulting steam production and condenser pressure will determine the volume of steam leaving the steam turbine. When the volume flow of steam is appropriate for a single flow (axial exhaust) or double flow (single side exhaust) steam turbine a low centerline configuration can be used. In situations where the volume flow of steam requires two double flow low pressure (LP) sections (also known as a four-flow low pressure section), a more traditional down flow, high centerline building will be needed.

Side and axial exhaust steam turbines have an increased footprint compared to down exhaust, so in some circumstances there may be site constraints where a high centerline construction is preferred. Most commonly this would be when acreage is limited. For example, in a repowering scenario it may be necessary to use a down exhaust to fit into structures at an existing power station.

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System Interactions & Engineering Requirements

P93 Crane

For a low centerline multi-shaft plant, the crane rails for maintenance of the steam turbine are oriented transverse to the shaft centerline minimizing the amount of building steel sized to support these loads.

P92 Buildings

The ST building features a P95 access road alongside the P91 steam turbine foundation to minimize the transit of heavy equipment lifts both during initial construction and maintenance.

P91 Foundation, B34 Bypasses, B41 Condensing Steam, H10 Circulating Water

The foundation (and piping systems) connected to both side and axial exhaust condensers must be engineered to facilitate sliding movement of the condenser. This accommodates thermal growth during transient events and the deflections associated with vacuum loads on the structure.

B35 ST Drains, P30 Oil Systems, P66 Plant Drains

Application of a low centerline foundation results in less vertical drop available for gravity driven piping systems. Attention must be paid to the routing of these lines to ensure adequate service.

Physical Implementation

Gantry structures used for installation of turbine sections are much simpler in a low centerline foundation when compared to lifting to a higher centerline structure. An additional advantage of the low centerline foundation is the ability to use the roadway through the building to stage heavy gantry lifts. Because the centerline components can be lifted in from the side, the erection sequence can be adapted to suit the site-specific delivery schedule and construction conditions more easily. In other words, the assembly of the LP section can proceed independent of loading the HP/IP section since the HP/IP does not need to be lifted through the area where the LP is located. Since the areas where lifting is performed (like a road) will never have piping systems running through them, there is no conflict with waiting on turbine delivery prior to starting construction of the piping systems that will serve it.

In single-shaft configurations, special tooling is needed to pull the generator stator sideways from the centerline for rotor maintenance. This tooling is pre-engineered and pre-staged at strategic locations around the world to support maintenance operations. Specialty subcontractors, already trained in the use of this equipment are brought in to perform this work. In previous configurations, the stator was not pulled to the side, but was jacked vertically until the rotor could be removed by pulling it out of the generator directly over the steam turbine.

In multi-shaft low centerline units, the generator rotor can be pulled out of the stator directly, since the generator is at the end of the unit. Because of the low centerline, rotor removal is possible with a specially engineered rail system supported off the ground level instead of the more traditional approach of using the steam turbine maintenance crane. This system is currently in use with generators coupled to gas turbines and has been demonstrated to be a safe and effective method of pulling the rotor.

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1.5 Compact Gas Turbine Building for Multi-Shaft Configurations

What It Is

For multi-shaft combined cycle plants, gas turbines (GT) and their generators are usually outdoor units. If environmental requirements such as noise, temperature and precipitation or other customer requirements warrant an indoor solution, the GT is installed in a building.

Why It Matters

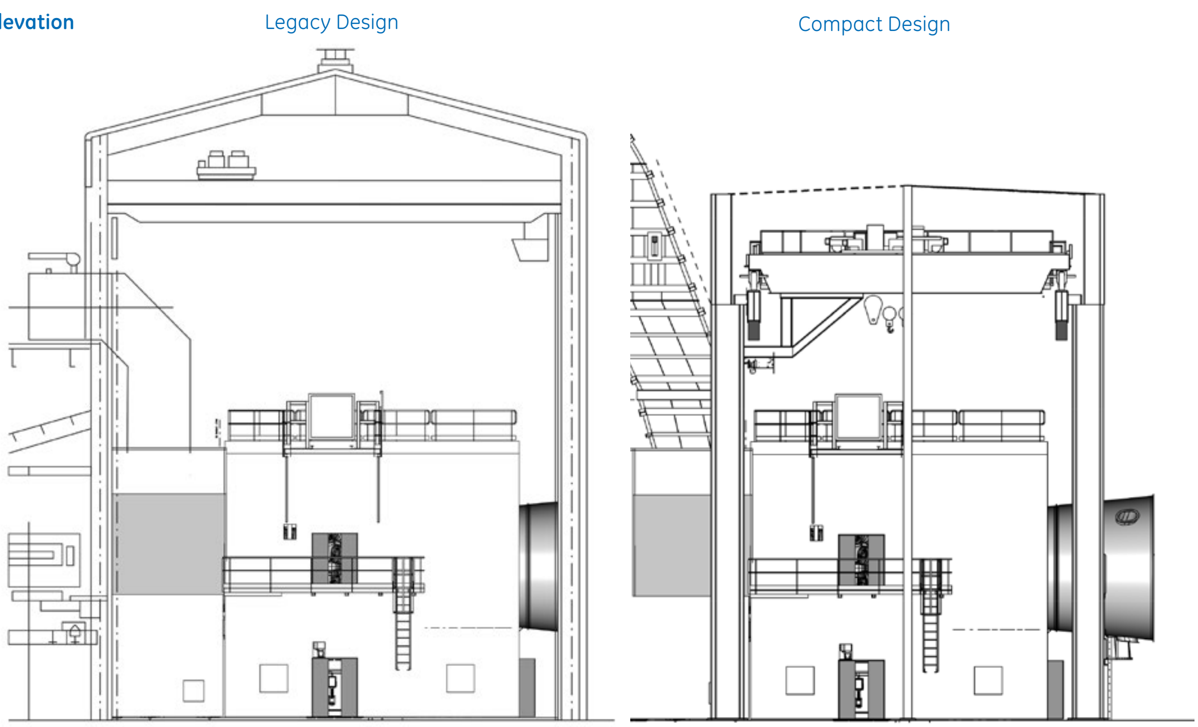
Buildings, when required, add substantial capital cost to a combined cycle plant. For a typical 2x1 9HA.01 configuration, the cost is ~$7-10 MM ($6-8/kW) depending on GT design needs. Key cost drivers are the building footprint and height requirements.

The GE building concept facilitates construction and maintenance within a compact building configuration. Compared to legacy configurations, building volume is reduced by 34% and steel by 19% (86 metric tonnes) for a typical 2x1 9HA configuration. In a typical installation, the savings is expected to be $2M (~$1.7/kW). Similar savings are achieved for other GT models.

Key Enablers

By angling the GT air inlet as shown in the figure at right, the building height and width are significantly reduced. Adding a low-drop telescopic crane to the main crane rail allows installation and removal of the air inlet panels for GT maintenance activities such as rotor removal.

GT Building Elevation



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Requirements & Constraints

Far-field noise requirements can dictate a need for a GT building. When the noise limit is 58dbA at 122m (400 ft.) or less, GE acoustic engineering specialists should be consulted to determine if a building is needed.

The GE GT and generator package can tolerate most site atmospheric temperature ranges and rain/snow frequency and quantities. However, in extreme cold or snow (e.g., Russia) or rain (e.g., Bangladesh) conditions, GE recommends a GT building for maintenance and constructability. Typically, conditions that warrant further discussion between the end user and plant constructor are:

- Ambient temperature extremes colder than -30°C (-20°F)
- Snow amounts > 1m (40 inches) /year
- Rain amounts > 1.5m (60 inches)/year

In these situations, the GE application team will meet with the customer and contractor to discuss applying a GT building and to determine the final offering. Customers usually request indoor GTs under these circumstances.

System Interactions & Engineering Requirements

Building

Building height will be determined by the lifting requirements to remove the GT rotor for servicing. The building must be capable of supporting a crane that can lift the GT rotor.

The addition of a GT building system (GE Function P92 Buildings) affects the following other GE functions:

P91 Foundations

A suitable foundation is needed for the building that considers the site soil conditions, rain and snow loads plus the crane lifting (GE Function P93) capacity.

P93 Cranes

A single main-building crane of sufficient capacity to lift the GT rotor is necessary. The capacity of this crane must be considered in the engineering of building structure (P92) and foundation (P91). In addition, a smaller capacity low-drop telescopic crane capable of lifting the GT inlet panels must be provided as shown in the figure above.

P95 Roads

The addition of a building requires the roadway between gas turbines for multiple GT configurations.

P74 HVAC of Plant Aux

The addition of a building requires HVAC systems suitable to maintain interior conditions based on internal and external heat loads.

T50 GT Inlet

The smaller building requires the GT inlet to have a sloped duct to clear the building crane.

E32 Low Voltage

Additional building lighting, HVAC and crane are powered by this system. They need to be added to the plant electrical load list, single line diagram, cable list, installation drawings and bill of quantities as appropriate. Outdoor lighting in the GT building area must also be adapted for the presence of a structure.

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Physical Implementation

The addition of a building affects the physical implementation attributes as compared to an outdoor GT plant.

Layout Interfaces

The typical GE plant 2x1 MS layout will accommodate the GT building without change to equipment and accessory arrangement.

Lifting Capability/Availability Cranes

Placement of the GT will be accomplished by a constructor-provided gantry crane system, regardless of whether the GTs are indoors or outdoors. The building crane will be used in lieu of an outdoor crane for inside building GT accessory, compartment and external component assembly.

Construction Laydown

Laydown space typically provided between the GTs for outdoor units is now inside the building.

Maintenance Laydown Requirements

Laydown space provided between the GTs is now inside the building.

Maintenance Lifting Needs/Availability

Building crane provides for typical GT maintenance including rotor removal. An outdoor crane is not needed for this servicing.

Maintenance Assembly/Disassembly

With a single heavy capacity crane, heavy work on multiple GTs at the same time is not possible. However, since GT maintenance is typically performed sequentially, this does not normally impact servicing outage duration. Note that for added cost, a second heavy-capacity crane can be installed at customer request to provide for simultaneous usage on multiple GTs.

Other

The critical path schedule for the plant is unchanged by the addition of a building. However, the presence of a building does impact the amount of parallel work that can be accomplished with two or more GTs in the multi-shaft configuration. Because of limited unit access, there is limited construction benefit to two heavy-lift capacity cranes. Because of this, the GE standard practice provides one main building crane for indoor units. Outdoor units typically employ two outdoor mobile cranes to support GT accessory and compartment erection.

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2.0 Schedule

A critical factor affecting the Total Installed Cost (TIC) of a new power plant is the amount of time required for plant construction and commissioning. The typical standard for measuring this duration is the time from when the customer issues the official Notice to Proceed (NTP), until the plant is capable of generating full revenue at the plant Commercial Operation Date (COD). OEMs and Engineering, Procurement & Construction (EPC) contractors, strive to cost effectively reduce this NTP-COD schedule in order to reduce plant TIC and provide a more competitive equipment/plant offering and win more orders. For a 1,000 MW combined cycle power plant, the interest charged on the money the typical customer borrows to build the plant averages $2.3 million per month. Shortening the NTP-COD schedule means the customer can generate revenue earlier, pay off their construction loans faster and be more profitable. Plant and equipment offerings with reduced NTP to COD schedules are therefore the most competitive.

NTP-COD schedules can be shortened in a number of ways. Providing the EPC with accurate drawings and information early in the plant bidding and design process allows plant engineering to proceed and be completed more quickly. Such engineering is critical to competitive bidding for sales opportunities as well as timely and smooth plant construction.

Another method for attaining a shorter, more predictable NTP-COD schedule is the reduction in the total volume and complexity of installation work required for GE equipment. The following features all reduce the labor and time required to install/commission GE turbine/generators.

- Modularized gas turbine compartment
- Steam Turbine Installation and Constructability Features
- Lube Oil System Flush Features
- Flanged Steam Turbine Valve Connections

By incorporating the above features and by supplying accurate drawings/information to the EPC, GE enables a faster and more predictable NTP-COD schedule. This results in GE's equipment being more competitive and also enhances the competitiveness of EPCs that bid for projects with GE equipment.

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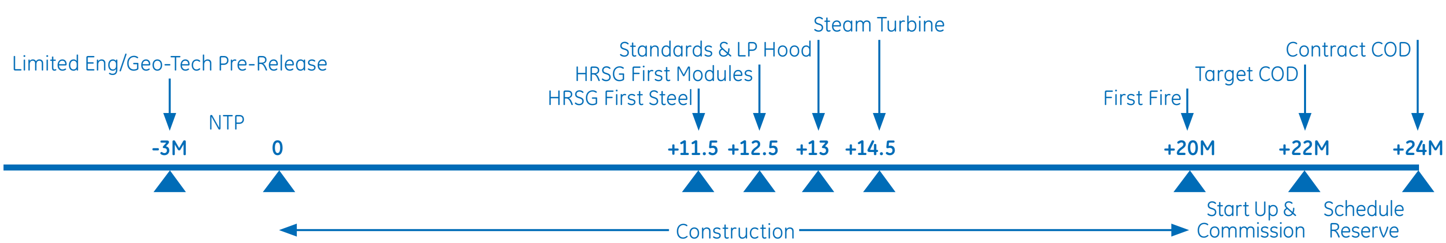
2.1 Project Schedules for Single-Shaft and Multi-Shaft Plants

The project schedule is a comprehensive view of all the elements of bidding and building a power plant. Understanding the key elements of a project schedule is important when determining critical path of the power plant cycle. The schedule or total cycle is usually expressed in months from Notice to Proceed (NTP) to Commercial Operation Date (COD). Several levels of project schedule are used and a Level One (L1) schedule is often included in the contract with the customer.

Different elements of the schedule are owned and controlled by different parties, yet the total project schedule is very important to the economics and competitiveness of a power plant. Without a good and reasonable project schedule, it is possible for an OEM to have the most efficient power generation equipment in the world and still lose a bid because it will take too long to install the power plant. In general, GE's power generation equipment will be one critical path from NTP to the delivery of the GT, ST and Generator(s). Once delivered, the EPC is typically the critical path for installation and commissioning up to COD.

Single-Shaft – 24 Month Schedule at a Glance



Plant Enablers

- Parallel Erection of GT/ST/Gen/HRSG
- GT/ST/Gen Flexible Installation Sequence
- Separated Mechanical and Electrical
- Roadway Through Turbine Building
- Low Centerline
- Mechanical Steam Pipe Cleaning
- E-Room Electrical Compartment

Equipment Enablers

- Modularized GT Compartment, Piping and Accessories
- ST Constructability Features
- Side or Axial Exhaust ST, Side Inlet GT

Assumptions

Site access 90 days prior to NTP for Geo-Tech survey, greenfield site, no pilings required, liquid fuel commissioning after COD, customer reliability run requirements add to schedule duration.

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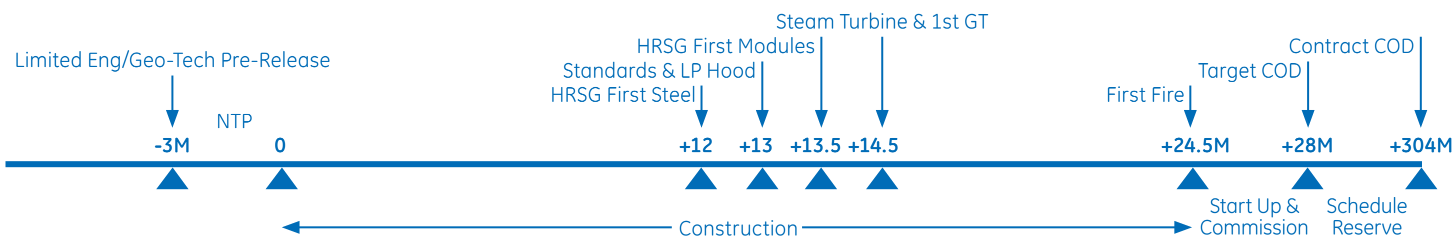
The schedule of a CC power plant can range from 24 to 36 months or more, depending on such variables as where it is installed, the climate of that region, the labor force who build the plant, logistics of the project site, etc. GE and the EPC share the critical path of these schedules. Shorter equipment engineering and manufacturing cycles support earlier construction. In addition, there is value in a configuration that is conducive to easy and timely installation. During the bidding phase of a project, the customer puts a value of the schedule and it is factored into their evaluation of the power plant. For recent international projects, the value of one month of the schedule was worth over ~$10.7M of Net Present Value (NPV).

2x1 Multi-Shaft – 30 Month Schedule at a Glance



Plant Enablers

- Parallel Erection of GT/ST/Gen/HRSG
- GT/ST/Gen Flexible Installation Sequence
- Separated Mechanical and Electrical
- Truck Access Roadways & Crane Planning
- Low Centerline
- Mechanical Steam Pipe Cleaning

Equipment Enablers

- Modularized GT Compartment, Piping and Accessories
- Side or Axial Exhaust ST

Assumptions

Site access 90 days prior to NTP for Geo-Tech survey, greenfield site, no pilings required, liquid fuel commissioning after COD, customer reliability run requirements greater than one week add to schedule duration.

Project schedules for SS and MS differ slightly due to the configuration and layout of the plant. The target for a SS plant is 24 months and for a MS it is 30 months. The primary difference between the durations of SS and MS is the added volume of labor for multiple shaft lines and generators (for a 2x1 that is three shaftlines compared to one in a 1x1) that require more integration and labor to coordinate the commissioning of the power plant.

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2.2 Modularized Gas Turbine Enclosure

What It Is

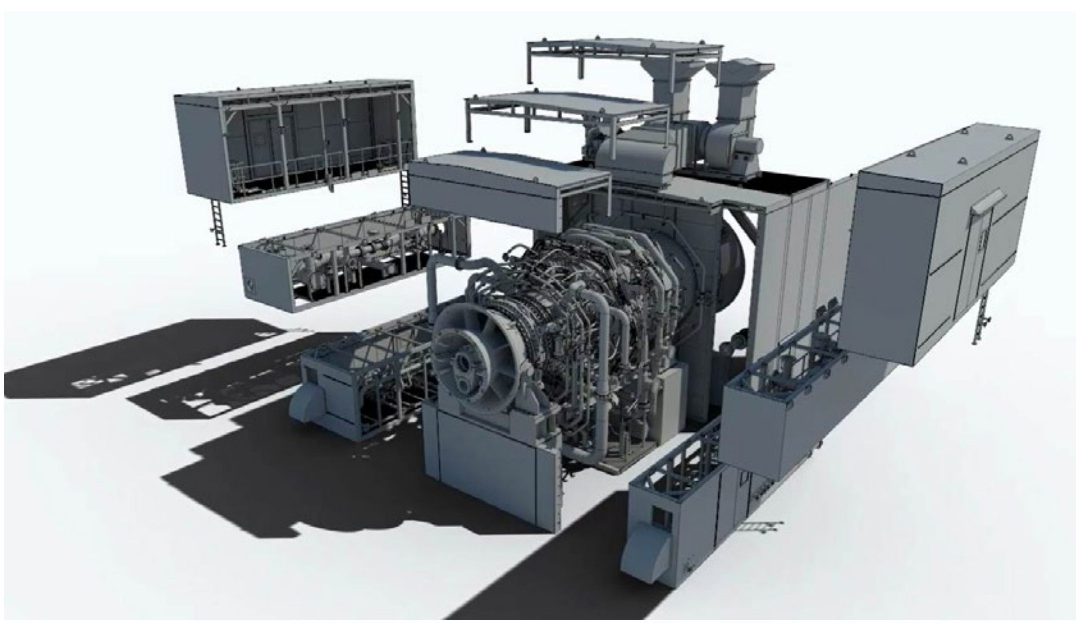
Modularization is used to meet the objectives of high quality, low cost and short lead times. In this case, a modularized gas turbine (GT) enclosure can reduce site installation labor, improves overall quality and maintainability.

Why It Matters

By modularizing the GT enclosure, the gas turbine critical path installation cycle is shortened by 8 weeks and labor reduced up to ~10,000 hours. Packaging piping and valves into modules that stack together to form the enclosure virtually eliminates the need to install them in the field. They arrive at the site fully commissioned and tested, leading to better quality control and less time spent troubleshooting. GE has also extended the scope of modularization to include instrument air and all drain piping within the GT enclosure resulting in more critical maintenance space and easier access. A clean roof configuration is incorporated with no electrical or mechanical equipment located on the roof panels. These panels are engineered with quick removal features for faster GT inspections.

Key Enablers

The enclosure modules have been packaged together to allow for a simplified installation. The modules ship to site with all piping, valves, instrumentation tubing, cable tray and insulation already installed and commissioned in the factory. Instrumentation is mounted to the exterior of the modules and is simply connected to the home-run cable back to the control panel at the site.



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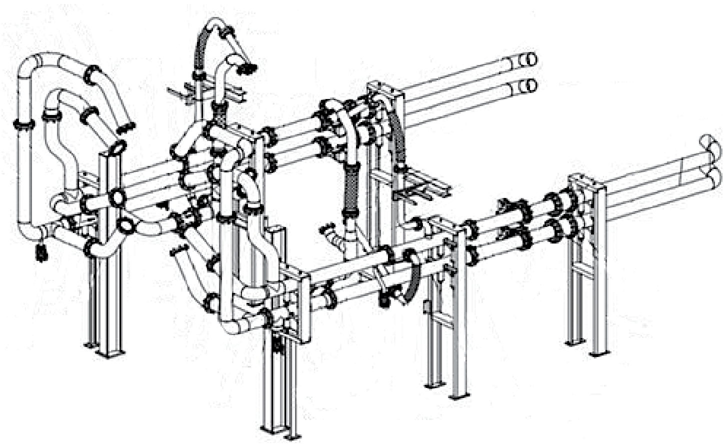
The equipment package allows for a construction schedule that is more flexible and enables parallel paths of construction. Once the modules are set in place, work can begin simultaneously to install on-base piping to the gas turbine while crews work separately to join instrumentation to the control system with interconnect cables.

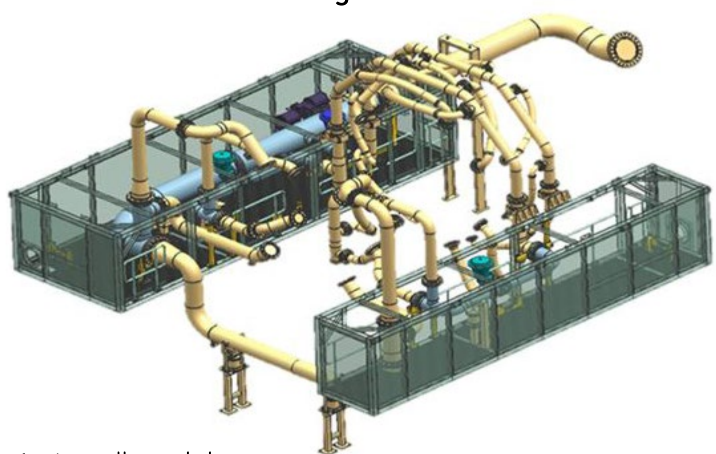
Modularization Comparison… Cooling and Sealing Air



7F.03 Cooling and Sealing Air

1. Build scaffolding
2. Install piping and piping supports
3. Install ship loose valves in piping
4. Build enclosure around pipe, mount junction boxes, cut piping penetrations through walls
5. Route instrument air tubing, electrical wiring & conduit to wall of enclosure
6. Complete water wash drain piping (epc scope of design & supply within enclosure)
7. Commission valves and instrumentation
8. Insulate all piping
9. Install turbine maintenance grating and handrails

7HA.01 Modularized Design



1. Install modules
2. Install piping between GT and modules
3. Insulate field installed piping

Results	7F.03	7HA	Reduction
Install Hours	1,641	850	48%
Field Welds	74	35	52%
Field Install Valves	6	0	100%

Requirements & Constraints

This feature has been engineered as the standard offering for the 7HA and 9HA configurations. There are no constraints to application.

System Interactions & Engineering Requirements

This configuration impacts the gas turbine piping for all of the sub-systems which are packaged inside the gas turbine enclosure. Cooling and sealing air and fuel systems are integrated with the enclosure structure as modularized sections.

T10 Gas Turbine Unit

Base piping systems are integrated with the modularized sections of the GT enclosure.

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T12 Cooling and Sealing Air

Piping systems are integrated into the modularized sections of the GT enclosure.

T20, 30 Gas Fuel, Liquid Fuel Delivery

Fuel skids are integrated into the modularized sections of the GT enclosure.

P91 Foundation

The foundation needs to account for the modularized GT enclosure.

Physical Implementation

This has a significant impact on the packaging of the GT unit and enclosure.

Layout Location and Interfaces

The layout is not impacted by the modularized enclosure, but interfaces are adjusted to accommodate standardized locations.

Packaging Modularity

Liquid fuel and gas systems now arrive packaged within the GT enclosure structure vs. separate skids.

Construction Connections

Significantly less flanges and welding are required to install modularized sections.

Plant Critical Path

Schedule is improved utilizing a modularized configuration including parallel work paths.

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2.3 Steam Turbine Installation and Constructability Features

What It Is

This is the sequential mechanical erection, oil flush and electrical/controls connection of the steam turbine components and assemblies. Its completion is marked by the ST achieving turning gear status.

Why It Matters

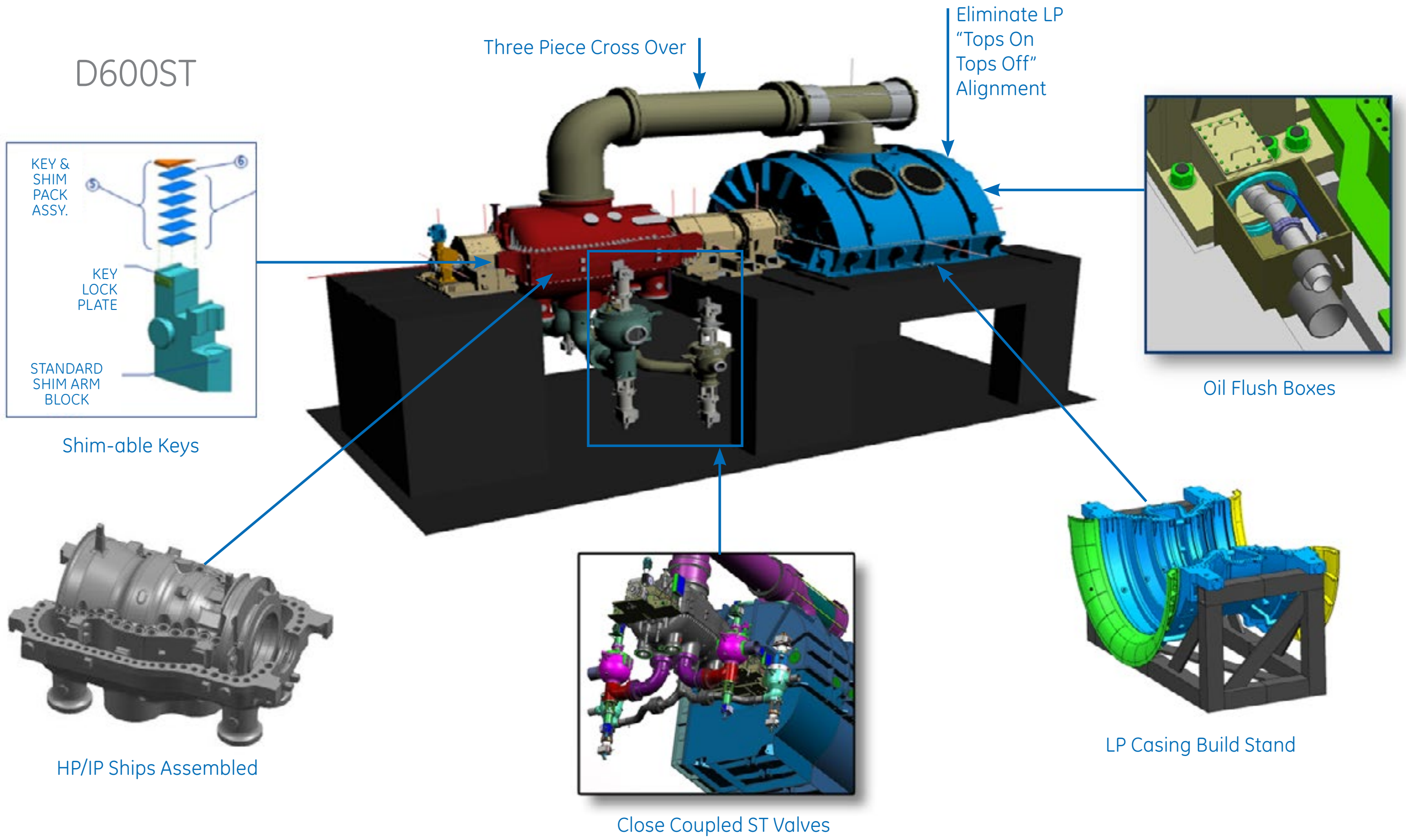
The duration of the steam turbine installation cycle is a primary driver of the total time required to construct a combined cycle power plant. Historical construction installation durations for the D400 have ranged from 8 to 10 months. For GE's new line of D600 and D650 turbines construction cycles have been reduced to ~5.5 to 6.5 months, depending on the specific model. At the same time, man hours required for turbine installation have been reduced by ~35%. A series (A200, A450 and A650) also include features to reduce installation cycles by 4 to 6.5 months, depending on the configuration.

These enhancements allow more ST installation work to be conducted in parallel, resulting in installation times that are faster and less variable. For the customer, that means plant construction costs are lower and more predictable.

Reduction of Construction Cycle

"Construct-Ability" Enabling Approach/Feature	Benefit	Cycle Reduction Estimate (Weeks) D600	A650
Standards, LP Stationary Parts & Build Stand Arrives Six Weeks Before HP-IP	Set and grout standards early. LP hood & inner casing build parallel path activities	3	N/A
No-Tops-On/Tops-Off Alignment	Removes activities from critical path	4	2
"Boltless" LP Diaphragm Support Bars	Once LP rotor is set – no need to lift to adjust steam path components	1	1
Steam Pipes Flanged	Reduces the critical path cycle for piping attachment	3	2
Oil Flushing Boxes	Removes oil flush from critical path activities	3+	3+
Shimmable Keys	No waiting for final machining of solid keys when finishing turbine construction	2	1
Three Piece Cross-Over	Ease of install & maneuvering. Small "lay down" space foot print	1	
Ship IP/LP Assembled	No IP-LP build at site	N/A	Yes 6 / No 0

Examples of Key Constructability Features



Key Enablers

Features implemented in the equipment combined with improved foundation and plant layouts are key to achieving this reduced cycle. Shown below are just a few of the enablers.

Requirements & Constraints

The selection/implementation of the constructability features is application specific.

Some code types will have "ship assembled" options depending primarily on factory capacity and logistics, followed by various considerations of the customer/EPC.

For example, lubrication oil features are included that put the oil flush on an independent and parallel path to the main centerline construction. Lubrication oil piping will be "dry" guard unless the customer or local regulations and standards require "wet" guard. Regardless, the benefits for schedule remain intact.

System Interactions & Engineering Requirements

B31 Steam Turbine Unit

New features are incorporated into the equipment as specified in Chapter 2.3.

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P91 Foundation

Foundation arrangement needs to suit the features below and should be reflected in the GE customer foundation interface drawings.

- Close coupled valves
- Lube oil flush features. Incorporate flush box features into plant layout and lube oil system drawings
- Height of A series LP hood supports
- Access under D series side exhaust

Physical Implementation

Construction Methods

The features are sufficiently independent and will be implemented into all new applicable steam turbines going forward. The plant critical path schedule is shortened due to the constructability features.

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2.4 Lube Oil System Flush Features

What It Is

By incorporating flush boxes on its turbine standards, GE reduces the time required to prepare for and recover from oil flush. It also enables the performance of lubrication oil flush in parallel with other critical path installation and maintenance activities to shorten the overall schedule.

Why It Matters

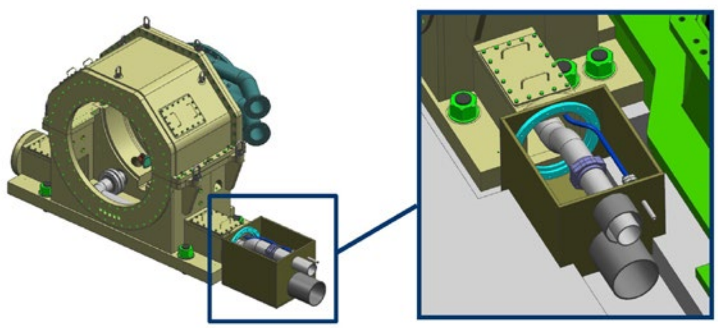
Turbine lubrication oil flush has historically been an activity that directly affected installation and maintenance durations because it had to be performed in sequence with other critical construction and maintenance activities. Also, the duration of the lubrication oil flush has been highly variable due to site-to-site variations in equipment and workmanship. The time required to prepare for, execute and recover from oil flush typically ranges from 3 to 6 weeks for steam turbine (ST) new unit installations. Eliminating lubrication oil flushing from "critical path" installation and maintenance work effectively removes the time required to do flush work from installation and maintenance durations.

Without this highly variable and time-consuming activity in the installation and maintenance cycles, the total installed cost of GE's equipment goes down and overall life cycle costs are reduced. The use of flush boxes reduces cycle time by 3 to 6 weeks.

Key Enablers

Dedicated flush boxes installed at the turbine standards are the key features required to perform oil flush in parallel with other turbine activities. Flush boxes provide the means for the oil feed piping and the oil itself to be isolated from the standards during flush. This allows coupling alignment, instrumentation installation and other critical activities to continue within the turbine standards while oil flush occurs in parallel.

The lubrication oil feed piping must be flanged between the flush boxes and the bearing that is served by the feed piping. This allows the piping that is not flushed to be removed and cleaned by hand. After cleaning, this short section of piping can also be easily inspected and verified as being free of contaminants.



Requirements & Constraints

Adequate space to install the flush boxes must be provided at the turbine standards. They are not to be installed remotely from the standards as this will increase the amount of unflushed piping requiring hand cleaning and inspection. Also, the use of separate feed and drain piping is highly recommended in order to reduce the work required to install this piping and make the system easier to flush. Note, the use of guards around the feed piping is required in locations where pressurized oil could spray on hot turbine components.

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System Interactions & Engineering Requirements

There are few system interactions affected by the use of lubrication oil flush boxes.

P30 Oil System

Oil supply piping needs to incorporate spool pieces to interface to the flush boxes. Flush boxes will need to be added to the scope of the piping system and scope of supply.

Physical Implementation

Layout Location

Flush boxes will not impact lube oil tank location, but boxes need to be located within the interconnecting piping between the lube oil tank and turbine.

Methods Cleaning

Implementation of flush boxes will lower the cycle time required to flush the lube oil system.

Construction Connections

The flush boxes will be shipped separately from the turbine standards. They are to be installed during the turbine erection process. The assembly will include typical bolting hardware and gaskets to assemble the flush boxes and piping in a leak free condition. The absence of external leaks is to be verified during the commissioning of the lubrication oil system.

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3.0 Simplification

Several new electrical and mechanical accessory system features are available that provide for a simplified system design and faster implementation in the field. The first feature, electric Inlet Guide Vane (IGV) and Variable Stator Vane (VSV) actuators, replace the hydraulic system for vane actuation. The second feature is the pressure atomized liquid fuel system which provides significant improvements in reliability, availability and maintainability (RAM) as well as greatly reduced number of components and piping. The third feature is factory commissioned skids which essentially commissions the skid in a vendor facility vs. in the field. The fourth feature is the consolidated electrical room bringing significant improvements in integrated electrical system packaging and factory checkout. The fifth feature is the water mist fire protection system which replaces the legacy CO_2 system.

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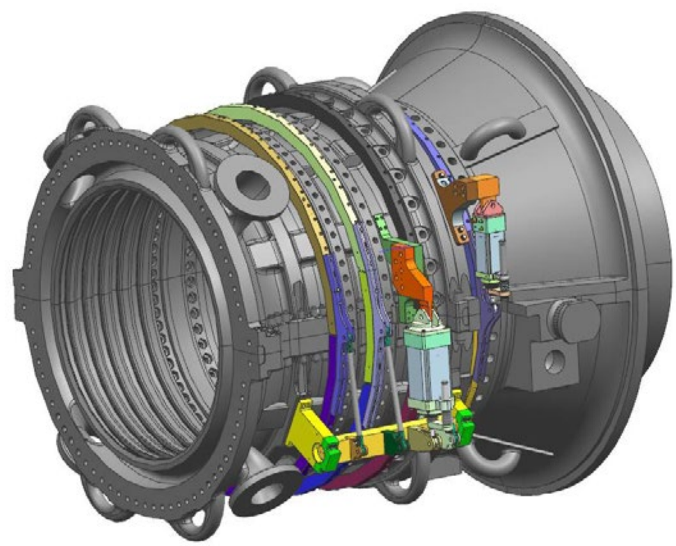
3.1 Electric Inlet Guide Vane and Variable Stator Vane Actuators

What It Is

Electromechanical actuators can be used in place of traditional hydraulically-driven actuators on and around the gas turbine to offer many operational advantages.



Why It Matters

Historically, Gas Turbine Inlet Guide Vane (IGV) and Variable Stator Vane (VSV) actuators have been hydraulically controlled. There are a lot of complexities with a hydraulically controlled system that can be simplified by going to a different form of actuation.

Electromechanical linear actuators are GE's preferred method to eliminate high pressure hydraulics inside the gas turbine (GT) enclosure.

Electric actuators only require cable trays and cable routing for installation at site. This eliminates field routing of hydraulic tubing and piping, removing the risk of leaks and removing costs associated with installation and flushing the piping.

By using electric IGV/VSV actuators, we eliminate all of the hydraulics on the gas turbine along with redundant hydraulic pumps and AC motors, accumulators, filters, tubing/piping, instrumentation and servos. This greatly reduces the number of components that require maintenance and commissioning. Although it is difficult to place a value on it, plant insurers typically view the removal of hydraulics favorably.

The actuators are located on the gas turbine and provide the linear actuation that drives the movement of the IGV and VSV vanes. The controller for the actuators is called the Digital Vane Positioner (DVP). The DVP converts commands from the Mark*VIe, reports back positioner feedback/fault information and controls the position of the actuators.

Key Enablers

The electric actuators are located in the same position on the GT as the hydraulic actuators and are supported by:

- 220v DC battery back-up system (typically supplied by GE)
- Two Can-bus network cables back to the Mark*VIe Power-Constrained Noise Optimizer (PCNO)
- Digital Positioner cabinet located outside of gas turbine enclosure (typically supplied by GE)
- Instrument air for digital positioner cabinet cooling

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Requirements & Constraints

When the gas turbine enclosure is supplied by GE, the digital positioner cabinet is located inside the Inlet Plenum Acoustical Enclosure. Cable length limits will set the location constraints for the E-Room. If the customer supplies the GT enclosure and locates the digital positioner cabinet (not typical), the cable lengths to the actuators will also be required to meet specific functional requirements for the configuration.

Greasing of the actuators once a year or after 8,000 hours of operation is the required maintenance. Also, actuators are to be sent back to the supplier for overhaul at the major 50,000 hour outages. GE provides removable platforms to allow walk-up access to the actuators.

System Interactions & Engineering Requirements

T10 Gas Turbine

Electrical actuators mount to support brackets located on the compressor casing. Mechanical actuation is through linkages to the compressor IGV and VSV actuation rings.

P10 Control System

Most system interactions are between the Mark*VIe and the Digital Positioners.

P82 Instrument Air

The Digital Positioner will use instrument air for cooling the cabinet. Sizing of the instrument air system needs to account for this cooling requirement.

E30 Auxiliary Power Distribution

PEECC and digital positioner cabinet distance requirements need to be taken into account when placing equipment in the plant layout. Cabling requirements to actuator need to be determined.

P31 Hydraulic System

The overall hydraulic system requirements are reduced which will enable a smaller hydraulic system and the elimination of piping supply and return for the IGV/VSV actuator.

Physical Implementation

Methods

With electrical actuation, system calibration methods are revised for electronic vs. hydraulic means.

Maintenance Lifting Needs/Availability

At major rotor outages, the building crane used for typical GT maintenance will be needed to pull the actuators off the gas turbine. An outdoor crane is not needed for this servicing.

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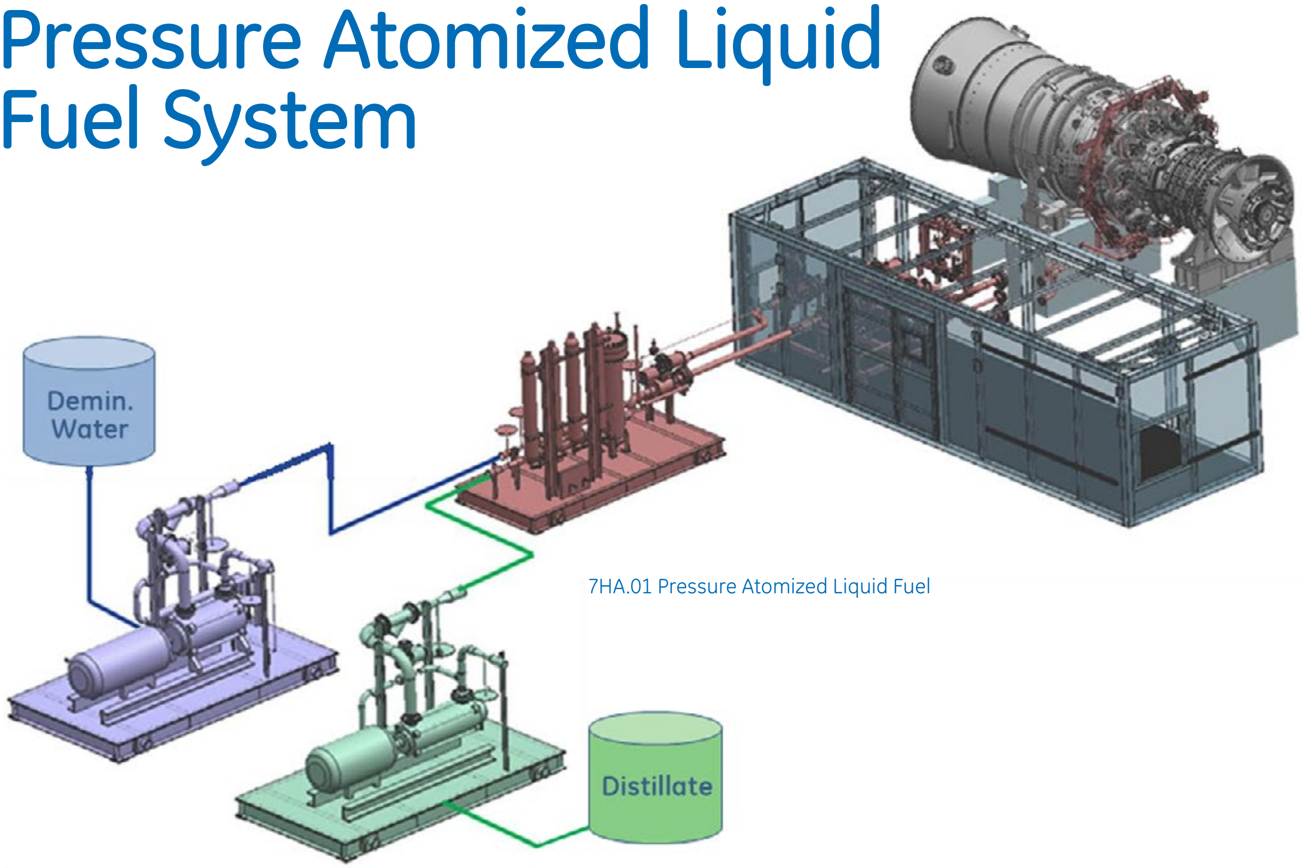
3.2 Pressure Atomized Liquid Fuel System



7HA.01 Pressure Atomized Liquid Fuel

What It Is

The pressure atomized liquid fuel system eliminates fuel coking by flushing residual fuel with high pressure water instead of air or nitrogen purging. It provides a more reliable fuel delivery system with less complexity compared to prior configurations.

Why It Matters

Reliable starting and transfers are critical for a back-up fuel system. System reliability is intrinsically improved by the removal of several components: atomizing air, flow divider, fuel heating, fuel forwarding and fuel recirculation. System installation and maintenance durations are also inherently reduced (installation reduced ~3,500 hours) by an order of magnitude as a result of the simplifications to the system. The arrangement of valves in the system provides a National Fire Protection Association (NFPA) purge credit-ready configuration. This system also utilizes 30% less water for NO_X control.

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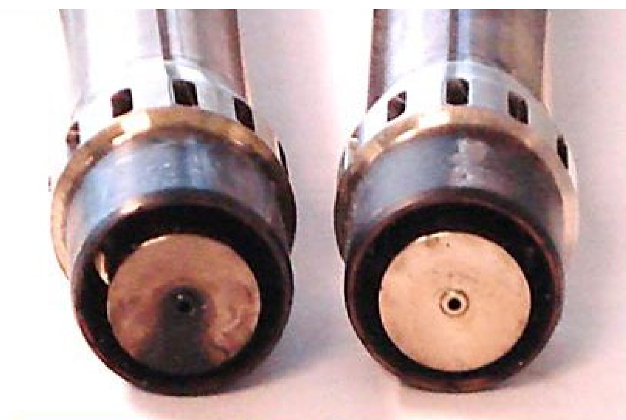
Key Enablers

The combustor utilizes a combination of both high pressure fuel delivery and passive air flow within the unit to atomize fuel, thereby eliminating the need for an atomizing air system.

The combustor requirements for fuel viscosity are less stringent, and do not require a fuel heating system. Nor is a fuel recirculation system required.

Higher pressure drop across combustion nozzles overcomes the effects of elevation/gravity head on fuel distribution. This, in combination with water flushing, allows removal of the flow divider.

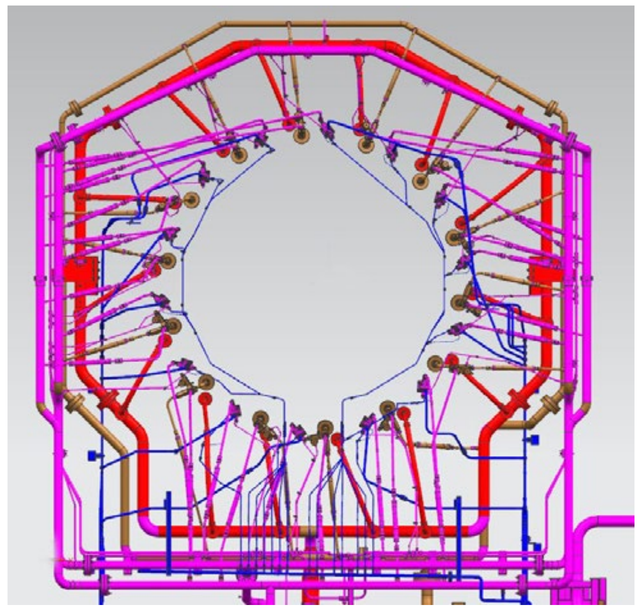
Hydraulically coupled, the pressure-atomized system mixes water with fuel prior to entering the combustor. This enables the existing water injection system to be used to flush the fuel system; downstream through the combustors as well as upstream into the fuel supply manifolds, greatly reducing the possibility of fuel coking. Water purge has proven superior to air purge in testing over many fuel cycles, as illustrated by the fuel nozzles below.



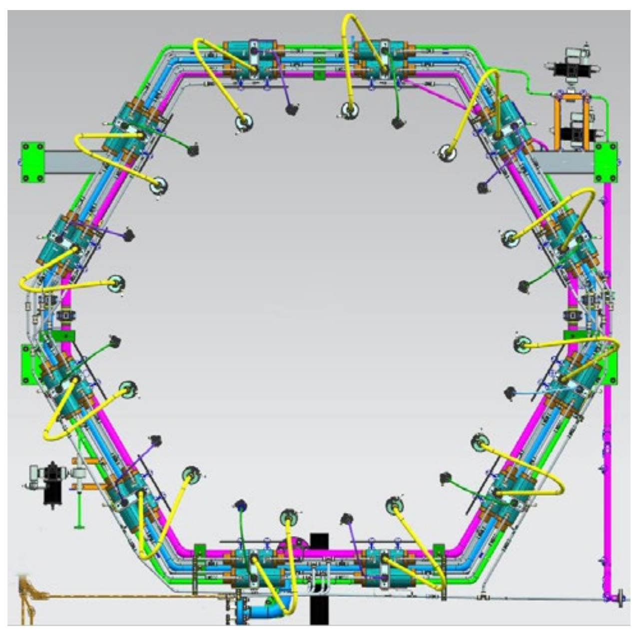
Air Purge Water Flush

A single, multi-stage, single-speed, centrifugal fuel pump delivers liquid fuel across all operating ranges. The single centrifugal pump replaces both the fuel forwarding system and the positive displacement pump which were used in prior configurations.

With the aforementioned reduction in systems and components in the liquid fuel system, the piping is significantly simplified with 70% fewer combustion can connections. Consequently, the potential for leakage at joints is also significantly reduced. Piping installation and system maintenance are reduced by an order of magnitude, further facilitated by the ability to remove the top half of the manifold assembly in one piece.



Atomizing Air Design GT Piping (Before)



Pressure Atomizing Design GT Piping (After)

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Requirements & Constraints

Fine filtration for fuel and water is required immediately upstream of the gas turbine (GT) compartment to protect the downstream control valves and fuel nozzles from particulates. Standard filtration considers liquid fuel as a backup. Continuous liquid fuel use as a primary fuel would necessitate filtration upgrades. Centrifugal pumps require only a strainer at the inlet, no fine filtration is required.

Water is used while running on natural gas to pressurize the manifolds as an additional measure to ensure no gases from the GT can enter. A small positive displacement pump is provided for this purpose.

System Interactions & Engineering Requirements

P91 Foundations

A suitable foundation is needed for the demineralized water tanks, fuel tanks and pumps that considers the site soil conditions, rain and snow loads and crane lifting (GE Function P93) capacity.

P93 Cranes

A single crane of sufficient capacity to lift the fuel and water pumps is necessary upon installation, as well as for any unplanned maintenance or pump replacement.

E31 Medium Voltage

The liquid fuel and water injection pumps need to be added to the plant electrical load list, single line diagram, cable list, installation drawings and bill of quantities as appropriate.

P22 Liquid Oil Conditions

A length of fuel piping immediately outside the GT must be maintained above a minimum temperature for viscosity purposes. Typically, this requirement is met when fuel piping is installed underground, below the frost line. Otherwise, some customer-provided heat tracing would be required.

P61 DI Water System

Demineralized water is required for the water injection system while running on liquid fuel.

P82 Instrument Air

Instrument air supply is required for the fuel and water pumps, filtration module, and within the GT compartment.

T30 Liquid Fuel Delivery

Delivery system to meet requirements for pressure atomized fuel and water supply.

Physical Implementation

The fuel delivery requires placement of both the water injection and fuel pumps in close proximity to the supply tanks. This reduces pressure losses on the pump inlet and the effects of any fluid transients on the pump casing. Spare pump inlet strainers should be maintained for water and fuel.

Piping between the pumps and the filtration module should be provided with low point drains and high point vents. Water piping requires freeze protection.

The filtration module should be located as close to the GT compartment as practical. This improves filtration of the supply piping upstream and facilitates drainage of fuel from filters and bleed valves to the false start drain tank. Spare filters should be maintained for both water and fuel.

Cable for FOUNDATION™ Fieldbus protocol is required for the water and fuel pumps.

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3.3 Factory Commissioning of Accessory Skids

What It Is

Factory commissioning of accessory systems moves the commissioning steps that would normally be completed in the field to the manufacturer, thereby minimizing the field labor and schedule impacts to conduct this work.

Why It Matters

Factory commissioning of accessory skids benefits both the EPC and end user by reducing field installation and commissioning time. Running the skid at or near operating conditions at the factory allows the vendor to verify that the skid meets basic operating requirements. It also enables activities like equipment calibration, leak check, loop check and other corrective actions needed to be performed prior to shipment to the field. Skids arrive fully tested, flushed and cleaned, as close to a 'plug and play' installation as possible. It is ~80% faster to commission a skid in the factory instead of the field. Depending on the type of issue, if problems are detected during commissioning and are caught at the factory instead of the field, savings to the schedule can be anywhere from days to weeks. With factory commissioning, delays in getting vendor technical or field support, diagnosing problems, waiting for shipment of replacement parts, and rework by site personnel are eliminated.

Key Enablers

Utilizing FOUNDATION™ Fieldbus devices provides the ability to calibrate these devices in the factory, eliminating the need to complete or repeat calibration in the field. A Mark*VIe Suitcase Controller is connected to the skid during testing to calibrate instrumentation. This suitcase controller allows full simulation of the unit control, including settings and protectives. Teams from engineering, sourcing and the vendor are then able to collaborate and execute on an optimum test plan to reduce commissioning activities in the field.

Mark*VIe Suitcase Controller

Requirements & Constraints

Factory commissioning of skids mitigates risks caused by lack of skilled labor availability in the field. It also improves schedule predictability and enhancement to maximize efficiency and reduce cost.

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System Interactions & Engineering Requirements

Skid Test Requirements

Systems currently factory commissioned on the 9HA platform:

- T20 Fuel Gas
- P33 Lube Oil
- P32 Seal Oil
- P31 Hydraulic and Lift Oil
- H22 Generator Stator Cooling Water
- B37 Steam Seal

Physical Implementation

Packaging

Factory commissioning provides for a pre-commissioned and functionally tested skid to be delivered to the field.

Commissioning

System is commissioned in the vendor's facility which reduces field commissioning activities. The skid arrives in the field with a detailed list of completed testing and calibration.

Methods and Work Force Planning

Reduces labor required to set-up, commission and functionally test systems in the field.


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ITEM	DESCRIPTION	DWG. NO.

LIST OF COMPLEMENTARY DOCUMENTS

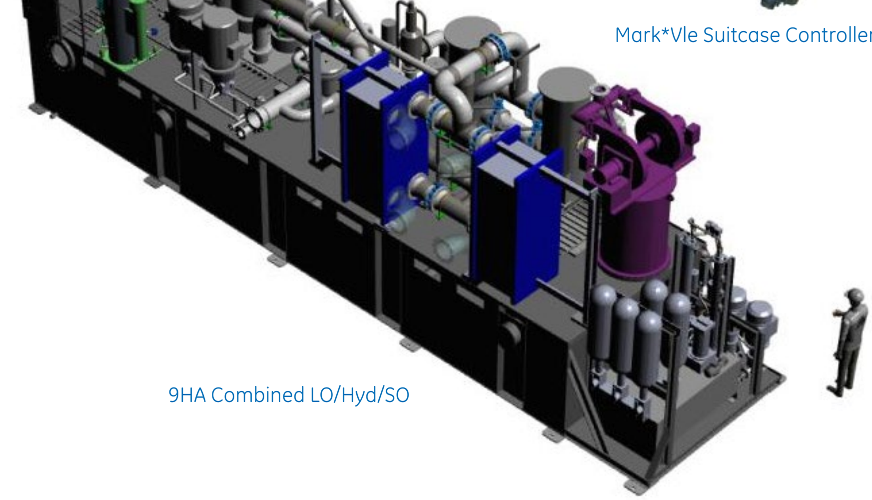
GE CLASS II (INTERNAL NON-CRITICAL)

GE Power & Water

FE50 LUBE OIL MODULE FACTORY FLUSH & TEST SPECIFICATION

A 110T2932


Mark*Vle Suitcase Controller


9HA Combined LO/Hyd/SO

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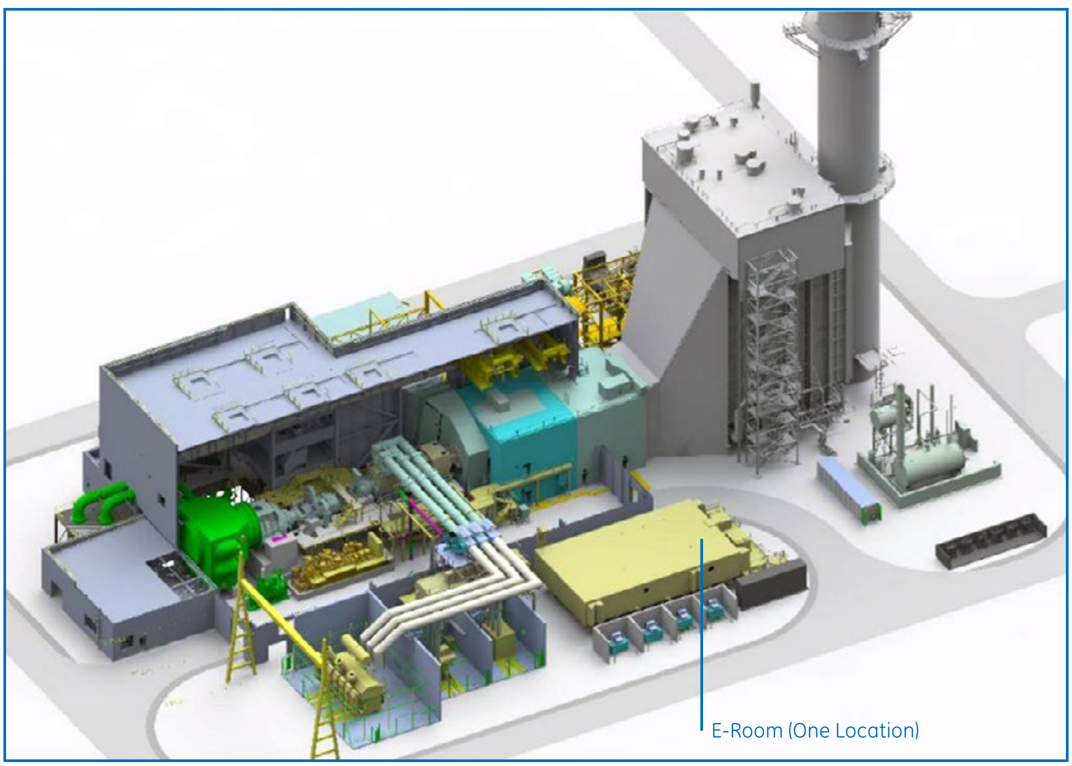
3.4 Consolidated Plant Electrical Room

What It Is

The Electrical Rooms (E-Rooms) contain all of the electrical and control equipment necessary for a power plant to operate properly. They are a fully integrated alternative to having multiple electrical and control equipment enclosures at various plant locations. The E-Room enclosure(s) contain as much state-of-the-art GE equipment as possible to address site layout constraints and project-specific customer requirements.

Why It Matters

There are many benefits to providing a pre-engineered and pre-tested E-Room for the total plant controls and battery placement. Consolidated power and controls E-rooms at optimal locations in the plant vs. various scattered containers reduces complexity and project risk (schedule, safety and cost), while lowering the total installed cost of controls and electrical systems. In addition to lower installation labor, the entire system of integrated components is factory tested before shipment to reduce quality risk and commissioning time at site.



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Key Enablers

GE is a major supplier of all required equipment needed in the E-Rooms, including breakers, controls and VFDs. Early definition of the E-Room scope ensures a high quality delivered product and enhances the customer AE design information. The need for lower plant TIC drives a more consolidated deliverable to reduce interfaces and site labor, which the E-Rooms deliver.

Inside the E-Room, a logical layout is utilized to consider Medium Voltage (MV) from Low Voltage (LV) separation, serviceability and plant operability. Modularized construction allows a scalable, repeatable configuration for various plant configurations.

Requirements & Constraints

The controls for plant components are either integrated in skids or packaged in electrical and electronic control containers (PEECC). This provides shelter from the elements for both operators and sensitive controls.

The E-Room consolidates controls and electrical distribution into one location as opposed to various functional units throughout the plant. Space for the E-Room location has to be considered in the plant layout. In some cases space constraints within the plant could limit the opportunity for its application.

System Interactions & Engineering Requirements

The E-Room is engineered in modules, each containing MV, LV, protection or control cabinet lineups. The overall size of the E-Room will depend on the amount of controls for the power plant and the customer/GE scope agreement.

The utilization of the E-Room concept (P90 Structures) affects/benefits other GE functions. The functions and impacts are:

P91 Foundations

A suitable foundation for the E-Room consisting of footers for the building piers is needed. Concrete piers located to GE's specifications can be used as well. The foundation engineering will also consider seismic requirements for the specific area of the plant as well as soil conditions.

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P95 Layout

Optimization of E-Room scope and location will vary with overall plant configuration.

Systems that can be integrated into the E-Rooms:

- P11 – GT Controls
- P12 – ST Controls
- P14 – Plant Controls
- P51 – GT Fire Protection
- E13 – Excitation
- E14 – Generator Protection
- E31 – Medium Voltage
- E32 – Low Voltage
- E41 – LCI
- B20 – HRSG Controls

Physical Implementation

The E-Room presents the following physical implementation attributes as compared to single PEECC and stand-alone silo controls configuration.

Layout Location

The E-Room enhances the plant layout by centralizing control and MV/LV systems in optimized locations.

Layout Interfaces

The E-Rooms present centralized locations for wiring of devices and loads. Wire runs should be considered in the plant layout.

Packaging Modularity

The E-Room is made up of sections or modules. Its modular construction allows for quick assembly upon delivery.

Packaging Preservation

Packaging for shipment is needed for over-the-road travel as it will have one or two open sides for modular assembly.

Construction

Lifting of the E-Room modules for off-loading is accomplished with an onsite crane.

Connections

Connections from plant equipment to the E-Room to join the various components to the MV, LV, MCCs and control cabinets and power panels can be done immediately after the E-Room is set on the foundation.

Commissioning

This is limited to offloading, mechanically tying the modules together and re-landing electrical interconnections. The systems are otherwise pre-installed and checked prior to shipment. Operations, testing of equipment, data access and automation can be done as required. Access to the E-Room is provided via metal doorways equipped with panic bars and door hardware to meet all NFPA and OSHA standards. Prefabricated stairways with platforms made to OSHA standards are supplied at each point of access to the E-Room. All controls and distribution equipment arrives to site pre-installed and tested.

Maintenance

Maintenance of the structure is expected to be minimal, limited to exterior paint. There is no additional impact in the maintenance and update of control systems.

Maintenance Access Requirements

The equipment contained within the E-Room can be accessed by engineers or qualified technicians for maintenance, operations and updates in a climate controlled environment. Physical access to panels and cabinets is provided via ample aisle ways that meet or exceed NFPA 70-110.

Maintenance Laydown Area

Clear access is recommended in the direction of the entry doors for eventual removal of MCC components, or removal/addition of a full MCC cabinet.

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3.5 Water Mist Fire Protection

What It Is

A fire protection scheme based on the use of water mist as a suppressant that meets the requirements for gas turbine and other protective enclosures.

Why It Matters

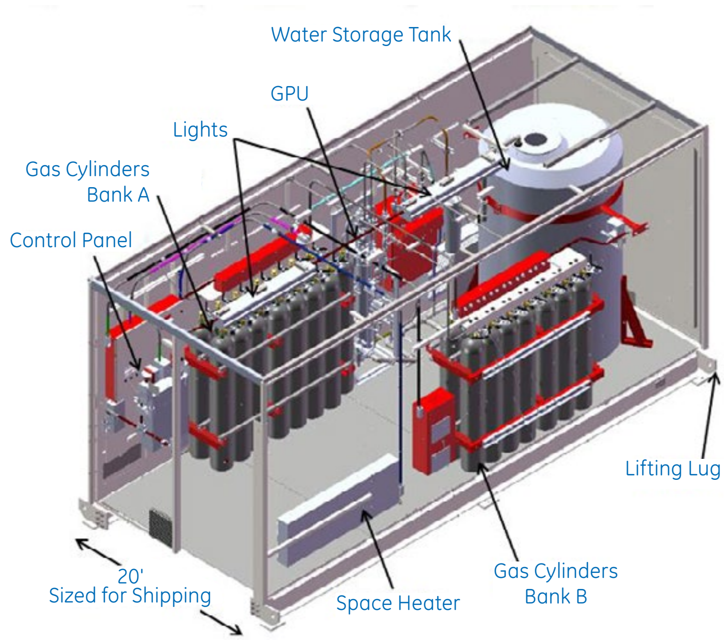
Insurers require equipment protection in the event of a fire. Water mist offers many benefits compared to CO_2 fire protection.

- Eliminates the potential asphyxiation risk associated with CO_2. Water mist is safe for personnel in the compartment during discharge
- Less costly to install and maintain/operate
- Does not require a highly sealed enclosure for the system to be effective
- Does not require a 30-second discharge delay to allow personnel to exit compartments

Key Enablers

The water mist system is a twin fluid type, employing water as the suppressant and compressed air as the atomizing medium. Immediately upon activation, water mist is discharged into the compartment, filling it with a fine water mist that extinguishes fires by:

- Cooling by evaporation and wetting by water mist droplets
- Reduction of local oxygen concentration by water vapor
- Blocking of radiant heat by water mist droplets



Requirements & Constraints

The water mist system is configured per National Fire Protection Association (NFPA) 750 which is a widely accepted standard. The fire protection system is engineered based on the site configuration (gas only or dual fuel) and customer requirements.

The plant operator is responsible for keeping the compressed air cylinders and water tank filled. The skid contains a fill and drain connection for the water tank. Power to the skid is required for the control panel, heater and other components.

The skid minimum operating temperature is 39°F, and the skid is provided with heater(s). The customer can choose to install the system in a temperature-controlled building and remove the water mist skid enclosure. The system has been tested with piping and nozzles at -40°F during discharge with no issues. Heat tracing is recommended in low temperature environments for post discharge blow down.

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System Interactions & Engineering Requirements

NFPA 750 requires the water mist system to have the capacity to provide protection to the largest group of hazards. The water mist skid exceeds this requirement by containing enough water and compressed air to discharge to the two largest zones.

The water mist system protects the turbine compartment, #2 bearing tunnel, and accessory compartment. Other compartments can be protected based on site configuration. Each protected compartment contains the water mist tubing, detectors and strobes/horns. During a discharge, the fire protection control panel sends a signal to the turbine control panel to trip the turbine and shut ventilation.

Testing was completed on turbines to compare the thermal shock of the casing between turbine shut down with compartment ventilation versus turbine shut down with water mist discharge. The conclusion was water mist does not increase thermal shock on the turbine casing. Other testing proved CO_2 has a larger effect on thermal shock.

P41 H_2, CO_2, N_2 Storage and Distribution

CO_2 is replaced with the water mist system, totally eliminating CO_2 from the plant.

P10 Control System

Control system modifications necessary to set up and control water mist system.

The following items are key components for this important safety system:

Gas Pump Unit (GPU)

Mechanical, piston-type pump powered by the pressurized gas cylinders.

Gas Cylinders

Two banks of high pressure gas cylinders provide compressed air to power the GPU.

Water Storage Tanks

Contains enough water to discharge to the two largest zones.

Control Panel

Listed electrical fire alarm control, monitoring and signaling panel (FACP).

Tubing & Nozzles

Stainless steel distribution tubing and spray nozzles for discharging the water mist.

Detectors

Bi-metallic temperature switches that are mounted in pairs in protected enclosures.

Annunciation

Strobes and horns provide visible and audible annunciation.

Physical Implementation

Skid

The water mist skid is located based on customer preference. The skid can be easily lifted to the desired location during installation.

Tubing

Tubing is provided for each protected compartment. Installation of the turbine compartment and bearing tunnel tubing is normally in the EPC contractors scope, as is providing and installing the interconnect tubing between the water mist skid and protected enclosures. Heat tracing may be necessary on the interconnect tubing as described in the Requirements & Constraints section.

Wiring

The detectors and strobes/horns must be wired to the fire protection control panel. The panel needs wiring to the turbine control panel.

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Commissioning

A discharge test should be completed to ensure the system functions properly.

Maintenance

The fire protection control panel should be inspected periodically or whenever the turbine control panel receives an alarm. Post discharge, the following must be completed:

- Inspect nozzles, piping and blow down tubing
- Fill water tank
- Empty and refill gas cylinders
- Reset system
- Update records

Tubing Disconnection During Outage

During an outage, fire protection tubing must be disconnected to facilitate roof removal. Tubing must be reconnected and tested for leaks before start up.

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4.0 Performance

This section describes in detail several new features that either improve performance (efficiency & heat rate) or maintain the same performance at lower cost.

Heat Recovery Steam Generator (HRSG) designs with bent serrated fins is a GE technology that improves heat transfer performance over the typical serrated fin tubes. HRSGs with enhanced fin design allow for a smaller unit with equivalent performance compared to configurations with traditional serrated fins. Plant configurations that support ~600°C (1112°F) main steam and reheat steam temperature enable the most efficient utilization of the GT exhaust energy. Fuel heating to 226°C (440°F) utilizing low temperature energy from the bottoming cycle results in an overall gain in combined cycle efficiency. Typically the intermediate pressure economizer discharge water is used to heat fuel in a three-pressure reheat cycle. In power plants with four-flow low pressure section steam turbines, a steam condenser that operates at two different vacuum (pressure) levels improves efficiency of the entire combined cycle.

Serious consideration should be given to all these performance enhancing features.

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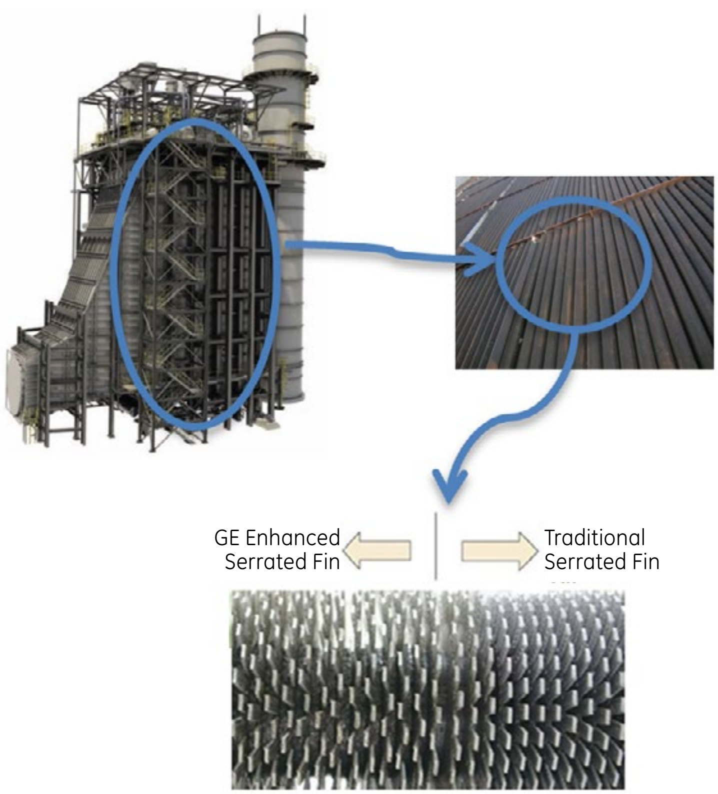
4.1 Heat Recovery Steam Generator Enhancements

What It Is

Heat Recovery Steam Generators (HRSG) utilize various heat exchangers to convert exhaust energy from the gas turbine into steam for the bottoming cycle. These heat exchangers are comprised of helically wound finned tubes. The modern HRSG utilizes a serrated fin for clean exhaust applications. The enhanced fin configuration (bent serrated fin) is a GE technology that improves heat transfer performance over the typical serrated fin.



Why It Matters

HRSGs with enhanced fin features allow for a smaller unit with equivalent performance over configurations with traditional serrated fins. This benefits the plant with a lower capital equipment cost and a reduced foundation footprint and size.

For a typical 7HA.01 HRSG the total surface area is reduced by ~5%. The reduction in foundation length is ~300mm (12”) as compared to an HRSG with conventional serrated fins resulting in a savings of ~8.4 cubic meters (11 cubic yards) of concrete.

Key Enablers

- HRSG OEM capability to produce the enhanced fin configuration.
- Advanced collaboration with the prospective HRSG suppliers to assure they have received the GE technical data/details on the technology.
- GE Quality team coordination with the HRSG OEM finning contractors to validate the process implementation to produce the product to GE defined tolerances.

Requirements & Constraints

Fuels – Enhanced fin technology has unrestricted applicability for the HRSGs in gaseous fuel applications in the GT and/or duct burner.

Enhanced fin technology can be applied in HRSGs for distillate and heavy fuel oil applications provided they are backup fuels with utilization of less than 200 hours/year.

Enhanced fin is not applicable for HRSGs where distillate and heavy fuel oil are the primary fuel.

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System Interactions & Engineering Requirements

B20 HRSG, B21 HP Steam, B22 IP Steam, B23 LP Steam

An HRSG with the enhanced fin provides for a smaller cross section for the HRSG heat exchanger sections. This equates to reduction in casing and interconnecting piping as well.

P91 Foundations

The resulting HRSG will have a reduced foundation footprint and a reduced weight. This positively impacts the sizing of the concrete foundations below the HRSG.

B10 Feedwater

Small reduction in feedwater piping that interfaces to the HRSG may be realized due to the reduced HRSG length.

B32 Steam Admission

Small reduction in LP steam piping that interfaces to the HRSG may be realized due to the reduced HRSG length.

B40 Condensate

Small reduction in condensate system piping that interfaces to the HRSG may be realized due to the reduced HRSG length.

Physical Implementation

As compared to typical serrated fin configurations:

- Will have no impact on the modularity of the heat exchangers. HRSG modularity remains a project specific evaluation based on logistics and site limitations.
- Implementation of enhanced fin has no impact on the cranes, laydown area or craft labor required for HRSG assembly.
- It will slightly reduce foundation excavation/forming and concrete work due to the reduced length of the HRSG.
- No impact on commissioning or operations.

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4.2 600°C (1112°F) Main Steam and Reheat Steam Temperatures

What It Is

Increasing high pressure (HP) and reheat (RH) steam turbine inlet temperatures increase bottoming cycle electrical output and overall combined cycle efficiency.

Why It Matters

Advanced F and H class gas turbines (GT), have high exhaust temperatures. In many cases, the exhaust temperatures are high enough to support increasing bottoming cycle HP and RH steam temperatures from 565°C/565°C (1050°F/1050°F) to 600°C/600°C (1112°F/1112°F). This improves combined cycle efficiency by approximately 0.2%.

Key Enablers

To achieve an ~600°C (1112°F) steam temperature there must be adequate gas turbine exhaust temperature. The typical Heat Recovery Steam Generator (HRSG) superheater minimum approach temperature (the difference between the incoming gas temperature and the exit steam temperature) is approximately +22°C (40°F). This means that the exhaust gas would need to be at least 622°C (1152°F) to attain a steam temperature of ~600°C (1112°F). This target/threshold may be reduced but it requires more HRSG heat transfer surface area. The extra area typically costs more than the value it brings in efficiency.

The steam turbine (ST) and its valves must be capable of accepting this temperature. The HRSG and steam piping must also be engineered to accommodate these temperatures and may require material modifications beyond that of a traditional 565°C (1050°F) cycle. These bottoming cycle aspects add significant cost, and in order to justify the increase, the performance value must outweigh the cost. The performance value is strongly driven by the number of operating hours per year and fuel price.

Requirements & Constraints

The performance value of an ~600°C/600°C (1112°F/1112°F) bottoming cycle will determine whether this option is selected. It depends heavily upon the operating regime of the plant, particularly the number of operating hours per year. Another important parameter affecting performance value is the fuel price.

System Interactions & Engineering Requirements

The implementation of an 600°C (1112°F) steam cycle impacts the following GE functions:

B21 HP Steam, B22 IP Steam

Austenitic stainless steel tubing and header alloys must be used in the highest temperature HP and RH superheater HRSG heat exchangers. This is a change from the ferritic steel T91/P91 materials used at 565°C (1050°F). Total superheater surface area must also be increased to heat the steam to higher temperatures.

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B31 Steam Turbine Unit

The steam turbine and its valves need to be engineered to accommodate ~600°C (1112°F) steam temperature for both the HP and intermediate pressure (IP) turbine inlets. Materials and turbine cooling schemes need modification from a traditional 565°C (1050°F) configuration.

B32 Steam Admission

Steam piping for both the HP and reheat (RH) systems need to be engineered to accommodate ~600°C (1112°F) steam temperature. This will require thicker piping compared to 565°C (1050°F) configurations. GE studies have shown P91 ferritic steel alloy is still applicable for current combined cycle plants up to 600°C (1112°F) steam temperature. Pipe routing should also be examined to allow proper features to handle piping stress and additional expansion due to the higher steam temperature. A study performed on a 2x1 7HA.01 multi-shaft plant estimated HP steam combined piping wall thickness would increase by 18-23mm (0.7-0.9 inches) depending on specific pipe run. Similarly RH steam piping wall thickness would increase by 10-12 mm (0.4 to 0.5 inches).

B10 Feedwater

Increasing steam temperature results in less steam production from the HRSG and slightly reduces the flow of the feedwater pump(s) and associated piping.

B40 Condensate

Increasing steam temperature results in less steam production from the HRSG and slightly reduces the flow of the condensate pump and associated piping.

B41 Condensing Steam

Increasing steam temperature results in less steam production from the HRSG and slightly reduces the overall duty to the condensing system.

H10 Circulating Water

Increasing steam temperature results in less steam production from the HRSG and slightly reduces the overall duty to the condensing system. Thus, slightly less water flow is required.

Physical Implementation

Implementing a ~600°C (1112°F) steam cycle affects the following physical implementation attributes as compared to a traditional 565°C (1050°F) steam cycle:

Connections, Flanges & Welding

The use of higher grade alloys in the HRSG will require proper connection to steam piping systems which may be dissimilar metals. The use of austenitic stainless steel in the HRSG has different post weld heat treatment and non-destructive testing requirements. The steam piping welds take additional time due to increased pipe wall thickness. Austenitic stainless steel in the HRSG metallurgy may impose additional requirements on the installing contractors for weld procedure preparation/qualification.

Layout

HRSG heat exchangers expand at startup as their temperature increases from ambient temperature to rated steam temperature. This expansion increases at higher steam temperature. Austenitic stainless steel heat exchangers expand about 50% more than ferritic steel. The vertical expansion increases from 225 to 330 mm (9 to 13 inches) for high temperature heat exchangers. Drains connected to these heat exchangers will also see this amount of movement. HRSG engineering and pipe routing shall accommodate this expansion at acceptable stress levels for the life of the plant.

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4.3 Fuel Heating to 226°C (440°F)

What It Is

Utilizing low temperature energy from the bottoming cycle to heat the fuel results in an overall gain in combined cycle efficiency.

Why It Matters

Increasing gas turbine inlet fuel temperature from 185°C (365°F) to 226°C (440°F) improves the combined cycle efficiency by approximately 0.1% pts. Heated fuel reduces the amount of fuel flow needed to meet the required gas turbine firing temperature.

Key Enablers

In order to achieve 226°C (440°F) fuel temperature there should be adequate feedwater temperature available from the Heat Recovery Steam Generator (HRSG). Typically the intermediate pressure economizer discharge water is used to heat fuel in a three-pressure reheat cycle. GE guidance for the fuel heater recommends a hot end approach no less than 14°C (25°F). That means to achieve 226°C (440°F) fuel temperature, a minimum of 241°C (465°F) water temperature is required.

The water temperature at the IP economizer discharge is dependent upon the evaporator pressure and evaporator subcool. Subcool is the difference between the IP economizer discharge temperature and the IP evaporator saturation temperature. GE guidance for the IP subcool is 8°C (15°F), which means the evaporator pressure must be at least 39.3 bara (570 psia) to achieve the required economizer discharge water temperature. The evaporator pressure is determined by adding the IP turbine inlet pressure to the associated reheat system pressure drop.

The fuel heating system must be engineered to accept the specified temperature and its heat exchanger is sized accordingly to provide the heating duty required. The gas turbine (GT) fuel nozzles must also be engineered to accept the Modified Wobbe Index resulting from the fuel temperature increase.

Requirements & Constraints

The performance value of 227°C (440°F) fuel will determine whether this option would be selected. Its value depends heavily upon the operating regime of the plant, particularly the number of operating hours per year. The other important parameter that affects performance value is the fuel price. GE experience has shown that the cost of raising fuel temperature to 227°C (440°F) is minimal and in almost all scenarios proves to be a worthy trade.

System Interactions & Engineering Requirements

The implementation of a 227°C (440°F) fuel heating cycle impacts the following GE functions:

T20 Gas Fuel Delivery

Gas turbine fuel nozzles must be engineered to accommodate the Modified Wobbe Index of the fuel at 227°C (440°F). This customization is completed on a project specific basis since fuel compositions and supply temperature varies. This process does not change for fuel heating to 227°C (440°F).

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B10 Feedwater

Increasing the level of fuel heating increases the IP feedwater flow required. The feedwater pump will be engineered accordingly.

B21 HP Steam

Increasing the IP system pressure to accommodate fuel heating to 226°C (440°F) will result in an increase in HP steam production from the HRSG and should be engineered accordingly.

B22 IP Steam

Increasing the IP system pressure to accommodate fuel heating to 226°C (440°F) will require the IP drum to be sized accordingly.

B23 LP Steam

Increasing the fuel heating temperature slightly decreases the LP steam production from the HRSG and shall be engineered accordingly.

B30 Steam Turbine Unit

Increasing the IP system pressure to accommodate fuel heating to 226°C (440°F) requires a decrease of the IP turbine inlet nozzle area.

B32 Steam Admission

Increasing the IP system pressure to accommodate fuel heating to 226°C (440F) requires the reheat system steam piping to be engineered for the higher steam pressures needed to support this temperature. The increase in HP steam production shall be considered when engineering the HP steam piping. The slight decrease in LP steam production should be considered when engineering the LP steam piping.

B40 Condensate

Increasing the fuel heating temperature slightly decreases the LP steam production from the HRSG and the condensate pump shall be engineered accordingly.

B41 Condensing Steam

Increasing the fuel heating temperature slightly decreases the LP steam production from the HRSG and slightly reduces the overall duty to the condensing system.

H10 Circulating Water

Increasing the level of fuel heating slightly decreases the LP steam production from the HRSG and slightly reduces the overall duty to the condensing system resulting in less cooling water flow rate required.

P21 Gas Conditioning

Increasing the level of fuel heating requires additional surface area in the fuel heater. An example from a study performed on the 7HA.01 predicted a heat transfer surface increase of 30% resulting in a cost impact of approximately $400K.

Physical Implementation

The implementation of a 226°C (440°F) fuel heating cycle impacts the following physical implementation attributes as compared to a traditional 185°C (365°F) fuel temperature:

Layout

The increased size of the fuel heater and associated piping shall be considered when configuring the plant layout and gas fuel skid.

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4.4 Two-Pressure Condenser for Steam Turbines w/4-Flow Low Pressure Sections

What It Is

This steam condenser, attached to a steam turbine (ST), operates at two different vacuum (pressure) levels. It is configured to interface with a four-flow ST.

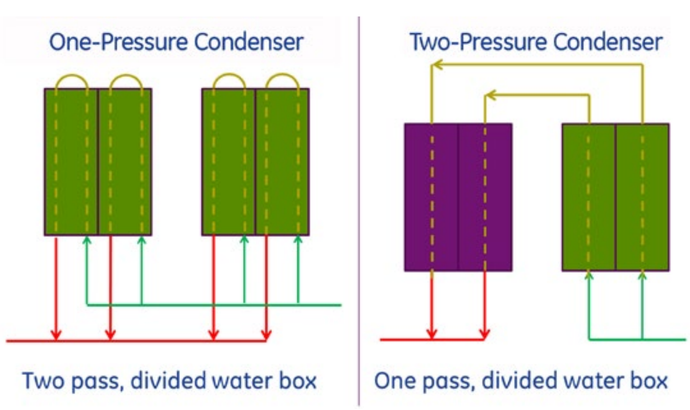
Why It Matters

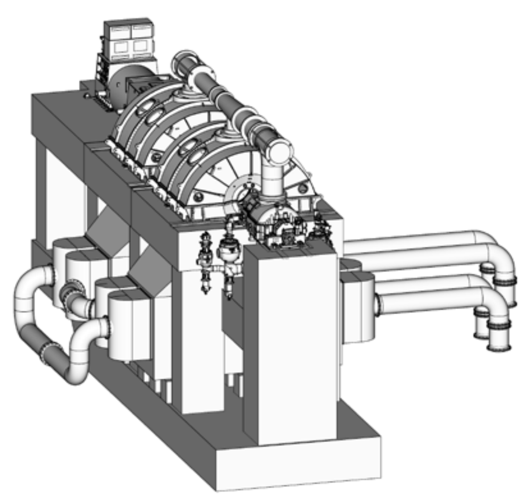
Site conditions and plant performance optimization sometimes require a four-flow steam turbine to enhance the electrical output from the ST generator. The typical application is in a multi-shaft configuration with multiple gas turbines. The four-flow steam turbine has two low-pressure shells, and each exhausts to a separate condenser shell. The two condenser shells can be engineered at the same pressure or different pressure levels, but configuring for two different pressure levels provides significantly better value to the customer. As an example, consider a 7HA.01 2x1 MS with a cooling tower at 15°C (59°F) and 60% relative humidity and 90 thousand fuel hours (fuel hours are the product of the fuel price in $/MMBtu and annual operating hours). A two-pressure condenser provides $2MM more customer value due to higher ST output [440 kW (.05%)] than a single-pressure condenser at approximately the same plant cost.

Key Enablers

The figure below compares cooling water circuits with a one-pressure condenser vs. a two-pressure condenser. The coldest cooling water enters only one condenser shell in the two-pressure configuration. This technique allows the shell to operate at a significantly lower condenser pressure (or vacuum) compared with the shells in the one-pressure case. By this method, the two low-pressure steam turbine sections connected to this condenser shell produce additional power due to their lower exhaust pressure.

Because the two condenser shells must operate at different pressures, the steam bypass system configuration is different. The high-energy bypass streams – high pressure (HP) and hot reheat (HRH) – from each heat recovery steam generator (HRSG) are split evenly to each condenser shell. Bypass valves are provided at the inlet to each condenser shell to prevent a direct connection through the piping within the shell. Direct connection would cause the shells to operate at the same condenser pressure and eliminate the benefit of this system.





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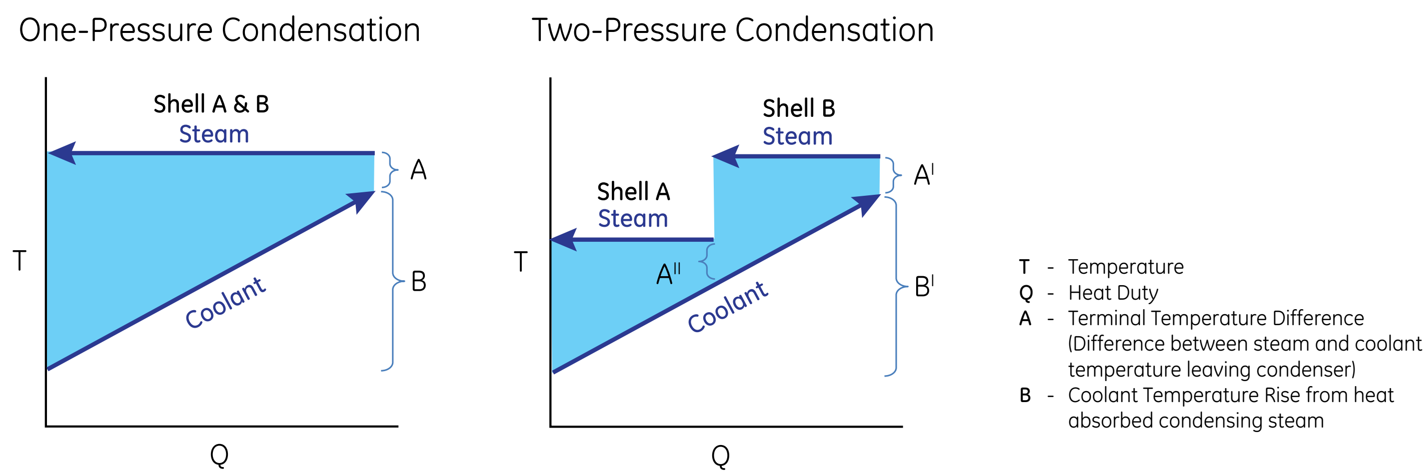

Note: the lower temperature steam with two pressure condensation means that condenser pressure is lower in that shell. Lower pressure means that section of steam turbine produces additional power.

Requirements & Constraints

The operating regime, product application, site atmospheric condition and fuel costs for the plant affect the final system configuration. The combined cycle application engineers should use this input, along with the reference models and combined cycle cooling system optimization tools to determine the optimum configuration.

System Interactions & Engineering Requirements

The two-pressure condenser configuration primarily affects the plant's heat rejection and bottoming cycle functions. The impacts to each system are enumerated below.

The differential pressure between the two condenser shells should not exceed 2.0 in Hg.

H10 Circulating Water

GE Application Engineers vary parameters such as the cooling water flow, cooling tower approach, condenser terminal temperature difference (TTD), etc. to select the optimal configuration by balancing the total installed cost of the system with the incremental performance value. Configurations vary depending on customer fuel price and operating hours.

The total installed cost includes the cooling tower, circulating water pumps, condenser and circulating water piping. The performance impact includes the incremental ST output, cooling tower fan power and circulating water pump power.

B41 Condensing Steam

The two-pressure condenser shall be once-through one-pass for each condenser shell. In addition, each condenser shall have connections for bypasses from each HRSG for HP and HRH steam, whichever is applicable. The lower pressure condenser shall also include provisions, such as a false bottom, to allow the condensate to drain to the higher pressure condenser.

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B34 Bypass

With two condenser shells operating at different pressures, each HRSG requires two (2x50%) HP-to-condenser (if applicable) and two (2x50%) HRH-to-condenser bypass valves. Each bypass is connected to one condenser shell. This balances the thermal load on each condenser shell while the unit is operating on steam bypass – avoiding high differential pressure in the two condenser shells, which could cause the ST to roll off the turning gear.

Changes to the heat rejection and bottoming cycle system also affect these GE functions:

E31 Medium Voltage

The circulating water pumps typically have medium voltage motors. The medium voltage system will support the circulating water pump power needs.

E32 Low Voltage

The cooling tower fans typically have low voltage motors. The low voltage system will support the cooling tower fan power needs.

P91 Foundations

The cooling tower cell size, fan size and number of fans affect the cooling tower basin/foundation. The condenser configuration details drive the condenser foundation engineering.

Physical Implementation

The two-pressure condenser affects the following physical implementation attributes as compared with a single-pressure condenser for a four-flow ST:

Layout Interfaces

The cooling tower and circulating water pumps are similar in two-pressure and single-pressure condensers. The size of the cooling tower will be enhanced and may impact the plot plan size. The 2x50% bypass configuration for each HRSG increases the number of high energy bypass valves (by a factor of 2) and the space requirement to route the bypass piping.

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5.0 Operability

Several new operability features are available. The first is plant hot starts in 30 minutes or less. This feature is also known as Rapid Response. It requires additional balance of plant equipment to achieve the short start time. Thus, it is incorporated in the plant design when needed to meet customer requirements. The second feature is achieving purge credit during plant and gas turbine shutdown (as compared to after plant shutdown, but prior to next startup). The third feature is a SSS clutch located between the generator and steam turbine on single-shaft applications.

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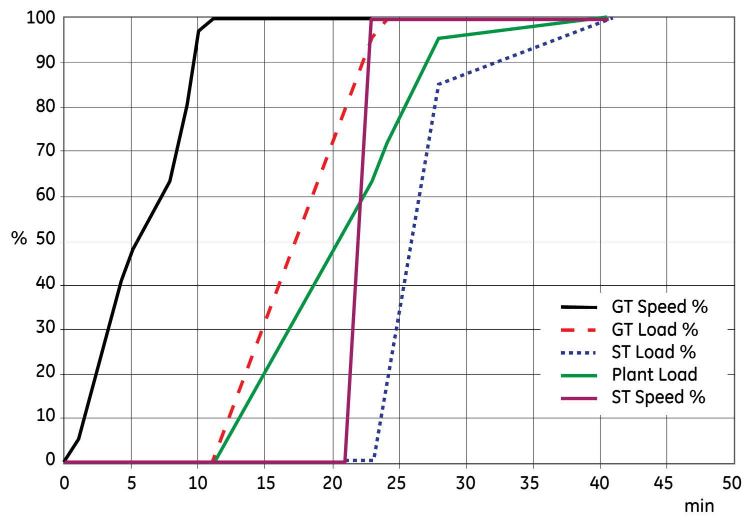
5.1 Plant Hot Starts in 30 Minutes or Less

What It Is

The ability to start the combined cycle power plant in hot condition (up to 8 hours after shutdown) in 30 minutes or less. The expected startup time begins when the gas turbine rolls off turning gear and ends when the gas turbine achieves base load and the steam turbine bypass valves are closed. At that time overall plant load is at about 95%. The remaining load is achieved when steam temperature reaches its normal operating level.



Why It Matters

The current power generation spectrum across the world includes heavy penetration of renewable energy sources such as wind and solar. The amount and availability of these sources can be highly unpredictable, bringing vulnerability to the electrical grid. To overcome this issue, the Gas Turbine (GT)/Combined Cycle Power Plants (CCPP) are often used for ancillary service, providing fast and reliable output in a cyclic operating profile that requires hot start times ≤ 30 minutes. In addition to cutting hot start times by half, this feature also reduces emissions up to 89% compared to conventional combined cycle plants.

Key Enablers

- Rapid Response plant configuration including fuel heating, additional HRSG bypass and HRSG terminal attemperators where the gas turbine operates independent of the bottoming cycle during startup
- Normal and/or fast gas turbine startup capability
- Purge Credit feature
- Rapid starting HRSG with steam piping engineered for minimized steam conditioning times
- Fast steam turbine startup capability

Requirements & Constraints

The requirements and constraints that drive this feature are operations related. Things like start times, starts per year, hours per start and environmental-related demands such as air permits all come in to play.

System Interactions & Engineering Requirements

T10 Gas Turbine

The gas turbine must have the capability to reach baseload within 20 minutes from turning gear operating mode. The fast start GT capability of 10 minutes from turning gear to baseload will reduce plant hot start time by approximately 5 minutes.

T20 Gas Fuel Delivery

The gas fuel delivery system must include the fuel isolation functionality according to purge credit compliance requirements.

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B10 Feedwater

The HRSG boiler feedwater system must be sized for additional attemperation required for HRSG terminal attemperators, high pressure (HP) bypass systems or HRSG interstage attemperation systems. The application team must also consider utilizing the redundant pump in the system during startup only.

B20 HRSG

The HRSG and particularly the critical stress components like water and steam headers must accommodate the simple cycle GT startup rates.

B21/22/23 HP/IP/LP Steam

Steam piping must include necessary warming features such as additional drains with increased sizing to minimize the duration of steam conditioning prior to steam turbine start.

B28 HRSG Supplemental Firing

All supplemental firing systems must include the gas fuel isolation functionality as per purge credit compliance requirements.

B31 Steam Turbine Stress/Life Consumption

The steam turbine must have a fast acceleration time of 2-3 minutes from turning gear to Full Speed No Load (FSNL) and fast loading of 4 to 5 minutes from FSNL to approximately 80% ST load capability. The design team must ensure that the ST allows fast startup capability within the hot start expected life consumption, based on the defined plant mission. If this is not possible, floating life consumption via scheduling the steam turbine start can be considered for hot starts only.

B31 Steam Turbine HP Exhaust Moisture

During fast loading of the steam turbine at lower-than-rated temperatures, expansion in the HP steam turbine section will result in HP section exhaust steam conditions in the moisture zone. This condition will result in erosion and corrosion of the last stages of the HP steam turbine section. Therefore, the last stages of the HP steam turbine must be designed to withstand these operating conditions. As an alternative, the inlet steam temperatures during steam turbine start can be set to avoid HP steam turbine exhaust moisture conditions. However, a steam turbine stress/life consumption impact evaluation is necessary with this alternative.

B34 Steam Bypass

The Rapid Response plant requires an HP Hybrid Bypass system consisting of an additional bypass directly connected to the condenser. This is due to additional steam flow at gas turbine baseload operating conditions. This additional bypass system cost is estimated to be approximately $1MM/HRSG for a typical installation including hardware and installation costs.

B40 Condensate System

The condenser and condensate pumps system must consider the additional steam generation and attemperation for the Rapid Response startup. Typical designs utilize the redundant condensate pump during startup only to provide additional water flow. The condenser duty during full load GT operation with ST bypassed must be part of system sizing definition.

B50 Auxiliary Steam

When the gas turbine requires heated fuel to reach base load, a steam-to-water heat exchanger startup fuel heating system is required. The auxiliary boiler must be sized for additional auxiliary steam flow in order to heat the gas turbine fuel. The larger sized auxiliary boiler is estimated to cost approximately $1.4MM for a typical 9HA.01 single-shaft combined cycle power plant.

H10 Circulating Water System

The Rapid Response condensing duty during startup must be considered in the system sizing definition.

E41 Load Commutating Inverter (LCI)

The LCI sizing must be determined based on the gas turbine start requirements and capability. In a plant with multiple GT/HRSG units feeding steam to a single steam turbine, each GT needs a dedicated LCI for shortest possible start time.

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P11 Gas Turbine Control

The control software must provide LCI pre-connect, purge credit, fire-on-the-fly and fast synchronization features in addition to traditional control functionality. For fast start GT applications, the fast acceleration and fast loading must be included in the package.

P12 Steam Turbine Control

In addition to traditional control functionality, the control software must provide model-based acceleration and loading (ATOS) along with HP steam turbine discharge moisture control features.

P13 Power Island Control

The control software must include HP system hybrid bypass control, feed-forward control for HP and Hot Reheat bypass, and terminal attemperator control in addition to traditional control functionality.

P14 Plant Control

In addition to traditional control functionality, control software must include automatic operation capability to achieve the best HRSG bottle-up conditions, both during shutdown and to execute the Rapid Response start sequence.

P21 Gas Conditioning

When the gas turbine requires heated fuel to reach base load, the gas fuel delivery system must include fuel heating independent from the HRSG for startup. Fuel heating to ensure there are no holds on transfer to emissions compliance combustion mode during GT startup. The startup fuel heating typically consists of a steam-to-water heat exchanger located upstream of the performance heater that is fed by steam from an auxiliary boiler. Startup fuel heating must be sized for gas turbine baseload fuel flow at rated fuel temperature sufficient to cover the Modified Wobbe Index range. The additional startup fuel heating heat exchanger cost is estimated to be approximately $300K for a typical 9HA.01 single-shaft combined cycle power plant.

Physical Implementation

In order to minimize steam conditioning time prior to steam turbine start, steam bypass valves must be located as close as possible to the steam turbine inlet.

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5.2 Plant Shutdown Purge Credit

What It Is

Establishment of a purge credit after shutdown is a way to provide faster dispatch availability for start requests on single and multiple units.

Why It Matters

Conventional starts (i.e., without shutdown purge credit) require a system purge during start-up that results in a longer startup time. For example, the 7F.04 with a conventional start is approximately 15 to 20 minutes longer than a plant with shutdown purge credit. Additionally, completing a shutdown purge credit using the unfired airflow of the gas turbine during coast-down reduces the thermal impact on the Heat Recovery Steam Generator (HRSG). Lowering the thermal impact on the HRSG is especially valuable to customers with plants that have cyclic operations involving daily starts and stops because the life of the HRSG is extended.

Key Enablers

Fuel Systems Design for Purge Credit

The National Fire Protection Association (NFPA) 85 or later revisions require GT and HRSG supplemental burner (if present) fuel systems to meet the requirements listed in the code. The NFPA fuel system requirements include hardware, software, operations and protective actions related to the fuel system.

Gas Turbine-based Purging Methods

The gas turbine (GT) compressor rotation is the source of clean air for purge in both startup and shutdown. Purge time is adjusted as needed based upon the HRSG size and configuration.

Power Plant Operations Philosophy and Controls

Plant designs should include the coordination of multiple fuel system and interlocking requirements as defined in NFPA 85. The plant operating philosophy defines the integration of the gas turbine with the other plant components and controls, resulting in an operable cost effective design. The plant philosophy is also the framework for the scope split between the multiple sources of engineering and controls.

Requirements & Constraints

Identification of all plant elements potentially involved in the purge credit is required for a complete design including:

- Gas turbine fuel systems (liquid, gas, other)
- HRSG Supplemental (a.k.a. Duct) burning systems
- Selective Catalytic Reduction (SCR) systems
- Compression Ratio (CR) systems
- Bypass dampers

The HA plant products utilize a “typical” max case horizontal HRSG to qualify the gas turbine coast-down air volume is sufficient to meet purge requirements. HRSG solutions (including vertical HRSGs or other variations) are evaluated during the proposal phase is required to confirm the volume flow is sufficient.

A supply of compressed air and demineralized water for GE and other vendor-supplied purge credit systems must be present to successfully integrate purge credit into a plant.

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System Interactions & Engineering Requirements

T10 Gas Turbine

The fuel isolation speed of the gas turbine is determined by the size of the HRSG.

T14 Starting Means

Units with non-GE starting means must consider actions to integrate new startup and shutdown operations related to purge credit. The starting means must be capable of accelerating the gas turbine to firing speed for a conventional purge credit start and purge in case of a fault in the purge credit system.

T20 Gas Fuel

The gas fuel systems of GE gas turbines utilize an NFPA 85 System 2 configuration consisting of a triple block and double vent system with a pressurized pipe section. The gas fuel system utilizes a connection of compressed air supplied by the plant to connect to the gas fuel system. Adequate supply air at specified conditions is required to execute the purge credit sequence correctly.

T30 Liquid Fuel

The liquid fuel systems of GE HA gas turbines utilize NFPA 85 System 3 requirements and are configured to accommodate a shutdown purge credit by isolating the liquid fuel system on normal shutdowns. These liquid fuel systems have a tie-to-plan demineralized water requirement that must be integrated into the fuel system purge credit sequences.

T41 Bypass Stack

Purge credit with a bypass stack includes the need for the stack damper to be positioned to the appropriate flow path for both purge and credit. The damper controls must be integrated into the plant master purge credit interlock by the designer of the plant.

B20 HRSG

The volume and configuration of the HRSG must be evaluated to determine the full scope of the purge credit. Additionally, operating sequences of the GT in purge credits (starts and shutdowns) must be communicated to the HRSG vendor in the proposal to ensure the configuration supports operability requirements.

B28 Supplemental Firing

If a plant has supplemental firing, then the system configuration must conform to one of the designated NFPA 85 system types and participate in the plant interlock for formation of a plant level purge credit.

The duct burner integration must be completed by the designer of the plant, which includes Input/Output (I/0) between the Distributed Control System (DCS) and burner programmable logic control (PLC).

B25 SCR/Ammonia

NFPA 85 considers the SCR ammonia systems a potential risk in a purge credit that must be factored into the engineering of the ammonia skid and blower systems. The SCR integration must be completed by the designer of the plant, which includes I/O between the DCS and burner PLC.

E41 LCI

The Load Commutator Inverter (LCI) or static starting system must be capable of meeting and sustaining a purge of the GT exhaust and HRSG at or above the NFPA 85 defined purge rate of ~8% or the full load rated airflow.

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P11 GT Control

The gas turbine controller manages the gas turbine fuel credit components (fuel systems) and will execute purging sequences. The gas turbine is one component in an integrated plant and requires inputs from the plant master control to inform it when specific plant level coordinated operations are occurring. The overall purge protective interlock related to fuel isolation is now managed by the plant level interlock and not just the gas turbine.

P14 Plant Control

The designer of the plant is responsible for configuration requirements, identification of scope split between the sub components, operational philosophy and supervisory control methods associated with a plant level purge credit. When GE engineers the plant controls, the operations philosophy for the purge credit will be included in the Plant Operating Philosophy T210 system.

P20 Fuel Systems

All plant fuel and combustible systems are required to meet NFPA 85 guidance for purge credit.

P31 Hydraulic

The gas turbine control methods for shutdown purge credit must include the management of fuel cutoff and potential restoration of hydraulics to complete the fuel system sequences forming a purge credit.

P60 Cooling Systems

Considerations for cooling systems need to be factored into plant configurations for purge credit because multiple auxiliary systems may be on-line to support purge credit operations. This can include water systems to support liquid fuel, compressed air, hydraulic and other systems requiring water or other mediums used for cooling.

P80 Compressed Air

The GE gas turbine fuel system utilizes plant compressed air for displacement of remaining fuel from gas manifolds and to form the pressurized pipe section. Each gas fuel system and sequence has different air demand mainly due to physical differences in piping. The plant designer is responsible for evaluation of air supplies and potential unit to unit interactions due to purge credit needs.

Physical Implementation

Sufficient supply of compressed air shall be included in the plant. Air receivers dedicated to each independent unit provide the most robust plant solution with each receiver sized to meet the needs of the unit.

Arrangement and containment for liquid fuel drainage associated with purge credit must be considered for dual fuel plants.

Physical communication between plant components must be factored into the division of responsibility and scope for each component. Direct communications are rare between the gas turbine and sub components within the DCS or PLC connected to the DCS.

I/O requirements for each component participating in a purge credit will contribute to the arrangement of the skids, I/O panel arrangements, and cabling schedules for each system. Delays in this information can result in rework and/or unexpected costly add-ons to the project.

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5.3 SSS Clutch for Single-Shaft Applications

What It Is

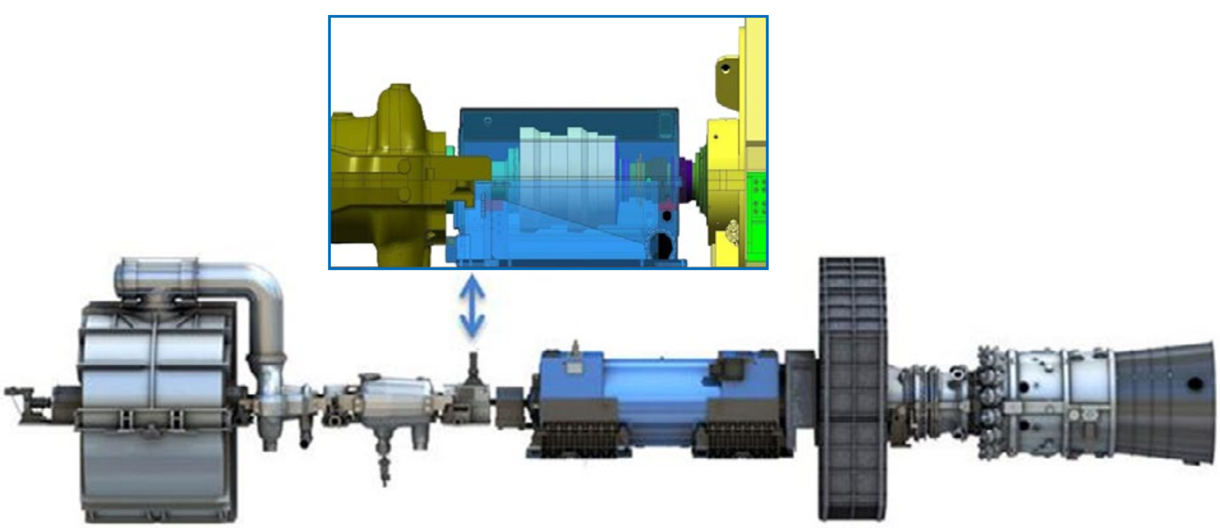
The synchro-self-shifting (SSS) clutch enhances operational flexibility and availability of a combined cycle single-shaft power plant by enabling the disengagement of the steam turbine from the gas turbine/generator. With SSS action, the clutch teeth are phased and then automatically shifted axially into engagement when rotating at precisely the same speed. The clutch disengages as soon as the input speed slows down relative to the output speed.

Why It Matters

On a single shaft power train without a clutch, the steam turbine accelerates to full speed with the gas turbine before the HRSG produces steam. At full speed, the steam turbine requires substantial amounts of cooling steam to maintain components within temperature limits. This steam is typically supplied by an auxiliary boiler. With a clutch, the ST is disconnected during the GT acceleration process and cooling steam is eliminated.

A clutch with an automatic overrunning feature allows the gas turbine/generator to accelerate while the ST remains near turning gear speed. Later, steam produced by the heat recovery steam generator (HRSG) accelerates and loads the steam turbine while maintaining components within temperature limits. The elimination of cooling steam significantly reduces the auxiliary boiler size and cost (approximately a $1.7M savings for a typical 9HA.01 plant).

In addition, the clutch allows access to the gas turbine for maintenance and inspection much sooner than conventional non-clutched single-shafts (access in 12 hours vs. 72 hours).



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The SSS Clutch is located in the Steam Turbine front standard which allows for rapid GT startup to baseload without the ST.

Key Enablers

Single-shaft power-train with the generator in the middle. The gas turbine and steam turbine drive the generator from opposite ends. Each turbine incorporates a thrust bearing.

Requirements & Constraints

The single-shaft line incorporates into the steam turbine front standard. Lube oil is provided from the combined lube oil system adjacent to the shaft line. Rotor connections on both ends of the clutch are integrated into the flanges for the steam turbine and generator.

At startup, the clutch enables the gas turbine to accelerate to Full Speed No Load (FSNL) without the steam turbine in operation. Later, HRSG steam accelerates the steam turbine. The clutch engages once the steam turbine speed matches the speed of the gas turbine.

The clutch meets the following criteria:

- Transmits steady state torque to the steam turbine
- Sustains torque from fault conditions
- Tolerates torque from minor transients
- Accommodates relative axial flange motion of the connected rotors
- Tolerates small angular or radial misalignment

Among the operational benefits, the clutch:

- Engages smoothly when the steam turbine speed matches the generator speed
- Disengages smoothly when the steam turbine speed falls below the generator speed

P91 Foundations

In addition to the normal ST needs, the centerline foundation must provide adequate length, support and stiffness for the SSS clutch. This ensures the clutch gear teeth remain in alignment and transmit the required torque. Consult the ST Design Practices for detailed guidelines.

P92 Building

Compared to a direct coupled single-shaft train, the building length is longer by the length of the clutch.

B31 Steam Turbine

The SSS clutch-enabled steam turbine is configured with two support bearings.

P10 Controls

The acceleration of the steam turbine shaft is controlled to meet the clutch engagement requirement for smooth operation.

T11 GT Thrust

The gas turbine thrust bearing takes into account the rotor thrust in the direction of the gas turbine from the steam turbine.

E10 Generator

The generator collector end and stub shaft to the clutch are enhanced to meet rotor dynamics and collector brush requirements.

B50 Aux Steam

No LP cooling is required with the SSS clutch, reducing auxiliary steam system complexity and cost.

P33 Lube Oil

The clutch is supplied with its own oil supply line from the common lube oil system to ensure long life. The system sizing supports the flow and return of oil to the lube oil system.

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Physical Implementation

The clutch's location in the main shaft line impacts the rotor train length and thus the foundation and building sizes.

Steam Turbine and Generator Interfaces

Both steam turbine and generator accommodate the clutch through flange connection modifications.

Maintenance Assembly/Disassembly

The clutch weight is approximately 2,300 kg (5,071 lb.)for a 9HA.01 gas turbine, so the building crane can be used with no added laydown space required. Special tools are provided with the clutch for maintenance activities.

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6.0 Controls/User Experience (UX)

Several new Controls and User Experience (UX) features are available to reduce total installed cost, improve reliability, availability and operability, and lower operating and maintenance costs.

The first feature is Digital Bus Technology, which allows several signals to be transmitted over one set of wires, as opposed to traditional technology that uses dedicated sets of wires for each sensor/signal. This provides significant savings in overall plant installed cost by reducing field-run wiring, making wiring checkout easier and speeding system commissioning. Digital Bus Technology also provides additional sensor and actuator health information, enabling enhanced diagnostics and prognostics to improve reliability and reduce maintenance costs.

The second feature is Plant AutoStart, which automates startup by augmenting the traditional plant start from GT turning gear rolloff with elimination of manual operator actions previously needed to establish a ready to start state. Plant AutoStart delivers predictable, improved start times following a normal shutdown, thereby reducing fuel costs and startup emissions, and improving the ability to meet dispatch requirements.

The third feature is a State-of-the-Art Human-Machine Interface (HMI) that is simple, intuitive and efficient; designed to improve both the functionality of the interface and the user experience. This HMI delivers improved situational awareness and anomaly detection and simplified decision making.

The fourth feature is Plant Level Alarm Management & Fault Tolerant Protection. This feature helps improve the availability and operational flexibility of the power plant. The Alarm Management system displays only actionable alarms and pertinent information to the operator, providing visibility into plant issues without causing alarm fatigue. The Fault Tolerant Protection System automatically places the equipment in a safe, but reduced mode of operation following certain failures, rather than tripping the unit.

The fifth feature is Intelligent Dual Control Redundancy (IDCR). Compared to the traditional Triple Modular Redundant (TMR) system, IDCR improves reliability and reduces control cabinet I/O. Safety systems remain TMR, while active in-range fault detection and surrogate sensor modeling allow IDCR to reduce control system hardware and maintenance costs.

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6.1 Digital Bus Technology for Instrumentation and Controls

What It Is

Digital Bus Technologies are digital protocols used to communicate information regarding command, control, feedback and monitoring. They are applied to various power plant control input and output (I/O) signals. Digital Bus Technology allows several signals to be transmitted over one set of wires as opposed to traditional, individually wired means (e.g., 4-20 mA current loops). This technology also provides additional functionality in areas such as sensor and actuator health at low or no incremental cost. This ability is not readily available with traditional approaches. There are several Digital Bus protocols available and adopted in GE Power Plant equipment.

Why It Matters

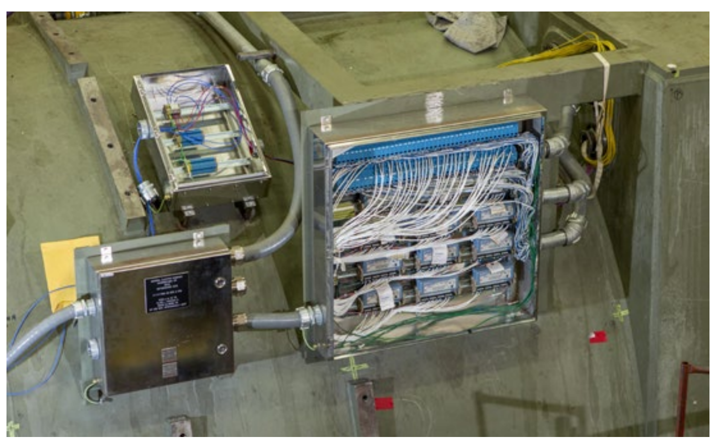
Utilizing Digital Bus Technologies for control I/O signals provides significant savings in overall plant installed cost. They reduce field-run wiring, make wiring checkout easier and speed system commissioning.

The control system for a plant with a single combined cycle block may include as many as 3000 I/O devices such as sensors and actuators to properly control, protect and monitor the equipment. Typically, each of these requires dedicated wiring of 2, 3, or more wires that run from the device to the control panel. Installation and checkout of this field-run wiring requires a considerable amount of material, labor and commissioning time. It also includes significant opportunity for errors during plant construction. Reducing the amount of wiring and providing the means for rapid field checkout saves significant material, time and rework. That translates into a lower total installed cost for the plant equipment. The first 9HA plant outfitted with Digital Bus Technology will save approximately $1M in total installed cost.

Digital Bus Technologies also provide benefits over the life of the plant. Digital Bus sensors and actuators provide more information to the control system, facilitating enhanced fault detection and accommodation, analytics and prognostics. These features support moving what would be unplanned maintenance activities to planned plant outages. That means improved spare parts planning, higher plant operating reliability, availability and lower operating costs.

Key Enablers

Several Digital Bus protocols/standards such as CANopen®, Profibus™ DP and FOUNDATION™ Fieldbus (FFB) are suitable for use in power plant equipment and are both established and maintained by various industry organizations. Also, a significant number of reliable, mature components including sensors, MOVs, motor control centers and segment protectors are available from multiple suppliers for power plant use.



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Requirements & Constraints

GE's approach is to have Digital Bus I/O across the plant.

- Some signals may be required to be hardwired per local codes or standards (e.g., SIL safety systems).
- Balance of Plant (BOP) and other equipment should adopt a similar level of digital bus technologies, but commercial and other preferences may prevent this.
- Some customers, including EPCs, will require GE support to design/integrate Digital Bus Technologies for equipment outside of GE scope. For example, FOUNDATION™ Fieldbus devices need to be qualified to operate with the chosen control system. GE Controls engineering has a process in place to facilitate this.

Other constraints, based on internal technical issues are described in the System Interactions & Engineering Requirements section below.

System Interactions & Engineering Requirements

Implementation of Digital Bus Technologies will impact all plant systems that are connected to the control system, whether for adoption or technical or commercial evaluation of the technologies.

Various Digital Bus Technologies and formats have varying characteristics (e.g., data transmission rates) and different levels of adoption/familiarity in certain areas. For example, Profibus™ DP for electrical integration with Smart MCCs has a relatively high adoption level. Careful assessment of control requirements including transmission rates and latency is necessary to determine which Digital Bus Technology to apply to which I/O signal. How signals are combined and configured will also depend on plant layout and signal path distances.

Some signals, such as those requiring relatively high voltage or current may not be contenders for digital bus I/O.

Technical considerations are too numerous to describe fully in this document. The majority of signals are FFB but faster loops may require CANopen®. Smart MCCs are typically provided with Profibus™ DP.

Physical Implementation

The physical interconnection of digital bus signals (e.g., FOUNDATION™ Fieldbus Segment Protector locations) will be determined as part of the electrical and controls design for each system. As indicated in the System Interactions & Engineering Requirements section, plant layout may impact the design.

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6.2 Plant AutoStart (Pre-Start & End State Automation)

What It Is

Plant AutoStart is a feature that automates startup to reduce operator manual action. Legacy plant control automation systems often automated plant start from GT roll-off of turning gear, but still required the operator to take significant pre-start manual actions to achieve the plant ready-to-start state. The addition of automated pre-start control eliminates these actions when restarting from a normal plant shutdown. Additional automation now provides automatic transition to a variety of typical end states such as simple cycle operation and intermediate shutdown states. With appropriate system engineering, the plant control system integrates sequencing and operation of systems and components including the gas turbine (GT), steam turbine (ST), generator, accessories, heat recovery steam generator (HRSG),and BOP auxiliaries required to start and load the plant from a normal shutdown to an operator-selected load.

Why It Matters

Plant AutoStart now delivers predictable, improved pre-start and start times from the ready-to-start condition. This reduces the emissions and cost, and increases the certainty of meeting plant dispatched load in an efficient manner.

Key Enablers

An extended scope GE offering is required, including a Mark*VIe Plant Control System that integrates gas turbine, steam turbine and generator control with control and operation of the HRSG and BOP systems, and HMI screens providing a single plant operator interface.

Group Control

Utilizing a group control approach, control of associated components and systems is combined into sets of plant pre-start building blocks, or groups. The plant control automatically starts the groups in the proper sequence to achieve ready-to-start and plant start.

Requirements & Constraints

Plant AutoStart requires automation of equipment that may be outside of GE's normal scope of supply and therefore requires interaction with the plant designer to coordinate control of this equipment.

System Interactions & Engineering Requirements

Automation is provided from a normal plant shutdown condition. This means BOP systems such as electrical switchgear and electrical plant systems, instrument air, and demineralized water train and water chemistry systems are operating. Transition from a maintenance shutdown (i.e., where the electrical plant is de-energized) to normal shutdown will still require manual operator action.

P10 Control System

A GE Plant Control System is required. Typical control interfaces of most plant systems are adequate to support Plant AutoStart from a normal shutdown condition.

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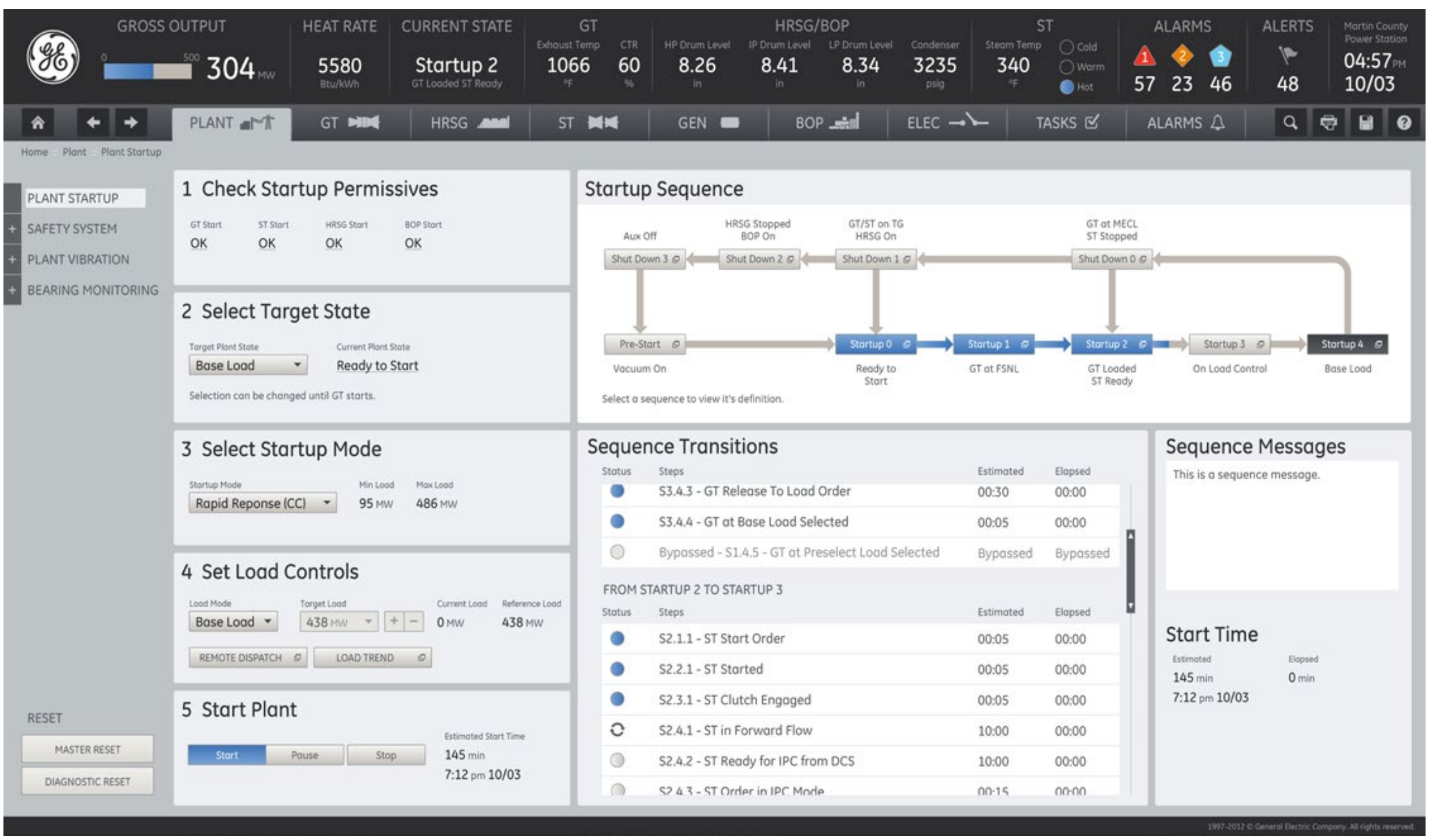
Physical Implementation

Plant AutoStart is implemented via software and hardware of the GT, ST, Generator and Plant (including HRSG and Electrical) control systems.

Plant AutoStart is implemented within the integrated control system. All systems requiring control, sequencing, operation and/or monitoring must be appropriately enabled and interfaced with the control system. The operator interface HMI screens are located in the control room.



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6.3 State-of-the-Art Human-Machine Interfaces (HMI)

What It Is

GE's latest operator-centered human-machine interface (HMI) is simple, intuitive and efficient; engineered to improve both the functionality of the interface and the user experience.

Why It Matters

Operators experience the plant equipment through the control system, therefore the interface and user experience are important. Research shows that poorly engineered HMIs contribute to operator errors and lost revenue. Through research, engineering and validation with 88 operators in 25 plants and 5 countries, GE's advanced HMIs conform to a simple principle: with a glance, operators should be able to recognize which information they need to attend to and what it indicates. In the figures below, note the simple display of critical plant parameters in the "after" view. The parameters outside of normal operating levels are much easier to detect via the different color (yellow, orange or red) than the normal parameters shown in blue.

Key Enablers

GE's HMI is a significant departure from the industry's status quo. It has been developed in close cooperation with GE customers to drive more consistent and efficient power plant operations. It delivers improved situational awareness and anomaly detection along with simplified decision-making through:

- Conformance to International Society of Automation (ISA) 18.2, The High Performance HMI Handbook (PAS), and other industry guidelines
- Reduced information and cognitive overload
- Less operator fatigue
- 21% usability improvement ratings over past systems
- Efficient maintenance and troubleshooting

Before

After – Level 1 Overall Plant

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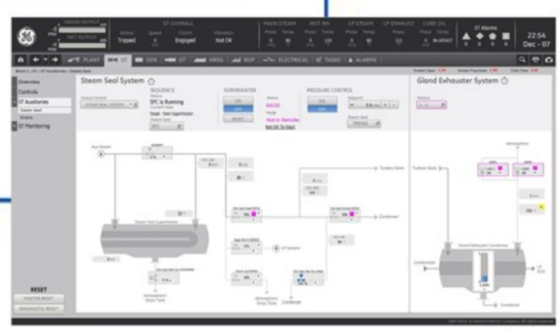
After – Levels 2-4

Unit or Major Process Overview

GLANCEABLE and CONTROLLABLE
High level view of key performance indicators and other data summaries with support for routine control/ manipulation of equipment.

Sub System Overview

OVERVIEW and CONTROLLABLE
A collection of features, organized around a specific theme. Provides an overview of equipment/subsystem within the unit/ major process.



Detail P&ID-Style View

DETAIL and CONTROLLABLE
A specific view of data and support information/ functionalities, or a system diagram.

Requirements & Constraints

The HMI philosophy remains the same regardless of the various site or plant requirements and constraints. The detailed content is adjusted as needed based on these requirements. For example, if dual fuel capability (natural gas and distillate) is needed, the HMI screens will be adapted to show both sources.

System Interactions & Engineering Requirements

The HMI provides operator interaction and display for all systems except for the P90 Structures function and its sub-functions consisting of P91 Foundations, P92 Buildings, P92 Cranes, P94 Duct Banks, P95 Roads. The HMI is part of the P10 Control Systems function and its sub-functions P11 GT Control, P12 ST Control, P13 Power Island Control, P14 Plant Control.

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An HMI set can comprise 50 to 200 screens for a single-block and single-shaft power plant. Therefore, the systematic categorization of screens improves navigation efficiency and operation efficiency. Some HMI screens are organized by plant topology in which the lower level of screens progressively describes more details of a process and/or assets. Other screens are organized by process or operator task.

By plant topology:

- Level 1: Overall Plant
- Level 2: Major units (GT, ST, HRSG, BOP, Electrical, Generator)
- Level 3: Major systems/sub systems of the respective units
- Level 4: Sub systems/Individual equipment or devices.
- Faceplate: Individual data points.

By process control or operator task:

- Screens that provide a single representation of controlling a process that includes multiple systems
- Screens that support an operator task. (e.g., startup, shut down, etc.)

Alarm visualization is an integral part of the HMI user experience to enhance operator sensitivity to abnormal conditions and improve identification and response effectiveness. The following guidelines are applicable to the HMI:

- Shape, color, and number indicate/differentiate different priorities of alarms. Red Triangle with 1 = Priority 1, Orange Diamond with 2 = Priority 2, and Yellow Pentagon with 3 = Priority 3.
- Visual effects on alarm indicators differentiate the status of alarms (acknowledged, active, normal, etc.). Acknowledged alarms keep shape and number, but change to gray background.
- Seamless navigation is provided between the alarm window and the alarm indicators on HMI screens.
- Colors specified for alarms are not used for other HMI display components.

Physical Implementation

As described above, the operator experience, interface and display via the HMI has been improved.

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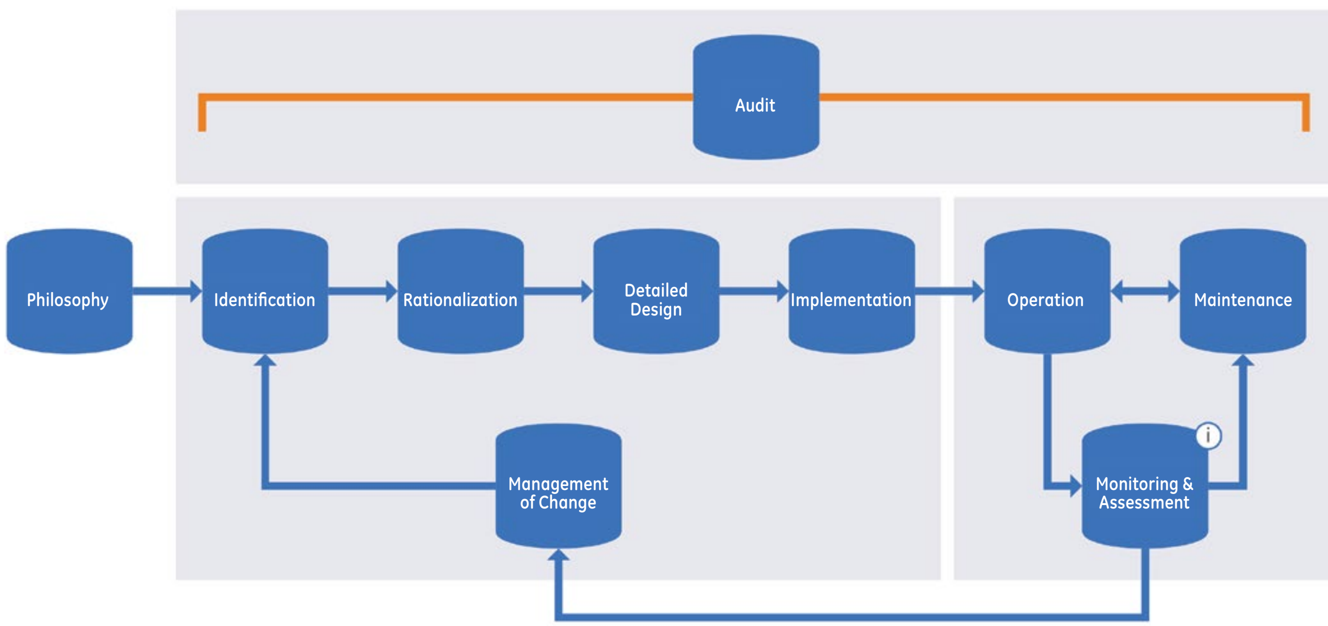
6.4 Plant Level Alarm Management & Fault Tolerant Protection System

What It Is

Alarm Management and the Fault Tolerant Protection System are two separate, but complementary features of a control system that help improve the availability and operational flexibility of the power plant. The purpose of these features is to alert operators to abnormal operating conditions and to also take automatic action when system/equipment operating conditions reach inoperable levels, with the objective of preventing personnel, environmental and equipment damage as well as economic loss. Alarm Management is the process by which alarms are defined, engineered, monitored and managed to provide the highest level of operator effectiveness. The Fault Tolerant Protection System provides the owner/operator with the opportunity to make commercial decisions to extend plant operation in a degraded mode without sacrificing personnel and equipment safety.



ⓘ Monitoring & Assessment Analysis

Provides guidance for analysis

- Alarm system measurement
- Unauthorized alarm suppression
- Alarm attribute monitoring
- Reporting of alarm system analysis
- Alarm performance metric summary
- Performance metrics
  - Average annunciated alarm rate per operating position
  - Peak annunciated alarm rate per operating position
  - Alarm floods
  - Frequently occurring alarms
  - Stale alarms
  - Annunciated alarm priority distribution
  - Alarm attributes priority distribution

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Why It Matters

Operating effectively in the midst of equipment or other plant challenges is a necessity. Alarm Management and the Fault Tolerant Protection System improve plant operations and the ability to keep the power plant up and running. The fundamental purpose of an alarm system is to alert the operator to abnormal operating situations by means of an audible and visible annunciation. A key factor in operator response effectiveness is the speed and ease with which the operator can isolate the root cause of the problem and choose a course of action. Legacy alarm systems flood the operator with data. With the introduction of fully digital control systems, alarms became easy to implement and inexpensive to configure and deploy. The unintended result is that almost anything would be alarmed. The quantity of information displayed by the alarm system was only limited by the size of the monitor. Incidents of misoperation began to increase as a result of having too much data available with too little useful information being presented. In 2009, the ANSI/ISA–18.2 standard was introduced to address this issue.

Using ISA-18.2 principles, GE's Alarm Management system provides visibility into plant issues without causing alarm fatigue by considering human factors in alarm system engineering. With Human Factors Engineering (HFE) techniques such as alarm rationalization coupled with GE control system's advanced functionality and intuitive Human-Machine Interface (HMI), only actionable alarms and pertinent information are displayed. As a result, compared to legacy alarm systems, the total number of alarms is reduced by 80% and a root cause is easily obtained from the information displayed.

The purpose of GE's Fault Tolerant Protection System is to take automatic action when system/equipment operating conditions reach inoperable levels. Each failure mode is individually evaluated to determine if a trip or shutdown can be eliminated and replaced with a Fault Tolerant Protection System mode of operation.

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Upon entering a Fault Tolerant Protection System mode of operation, appropriate alarms and alerts are passed to the Alarm Management system to alert operators and maintenance personnel of necessary actions, while the equipment is automatically placed into a safe mode of operation. This mode of operation may be one of reduced performance (e.g., reduced output) rather than a trip, if possible, to allow continued operation prior to corrective action.

Key Enablers

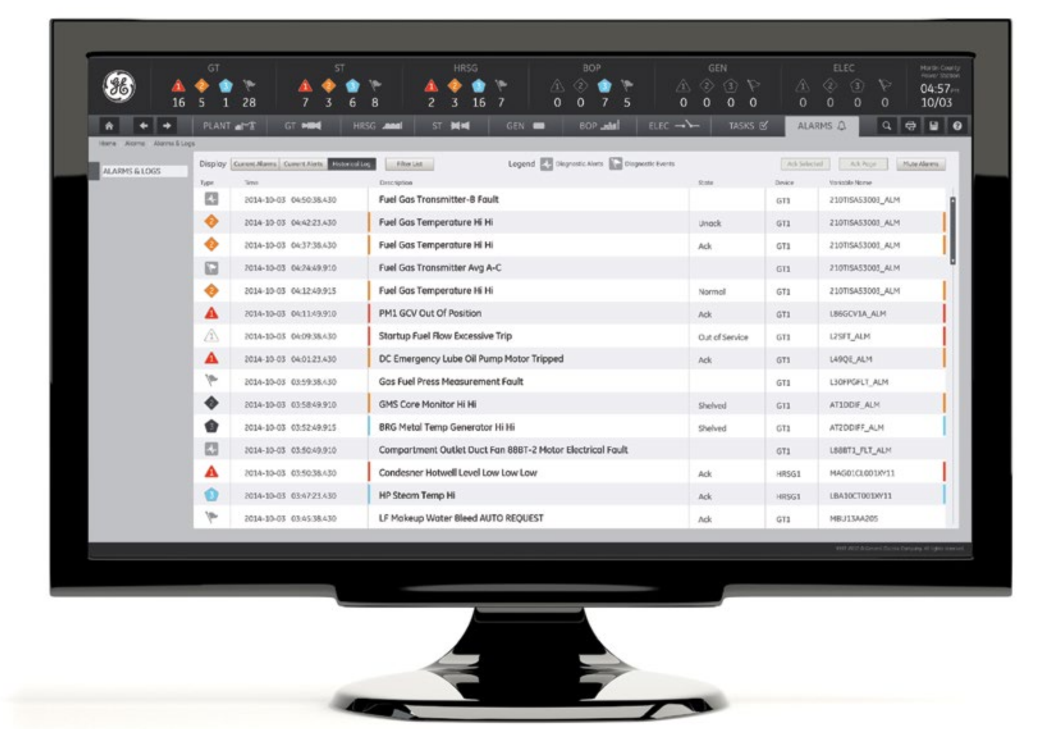
GE's Alarm Management system is engineered to address operator alarm fatigue and blindness through key enablers such as conformance to ISA-18.2 guidelines and GE's Control System Alarm Viewer, ToolboxST and Workstation ST products, that include advanced filtering and intuitive viewing features. Specifically, functions such as alarm "Out of Service," "Shelving," and "Parent/ Child Pairing," enable only the pertinent information to be presented to the operator.

It is not sufficient to use a multiple alarm priority-level system. The solution must be an alarm system that can dynamically filter the alarms based on the current plant operation and conditions so that only the currently significant and important alarms are annunciated. Dynamic alarm management focuses the operator's attention by eliminating extraneous alarms, providing recognition of critical problems, and informing more accurate operator response.

For the Fault Tolerant Protection System, key enablers are Model Based Control (MBC) and other fault detection software utilizing Kalman filters to determine sensor diagnostic, isolation and accommodation through surrogates and intelligent sensor technology coupled with Input Signal Processing (ISP) technology.

Requirements & Constraints

The requirements and constraints that drive this feature are operations-related such as reliability, availability and redundancy requirements.



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System Interactions & Engineering Requirements

The alarm management and fault tolerance philosophy remain the same regardless of the various site or plant requirements and constraints. The detailed content of the system is adjusted as needed based on these requirements. For example, if dual fuel capability (natural gas and distillate) is needed, the system will be adapted to cover both fuel sources.

Plant Level Alarm Management and Fault Tolerant Protection Systems are part of the P10 Control Systems function and its sub-functions P11 GT Control, P12 ST Control, P13 Power Island Control, P14 Plant Control.

They interact with and cover all plant functions except for the P90 Structures function and its sub-functions consisting of P91 Foundations, P92 Buildings, P93 Cranes, P94 Duct Banks, P95 Roads.

Requirements at the plant level are given below:

- Consistent alarm strategy across the plant functions with a reduced number of meaningful and actionable alarms
- Group alarm methodology developed following industry guidelines as part of a plant-level Alarm Management strategy
- Adaptive alarms including state-based alarm strategies compliant with ISA-18.2
- Guidance to the operator to inform decisions based on the alarms received
- Alarm structure allowing filtering and ordering of the alarms through different criteria
- Intelligent sensor technology and smart Motor Control Center feature
- Fault detection software utilizing Kalman filters to determine surrogates. The Fault Tolerant Protection System has the pre-requisite of having the Model-Based Control and Input Signal Processing software architectures applied

Alarm Management and the Fault Tolerant Protection System can be applied independently based on the above constraints.

Physical Implementation

There are no new physical implementation details. Alarm Management and the Fault Tolerant Protection System are updates to the existing Controls Application Software and HMI software packages which already exist.

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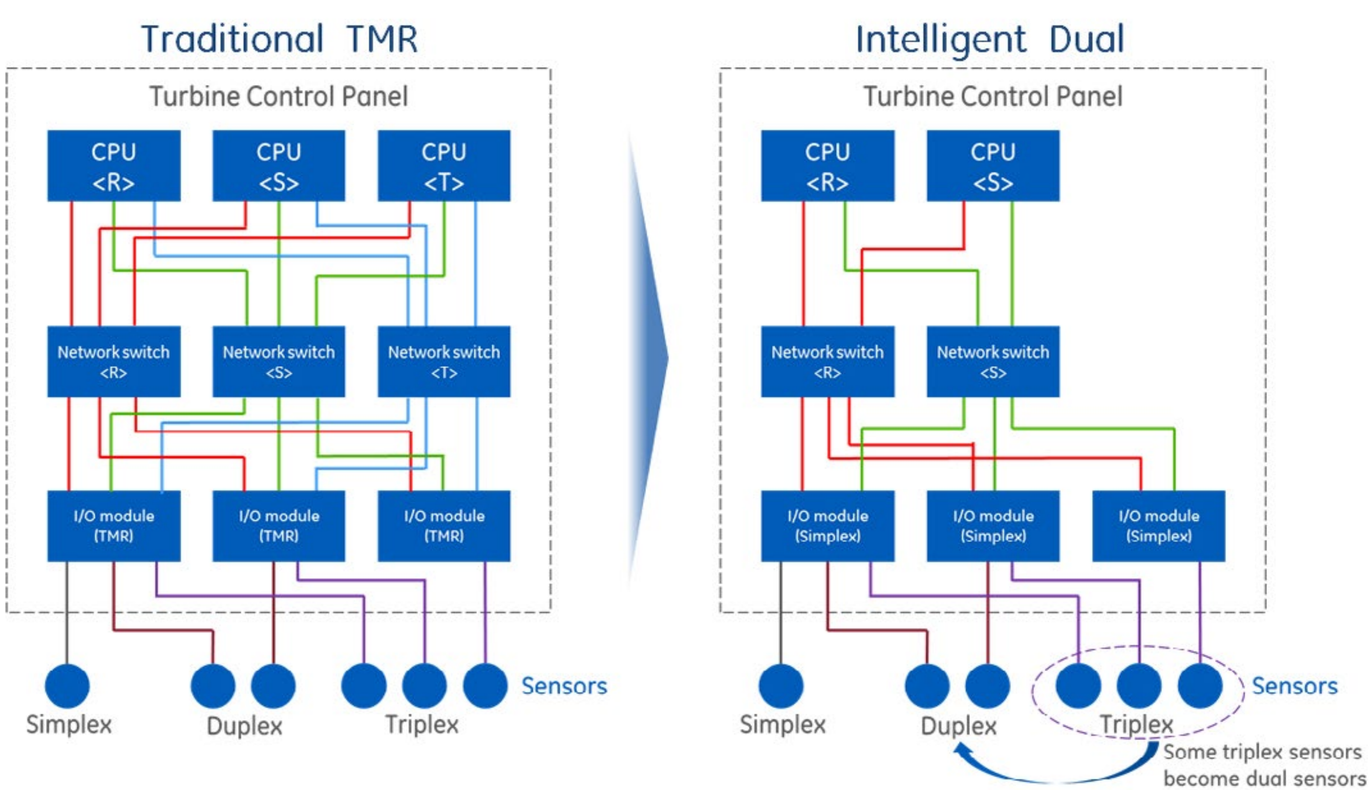
6.5 Intelligent Dual Control Redundancy

What It Is

Intelligent Dual Control Redundancy (IDCR) streamlines and simplifies the backup safety configurations of both the Turbine Control Panel CPUs and the instrumentation within the turbine accessory systems in a traditional Triple Modular Redundant (TMR) control architecture. With IDCR, the following updates are applied:

- Control Panel with dual CPUs and dual I/O networks
- Instrumentation redundancy determined on a case- by-case basis to meet reliability targets
- Active in-range fault detection and surrogate modeling to meet reliability targets

For example, all safety systems instrumentation remains triplicated to maintain tripping reliability, but some of the basic process control instrumentation redundancy can be consolidated to improve running reliability, while maintaining tripping reliability with surrogate sensor models.



Why It Matters

Compared to TMR, IDCR enables the following:

- Virtually identical tripping reliability while improving running reliability
- Lower cost solution
  - reduced product cost in control components and gas turbine accessories
- Lower cost to maintain
  - 20+ sensors reduced, 1 CPU, 4 network switches, and 15+ I/O modules reduced on the gas turbine control panel. 1 CPU, 4 network switches reduced on the steam turbine control panel
- I/O density reduction in control panel
  - 15+ I/O modules eliminated resulting in fewer panels required within controller cabinet

The benefits are illustrated in the figures below.

Key Enablers

The following technology features are applied to create an Intelligent Dual Control System:

- Surrogate sensor models – surrogate models acting as a 3rd sensor in voting
- In-range fault detection of previously undetectable faults

Requirements & Constraints

The IDCR philosophy remains the same regardless of the various site or plant requirements and constraints. The detailed content is adjusted as needed based on these requirements. For example, if dual fuel capability (natural gas and distillate) is needed, the IDCR philosophy will be adapted to cover both fuel sources.

System Interactions & Engineering Requirements

P11 GT Control

The configuration of Control Panel components is revised to Intelligent Dual configuration in the figure above. Where surrogate sensor models have been developed, triplex sensors become dual sensors.

P12 ST Control

The configuration of Control Panel components is revised to Intelligent Dual configuration in the figure above. Surrogate sensor models and changes to sensor count are not currently applied.

Physical Implementation

The footprint of the Control Panels remains the same. There are fewer components that need to be mounted within the Control Panel, but the number of reduced components does not currently drive the reduction of a Control cabinet.

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Instrumentation Redundancy

Below is an example list of sensors that were removed for a dual fuel 7F.05 gas turbine. Reduction in sensors also results in a reduction in vendor, field and customer wiring and terminations. For pressure instrumentation, this also results in a decrease in tubing lines and pressure taps on piping. In terms of footprint, less total sensors means the instrumentation on the 557T panels can be redistributed and eliminate unnecessary panels by consolidation.

MLI	Device	HW MLI	Description
471	96TD-1C	A122	Inlet Dew Point Temperature
417	96TS3P-1	557T	Cavity Pressure
417	96TS3P-2	557T	Cavity Pressure
417	96CD-1C	557T	Compressor Discharge Pressure
417	96TS2P-1	557T	Cavity Pressure
417	96TS2P-2	557T	Cavity Pressure
492	96AP-1C	557T	Barometric Pressure
422	96FG-2C	A60G	Gas Inner-stage Pressure (P2)
422	96GN-1B, -1C	557T	Gas Fuel System Differential Pressures
422	96GN-2B, -2C	557T	Gas Fuel System Differential Pressures
422	96GN-3B, -3C	557T	Gas Fuel System Differential Pressures
422	96FG-1D	A60G	P1X Inter-stage Fuel Gas Pressure Device
422	96FG-1E	A60G	P1X Inter-stage Fuel Gas Pressure Device
422	96FG-1F	A60G	P1X Inter-stage Fuel Gas Pressure Device
422	FTG-1C	A160	Gas Fuel Temperature
425	AAT-1C	A62A	Atomizing Air Cooler Discharge Thermocouple
471	96TF-1	A040	Turbine Inlet DP Transmitter
477	96PG-12C	A160	Inter-stage Purge Cavity Pressure Transmitter
416	LT-TH-3	A160	Lube Oil Header Temperature
492	96EP-3	557T	Exhaust Pressure Transmitter
422	96FG-1D, 1E, 1F	A160	P1X Inter-stage Fuel Gas Pressure Device

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Appendix

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Appendix A
Requirements and Constraints

Requirements and constraints capture the plant mission and goals, interface of the plant to infrastructure and location based constraints. These are broken down into six categories.

- Operations
- Site
- Fuel
- Grid
- Environmental
- Schedule

The purpose of this dimension is to capture the requirements and constraints that drive the minimum viable product offer. This is best illustrated by an example. Under the "Grid" category in the figure below, "capacity limit" is shown as a constraint. Assume the constraint for the site is 1000 MW. However, the customer asked for a 500 MW plant. The true constraint is 1000 MW. The customer preference is 500 MW. GE would discuss the situation with the customer and adjust the offer as appropriate. Additional customer special requests or option preferences similar to this, such as paint color, material preferences or sources are captured for specific transaction and are in addition to this list. The figure below elaborates on the attributes for each of these six categories.

Operations

- Startup
  - Starting Times
  - Black Start
- Reliability Reqts
- Availability Reqts
- Redundancy Reqts
- Operating Regime
  - Starts/Year
  - Hours/Start
  - Peak Output
  - LF Operating Needs
  - Output
  - Heat Rate
- Fuel Transfers

Site

- Atmospheric
  - Airborn Contamination
  - Wind Direction & Loads
  - Rain/snow Loads
  - Temperature Range
  - Humidity
  - Pressure (Altitude)
- Local codes/standards
- Geologic
  - Seismic Zone
  - Properties
  - Contamination
  - Water Table
- Pre-existing Utilities
- Pre-existing Structures
- Water Supply
  - Chemistry
  - Capacity
- Transportation
  - Heavy Transport
  - Bridges
  - Roads
  - Access
- Skilled Labor Availability

Fuel(s)

- Gas
  - Constituents
  - Pressure
  - Temperature
- Liquid
  - Constituents

Grid

- Connection
  - Voltage
  - Power Factor
  - Capacity Limit
- System
  - Grid Code
  - Characteristics

Environmental

- Air Permit
  - CO
  - CO_2
  - VOC
  - SO_2
  - PM10
  - PM2.5
  - Ammonia
  - Stack Temperature
  - Stack Location
  - Stack Height
- Water Consumption
- Heat Rejection Sink
- Water Discharge
  - Temperature
  - Contaminants
- Human Factors
  - Noise
  - Access
  - Hazop

Schedule

- Predictibility
- Material Availability
- Product Availability
- Shipping Cycles
- Engineering Cycles
  - Customer
  - GE
  - Partner
- Cost of Money

Customer requirements and site specific constraints

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Appendix B Plant Functions

System Interactions & Engineering Requirements

The primary goal of the system interaction section is to describe which functions of the power plant are affected by the feature. The functions of the plant are split into five primary systems. Along with defining the functionality of the power plant, it also provides the common language or system breakdown structure (SBS) for use across GE Power & Water teams when discussing the plant. The functional system design considers physical implementation needs while also supporting the plant requirements and constraints.

The five primary "parent" systems are:

Topping Cycle

The gas turbine and its dedicated systems.

Bottoming Cycle

The steam turbine, HRSG, condensate, feed water and associated system.

Heat Rejection

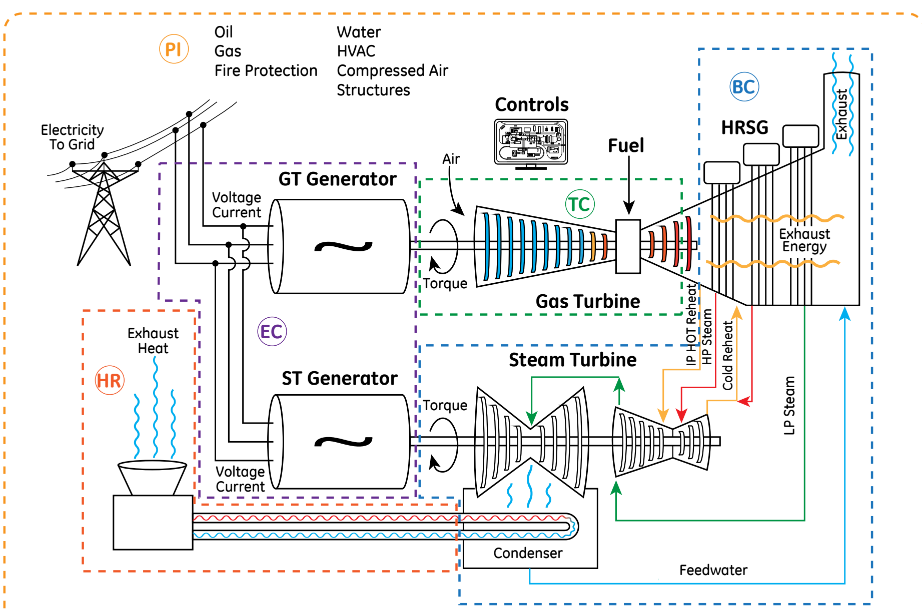
Systems that reject heat to the environment.

Electrical

Systems that export power to the grid or supply power to plant equipment.

Plant Integration

Systems that support the main plant equipment in converting fuel to electrical power.



PI — Plant Integration EC — Electrical Conversion TC — Topping Cycle

Topping Cycle

Codes RDS-PP	GE Systems Designation
MB	T10 Gas Turbine
MBB, MBC	T11 Gas Turbine Unit
MBH	T12 Cooling & Sealing
MBU	T13 Clearance Control
MBJ	T14 Starting Means
MBU	T15 Steam Injection
MBP, MBH	T20 Gas Fuel Delivery
MBN	T30 Liquid Fuel Delivery
MBN	T31 LF Atomizing Air
MBU	T32 LF Water Injection
MBR	T40 GT Exhaust
MBR	T41 Bypass Stack
MBL	T50 GT Inlet
MBL	T51 Inlet Conditioning

Bottoming Cycle

Codes RDS-PP	GE Systems Designation
LBB	B10 Feedwater
H	B20 HRSG
HAH, LBA	B21 HP Steam
HAB, LBB	B22 IP Steam
HAH, LBD	B23 LP Steam
HHA	B28 Supplemental Firing
QCG	B25 SCR/ Ammonia
QC	B26 Chemical Injection
HAN	B27 Blowdown
LB, MA	B30 Steam
MA	B31 Steam Turbine Unit
LB , MA	B32 Steam Admission
LB , MA	B33 Steam Extraction
MAN	B34 Bypass
MAL	B35 ST Drains
QU	B36 Steam Sampling
MA	B37 Steam Seal
LC	B40 Condensate
MAG	B41 Condensing Steam
MAJ	B42 Condenser Vacuum
LBG, QH	B50 Auxiliary Steam
LBD, HAD	B60 Deairator / Sparging
HAD	B70 Pegging Steam

Heat Rejection

Codes RDS-PP	GE Systems Designation
PA	H10 Circulating water
PC , PG	H20 Aux Cooling Water
MBE	H21 GT Cooling Water
MKF	H22 Gen Stator Cooling H_2O

Electrical Conversion

Codes RDS-PP	GE Systems Designation
MK	E10 Generator
MKA	E11 Generator Unit
MKG	E12 Gas Cooling
MKC	E13 Excitation
MKY	E14 Protection
MS	E20 Electrical Evacuation
MST	E21 Voltage Conversion
AA	E22 High Voltage
B	E30 Auxiliary Power Distribution
B	E31 Medium Voltage
B	E32 Low Voltage
B	E33 Essential Services
MJB	E40 Electrical Starting Systems
MJB	E41 LCI
BX	E42 Black Start Generation

Plant Integration

Codes RDS-PP	GE Systems Designation
C	P10 Control Systems
C	P11 GT Control
C	P12 ST Control
C	P13 Power Island Control
C	P14 Plant Control
EG , EK	P20 Fuel Systems-Gas/Liquid
EKE	P21 Gas Conditioning
EGE	P22 Liquid Oil Conditions
MV, MW, MX	P30 Oil System
MAX , MBX	P31 Hydraulic Oil / Lift
MKW	P32 Seal Oil
MAV, MBV, MKV	P33 Lube Oil
QJ	P40 Gas Systems
QJB, QJC, QJB	P41 H_2, CO_2, N_2 Strg & Dist
XG	P50 Fire Protection
XG	P51 GT Fire Protection
XG	P52 Plant Fire Protection
XG	P53 ST Protection
G	P60 Water Systems
GHC	P61 DI Water System
GAC	P62 Raw Water
GHF, MBU	P63 GT Water Wash
XL	P64 Potable Water
GHA	P65 Service Water
GM	P66 Plant Drains
XK	P67 Chilling
XA , XB	P70 HVAC
XAM	P71 GT HVAC
XAM	P72 HVAC of GT Aux
XAM	P73 HVAC of ST Aux
XA	P74 HVAC of Plant Aux
QF	P80 Compressed Air Systems
XC , QFA	P81 Service Air
QFB	P82 Instrument Air
U	P90 Structures
U	P91 Foundations
U	P92 Buildings
XM	P93 Cranes
UB	P94 Duct Banks
ZZA	P95 Roads

Systems Counts

TC	-	14
BC	-	23
HR	-	4
EC	-	15
PI	-	40
Total	-	96

Functions are sometimes split into three major groups

- **Group 1 – What GE Controls** – Equipment, accessories and system definition that GE supplies.
- **Group 2 – What GE Influences** – Customer, partner or EPC systems and equipment that directly support GE supplied systems.
- **Group 3 – Site Specific** – Systems and equipment beyond those in the first two groups that are necessary to meet site requirements and constraints. These systems are engineered by the customer, customer EPC, or GE partner (in case of Turnkey) and complete the plant package. Examples include raw water processing and waste water treatment systems.

These major groupings provide visibility to interactions between GE Equipment, GE Extended scope and Balance of Plant scope of supply. Such views give insight into total plant cost and optimization of functional design and implementation decisions.

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Appendix C Physical Implementation

Physical Implementation of the plant considers how the plant is built, operated and maintained. The implementation methods also consider the functional needs of the plant and the plant requirements and constraints. The physical implementation of the plant must be adaptable to meet the requirements and constraints of the plant such as manpower availability and logistical constraints.

Layout	Packaging	Construction	Commissioning	O&M

Location
Interfaces
Interferences
	Preservation
	Modularity
		Lifting Capability/ Availability
		  Cranes
		  Gantry
		Material Handling
		Laydown
		Connections
		  Flanges
		  Welding
		  Wiring
		Construction Waste
		Construction Tools Methods
		Work Face Planning
		Spares
			Methods
			  Test Requirements
			  Cleaning
			  System tuning
			Spares
				Operations
				  Test equipment
				  Data Access
				  Automation
				Maintenance
				  Special Tools
				  Access Reqts
				  Laydown Reqts
				  Spares
				  Predictivity
				  Lifting Needs/ Availability
				  Assembly/ Disassembly

How the plant is built, operated and maintained

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Appendix D Definitions and Acronyms

Definitions

Build to Interface: Drawings and specifications that define all mechanical, electrical and civil interface points.

Build-to-Print: Drawings and specifications include all supplier-specific components, materials, layout, dimensions, tolerances and special construction notes, including applicable codes and standards, required to facilitate the final design and construction of the equipment. The drawings and specifications are such that all mechanical, electrical and civil interface points are specified.

Architecture: The core technologies, assembly methods, and classes of materials associated with a given design concept. Gas turbine examples of these respectively include external vs. internal fed bucket cooling supply, bolted rotor vs. welded or curvic/hirth, and steel vs. nickel alloys.

Rapid Response: A plant configuration that adds HP and RH Steam terminal attemperation and additional steam bypass capability to allow the GT to operate unrestricted during the starting of the ST. A modified HRSG specification provides a robust HRSG that is capable of handling the new GT operating profile.

Rapid Response Lite: A plant configuration that adds HP and RH steam terminal attemperation to allow the GT to operate at loads up to Minimum Emissions Compliance during starting of the ST

Equipment Only: Contract scope in which GE provides the GT, ST, & Gen. Included are purchased auxiliary and MSD equipment related to the GE equipment such as Inlet filter house, excitation, controls and fuel systems.

Engineered Equipment Package: Contract scope in which GE provides power island equipment, plant construction engineering services, major equipment including HRSG, plant controls, condenser, and CC performance guarantees.

Turnkey: Contract scope in which GE provides GT, ST, Gen, HRSG, conceptual plant engineering, plant controls, plant commissioning, and performance CC guarantees and testing. A GE EPC partner generally provides detailed plant engineering, BOP equipment and materials, inland transportation, construction, commissioning labor.

Reference Plant: A typical plant design that includes power island layout and accommodation of standard options. The reference plant has sufficient detail to support proposal activities.

Fieldbus: An all-digital, serial, two-way industrial control network protocol for real time distributed control. Control signals and power are provided over the same wires. The two predominant standards are Profibus™ and FOUNDATION™ Fieldbus. The protocols are governed by a series of industrial standards.

Total Installed Cost: The total cost of a plant from initial order to COD. This includes permitting and insurance, capital carrying (finance), engineering, shipping, equipment, construction, installation, commissioning, taxes, cost of required spare components and project management.

Life Cycle Cost: Total cost of the plant owner/operator from purchase to the end of useful life, which is typically specified as 30 years. The current expected customer evaluation term is 20 years and includes the CSA, routine maintenance, major (capital) maintenance, fuel, inspections and operating labor.

Plant Cold Start: Plant shutdown ≥ 72 hours

Plant Warm Start: Plant shutdown < 72 hours but > 8 hours. Startup curves are made for 48 hours as representative of this range. The start time varies linearly with shutdown hours between 8 and 48 and between 48 and 72. Start time from 0 to 8 hours shutdown is constant as is time after 72 hours.

Plant Hot Start: Plant shutdown ≤ 8 hours

FOUNDATION™ is a trademark of Fieldbus Inc.
Profibus™ is a trademark of the Profibus User Organization.

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Acronyms

- ACC: Air Cooled Condenser
- ASR: Accident Scenario Review
- ATEX: Atmosphere Explosive
- BIL: Basic Insulation Level
- BOP: Balance of Plant
- B/L: Baseload
- BTI: Build-To-Interface
- BTP: Build-To-Print
- C&Q: Compliance and Quality
- CAPEX: Capital Expenditure
- CEMS: Continuous Emissions Monitoring System
- CC: Combined Cycle
- COD: Commercial Operation Date
- Conv: Conventional (Plant Start Type)
- CSA: Contractual Service Agreement
- CSQ: Coaching Service Quality
- DCS: Distributed Control System
- DD: Device Description
- DFR: Design for Reliability
- DoC: Declaration of Conformity
- DoI: Declaration of Incorporation
- DTC: Design to Cost
- DTM: Detailed Transient Model
- DVP: Digital Vane Positioner
- DWG: Drawing
- EC: European Commission
- EEP: Engineered Equipment Package
- EMFH: Events per Million Fired Hours
- EU: European Union (27 Countries in Europe)
- FFB: Foundation Fieldbus
- F-F: Flange-to-Flange
- FMEA: Failure Mode & Effects Analysis
- FSNL: Full Speed, No Load
- GTA: Gas Turbine Auxiliaries
- GT/G: Gas Turbine/Generator
- HFE: Human Factors Engineering
- HGP: Hot Gas Path
- HMI: Human Machine Interface
- HP: High Pressure (Designation for Steam Turbine or Steam System)
- HRH: Hot Reheat
- HRSG: Heat Recovery Steam Generator
- ICPE: Installation Classes for The Environment
- IDCR: Intelligent Dual Control Redundancy
- IED: Industrial Emission Directive
- IGV: Inlet Guide Vane
- IP: Intermediate Pressure (Designation for Steam Turbine or Steam System)
- IPB: Isolated Phase Bus
- IPPC: International Plant Protection Convention
- IRR: Internal Rate of Return
- ISA: International Society of Automation
- ISO: International Organization for Standardization
- KKS: "Kraftwerk Kennzeichensystem" – A Standardized Power Plant Designation System
- LCB: Life-cycle Control Board
- LCC: Life Cycle Cost
- LCI: Load Commutator Inverter
- LCPM: Life Cycle Product Management
- LHV: Lower Heating Value
- LNG: Liquefied Natural Gas
- LP: Low Pressure (Designation for Steam Turbine or Steam System)
- LSB: Last Stage Bucket
- LSL: Lower Specification Limit
- LTSA: Long Term Service Agreement

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- LVRT: Low Voltage Ride Through
- MCW: Main Circulating Water
- MECL: Minimum Emissions Compliance Load
- MF: Maintenance Factor
- MLI: Model List Item
- MS: Multi-Shaft
- MSD: Material Ship Direct
- MTBF: Mean Time Between Failures
- MTBFO: Mean Time Between Forced Outage
- MTBUE: Mean Time Between Unsafe Events
- MTTR: Mean Time to Repair
- NFPA: National Fire Protection Association
- NPV: Net Present Value
- NTI: New Technology Introduction
- NTP: Notice To Proceed
- O&MM: Operating and Maintenance Manual
- OSM: On Site Monitoring
- OTB: Once Through Boiler
- P&E: Plant & Equipment
- PBCS: Product Baseline Compliance Specification
- PCNO: Power-Constrained Noise Optimizer
- PDC: Power Distribution Center
- PED: Pressure Equipment Directive
- PEECC: Packaged Electronic/Electrical Control Compartment
- PIIO: Power Island Integration and Optimization
- P/L: Part Load
- PLC: Programmable Logic Control
- QMS: Quality Management System
- RAM: Reliability, Availability and Maintainability
- RDS-PP: Reference Designation Systems for Power Plants ISO/TS 16952-10
- RDSU: Remote Deployable Software Upgrades
- RH: Reheat Steam, Steam at Intermediate Pressure That is Superheated
- RoHS: Restriction of The Use of Certain Hazardous Substances in Electrical and Electronic Equipment
- RR: Rapid Response
- RSG: Remote Service Gateway
- SBS: System Breakdown Structure
- SC: Simple Cycle
- SI: International System of Units
- SIL: Safety Integrity Level
- SS: Single-Shaft
- SSt: Smart Start
- TDI: Technical Direction of Information
- TIC: Total Installed Cost

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Appendix E
Document Creation and Revision List

CH	Title	Created	Update	Description
1.0	**LAYOUT**	04/15		
1.1	Layout for Single-Shaft Plants	04/15		
1.2	Layout for Multi-Shaft Configuration	04/15		
1.3	Single-Shaft vs. 1x1 Multi-Shaft	04/15		
1.4	Preferred Steam Turbine Exhaust Direction	04/15		
1.5	Compact Gas Turbine Building for Multi-Shaft Configurations	04/15		
2.0	**SCHEDULE**	04/15		
2.1	Project Schedules for Single-Shaft and Multi-Shaft Plants	04/15		
2.2	Modularized Gas Turbine Enclosure	04/15		
2.3	Steam Turbine Installation and Constructability Features	04/15		
2.4	Lube Oil System Flush Features	04/15		
3.0	**SIMPLIFICATION**	04/15		
3.1	Electric Inlet Guide Vane and Variable Stator Vane Actuators	04/15		
3.2	Pressure Atomized Liquid Fuel System	04/15		
3.3	Factory Commissioning of Accessory Skids	04/15		
3.4	Consolidated Plant Electrical Room	04/15		
3.5	Water Mist Fire Protection	04/15		
4.0	**PERFORMANCE**	04/15		
4.1	Heat Recovery Steam Generator Enhancements	04/15		
4.2	600°C (1112°F) Main Steam and Reheat Steam Temperatures	04/15		
4.3	Fuel Heating to 226°C (440°F)	04/15		
4.4	Two Pressure Condenser for Steam Turbines with 4-Flow Low Pressure Sections	04/15		
5.0	**OPERABILITY**	04/15		
5.1	Plant Hot Starts in 30 minutes or less	04/15		
5.2	Plant Shutdown Purge Credit	04/15		
5.3	SSS Clutch for Single-Shaft Applications	04/15		
6.0	**CONTROLS/USER EXPERIENCE (UX)**	04/15		
6.1	Digital Bus Technology for Instrumentation and Controls	04/15		
6.2	Plant AutoStart	04/15		
6.3	State-of-the-Art Human-Machine Interfaces	04/15		
6.4	Plant Level Alarm Management and Fault Tolerant Protection Systems	04/15		
6.5	Intelligent Dual Control Redundancy	04/15		
APPENDIX		04/15		
A	Requirements and Constraints	04/15		
B	Plant Functions	04/15		
C	Physical Implementation	04/15		
D	Definitions and Acronyms	04/15		

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