GE
Intelligent Platforms

Benefits of Integrating a Single Plant-Wide Control System Into a Standard Plant Design Philosophy

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Introduction

Recent trends in the power industry call for reduced project execution cycle along with improved operability and maintainability of the power plant. In support of these trends, GE's Power Plant Controls Team, along with their partners, have implemented a number of combined-cycle power plants within Europe utilizing a standard plant design approach. *(Figure 1.)* This paper will use a case study to discuss the value of implementing a single plant-wide system for control, protection and safety within a standard plant design philosophy.

GE's system integration starts in the design phase of a power plant where it is important to define a plant control philosophy that reduces multiple systems and simplifies plant control. A single control platform for plant and unit level control improves integration; reduces system complexity, start-up problems and commissioning time; and reduces project cycle time and risk. The tight coupling of the equipment, enabled by the control system, provides operational benefits such as better fuel flexibility, faster startup, improved turndown capability and enhanced grid response.

This paper will examine three key phases of the power plant project life-cycle: plant equipment and control design phase, testing and commissioning, and the operational period. Additionally, we will review the Lares Project Case Study where two 109FB single shaft combined-cycle plants are being installed in Portugal.

I. Plant Equipment and Control System Design Phase

The initial design of the plant equipment and the distributed control system (DCS) is one of the most critical periods of the project life cycle. Decisions made during this portion of the project have a significant impact on the final implementation and overall schedule. A standardized design and collaborative engineering environment have great influence on both afore mentioned factors.

During the project bid development phase an overall design philosophy is established. GE and their engineering partner(s) collaboratively review specification items for best cost/value implementation strategies. Additionally, transparency between GE and their partner helps identify potential issues sooner and resolve those issues based on the impact to the overall project. The power island (heat recovery steam generator [HRSG], gas turbines, steam turbines and DCS) equipment is essentially pre-designed architecture. Site-specific options and customer preference influence the balance of plant (BOP) and power island design. Some examples include type of cooling used (air-cooled condensers, cooling towers or once-through condensers), type of feed pumps (variable speed or fixed speed), fuel type, and the switchyard. Early engagement between GE and their partner in these decisions fosters a team culture focused on common goals as compared to a transactional process focused on change orders and revenue improvement.

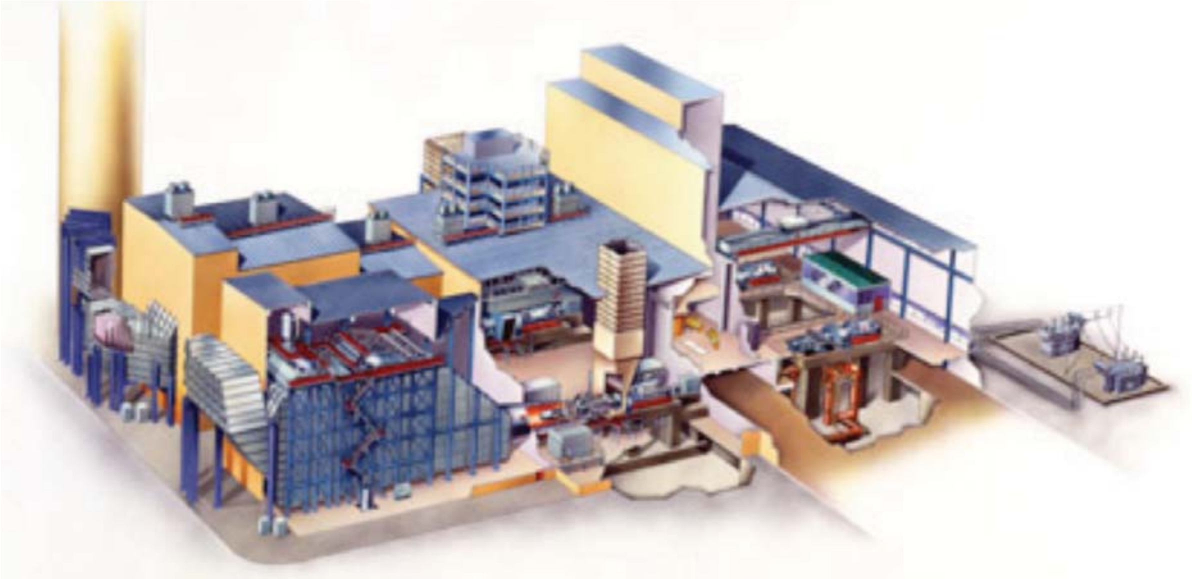

Figure 1. Typical combined-cycle plant

Simplification of the plant control system design involves the elimination of interfaces and third- party control equipment. Some customers may drive towards the complete elimination of programmable logic controllers (PLCs) by using DCS equipment. Major equipment interfaces may be eliminated if a common control platform and architecture is provided. This design simplification, known as the GE Integrated Control System, reduces configuration and commissioning effort, expands network interfaces and improves long-term maintainability. Operator interfaces are plant-wide and eliminate the need for turbine specific operator stations, simplifying the control room layout. Alarms, sequence of events and diagnostics are system-wide, time-coherent, in a common database, and conform to a plant-wide philosophy for alarm management. Trending can be accomplished at high data rates with historical retrieval for all plant equipment. Operator interface graphic and alarm philosophy are common across the complete plant control system. *(Figure 2.)* Decisions can be made by identifying which equipment should be on a common control platform, such as the Demineralized Water and Burner Management System, and which packaged equipment is best served by PLC control. When PLCs are required, GE Fanuc PLCs can exist on the same control network as the GE plant control system, further simplifying plant design. By using the same control network, protocol and operator interface, the integration effort is reduced and commands, feedback and alarms for operation can exist on all operator stations with common operator interface graphics, alarms and peer-to-peer data exchange.

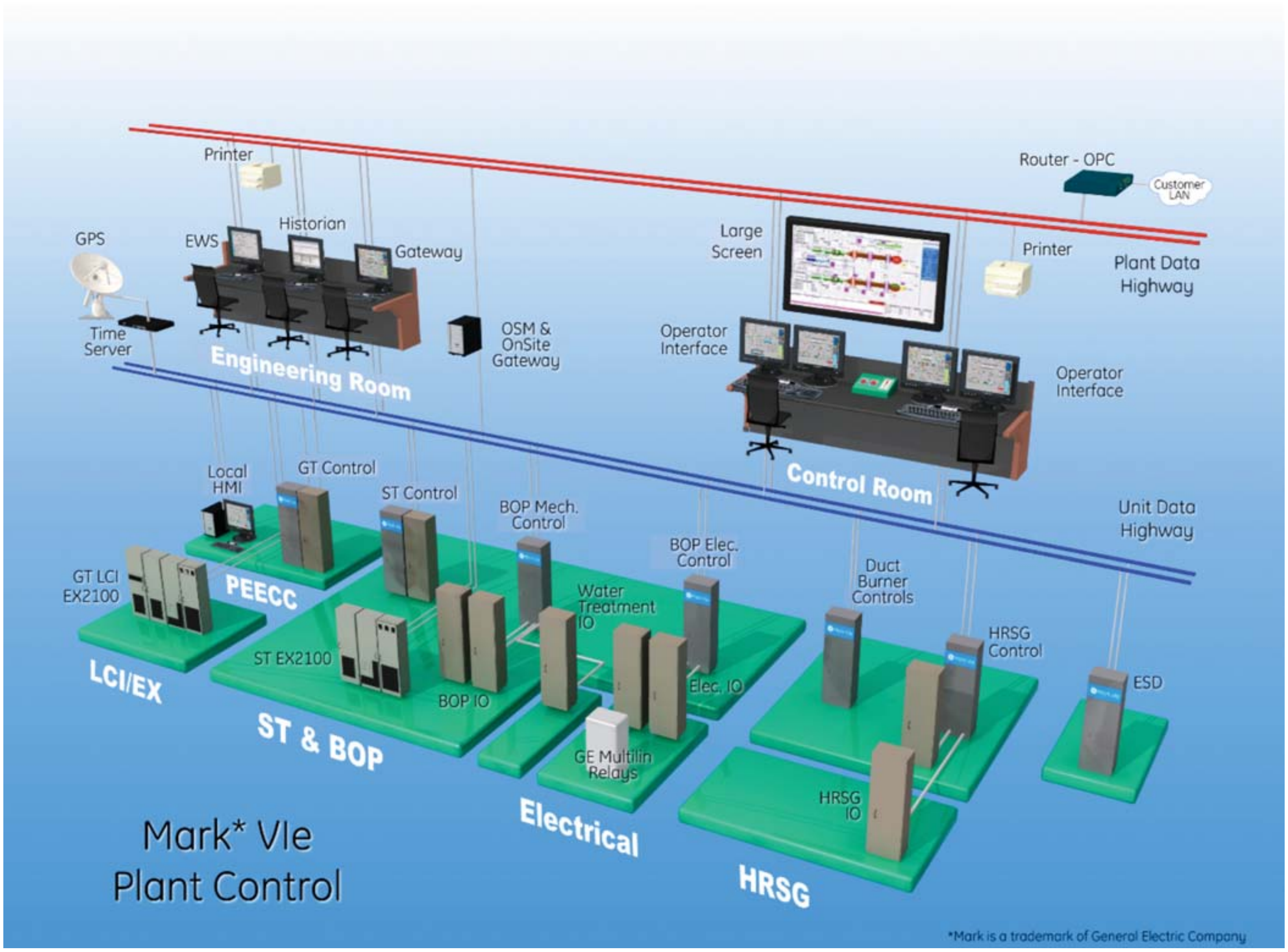

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Figure 2. Integrated Plant Control System

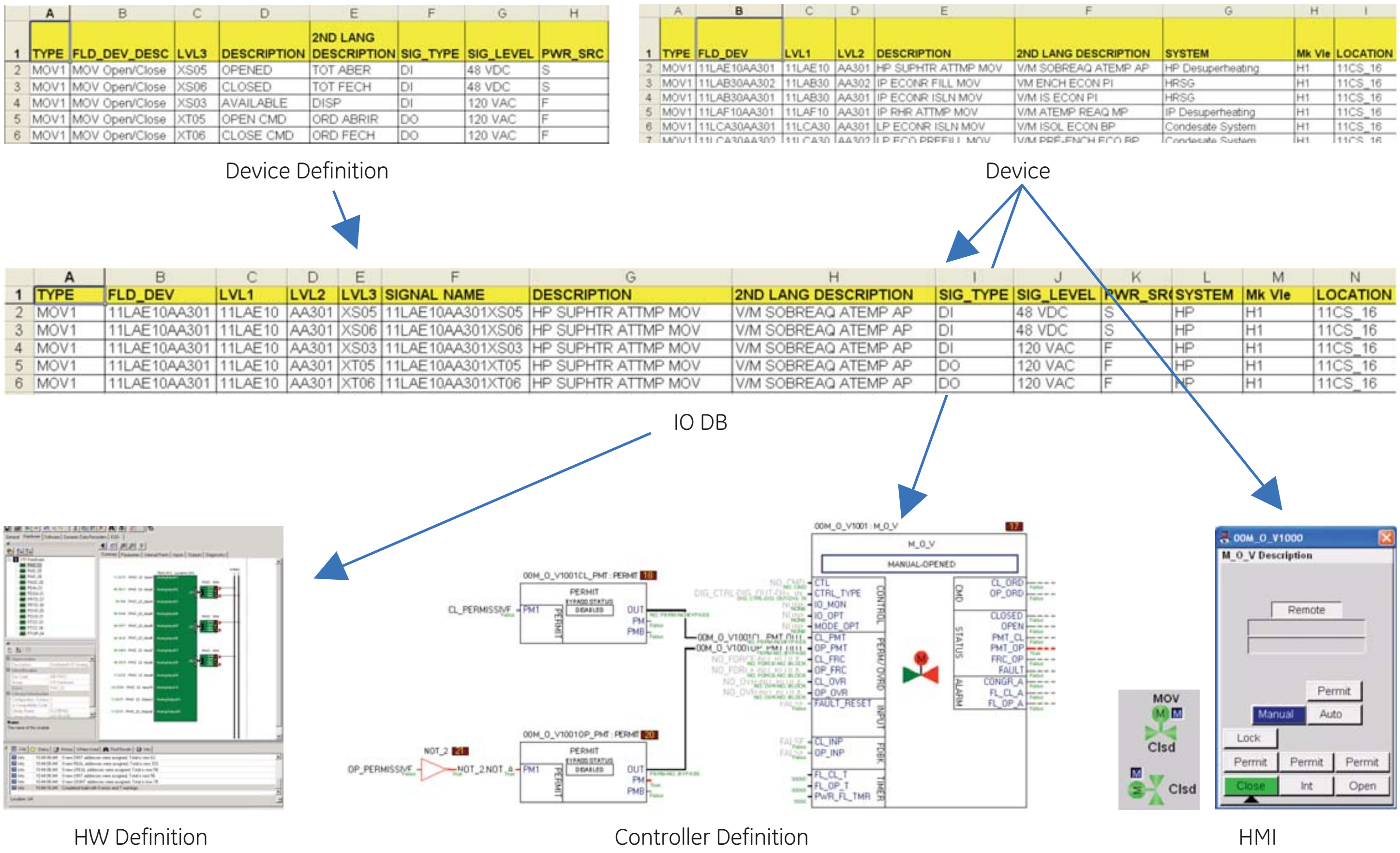
Structured Engineering

Developing structure early in the project and using a repeatable standard design reduces both the engineering effort and schedule time required to develop the plant control design. Collaboration between the partner, customer and GE early in the design phase strengthens the relationship between all parties throughout the project.

Structured physical layout of plant equipment allows for a predetermined, standardized and economical distributed I/O network. Cost and schedule trade-offs are made based on the reduction of cabling and associated installation, with the usage of remote I/O cabinets. By using a standard plant design early in the project, an accurate I/O estimation and cabling design is obtained, reducing the engineering effort needed to make the final I/O and cable design. Other design considerations include the use of fieldbus technologies, marshalling or disconnect options for the I/O cabinets, and environmental requirements.

Collaboration Tools

Collaboration tools used during the engineering phase of the project allow for integration of the engineering, procurement, and construction (EPC) and plant control configuration teams. *(Figure 3.)* A structured relational database, device control macro and operator interface object libraries—coupled with automation—drive consistent quality from initial implementation through commissioning. In the relational database, two worksheets are defined, one for the definition of the devices and a second for the list of devices. Typically, the plant includes more than one type of motor-operated valve (MOV) with multiple usages of each type. By using this approach, the MOV needs to be defined only once, eliminating any required changes to the single definition. Using the standard relational database ensures that definitions for partitioning, signal level, power source, descriptions (both English and native language) and tagging are consistent throughout the project. As a result, errors can be reduced that can impact commissioning and operation while providing consistent descriptions throughout the system.



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3	MOV1	MOV Open/Close	XS06	CLOSED	TOT FECH	DI	48 VDC	S
4	MOV1	MOV Open/Close	XS03	AVAILABLE	DISP	DI	120 VAC	F
5	MOV1	MOV Open/Close	XT05	OPEN CMD	ORD ABRIR	DO	120 VAC	F
6	MOV1	MOV Open/Close	XT06	CLOSE CMD	ORD FECH	DO	120 VAC	F

Device Definition

	A	B	C	D	E	F	G	H	I
1	TYPE	FLD_DEV	LVL1	LVL2	DESCRIPTION	2ND LANG DESCRIPTION	SYSTEM	Mk Vle	LOCATION
2	MOV1	11LAE10AA301	11LAE10	AA301	HP SUPHTR ATTMP MOV	V/M SOBREAQ ATEMP AP	HP Desuperheating	H1	11CS_16
3	MOV1	11LAB30AA302	11LAB30	AA302	IP ECONR FILL MOV	VM ENCH ECON PI	HRSG	H1	11CS_16
4	MOV1	11LAB30AA301	11LAB30	AA301	IP ECONR ISLN MOV	V/M IS ECON PI	HRSG	H1	11CS_16
5	MOV1	11LAF10AA301	11LAF10	AA301	IP RHR ATTMP MOV	V/M ATEMP REAQ MP	IP Desuperheating	H1	11CS_16
6	MOV1	11LCA30AA301	11LCA30	AA301	LP ECONR ISLN MOV	V/M ISOL ECON BP	Condesate System	H1	11CS_16
7	MOV1	11LCA30AA302	11LCA30	AA302	LP ECO PREFILL MOV	V/M PRÉ-ENCH ECO BP	Condesate System	H1	11CS_16

Device

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	TYPE	FLD_DEV	LVL1	LVL2	LVL3	SIGNAL NAME	DESCRIPTION	2ND LANG DESCRIPTION	SIG_TYPE	SIG_LEVEL	PWR_SR(	SYSTEM	Mk Vle	LOCATION
2	MOV1	11LAE10AA301	11LAE10	AA301	XS05	11LAE10AA301XS05	HP SUPHTR ATTMP MOV	V/M SOBREAQ ATEMP AP	DI	48 VDC	S	HP	H1	11CS_16
3	MOV1	11LAE10AA301	11LAE10	AA301	XS06	11LAE10AA301XS06	HP SUPHTR ATTMP MOV	V/M SOBREAQ ATEMP AP	DI	48 VDC	S	HP	H1	11CS_16
4	MOV1	11LAE10AA301	11LAE10	AA301	XS03	11LAE10AA301XS03	HP SUPHTR ATTMP MOV	V/M SOBREAQ ATEMP AP	DI	120 VAC	F	HP	H1	11CS_16
5	MOV1	11LAE10AA301	11LAE10	AA301	XT05	11LAE10AA301XT05	HP SUPHTR ATTMP MOV	V/M SOBREAQ ATEMP AP	DO	120 VAC	F	HP	H1	11CS_16
6	MOV1	11LAE10AA301	11LAE10	AA301	XT06	11LAE10AA301XT06	HP SUPHTR ATTMP MOV	V/M SOBREAQ ATEMP AP	DO	120 VAC	F	HP	H1	11CS_16

IO DB

HW Definition

Controller Definition

HMI

Figure 3. Collaboration tools

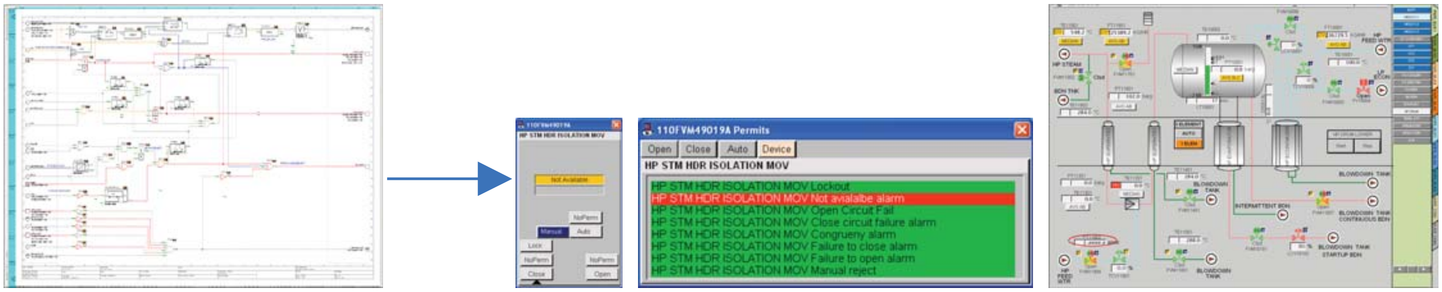
Feature rich device control macro and operator interface object libraries have options to accommodate unique customer requirements, reducing the need to change the macros from one project to another. It is only necessary to select the required options and associated IO. The partner can modify pre-existing static operator interface graphics in Cimplicity* for direct usage in both the project specification and implementation. This interface not only reduces engineering but also makes it easier to implement changes.

Structured Software

Utilizing structured software shortens project cycle time and limits surprises that delay commissioning. IO and logic requirements for the standard design portion of the DCS are available earlier in the project cycle and therefore allow for earlier implementation and testing. Standard controls algorithms and auto sequencing of the process control have been proven in commercial operation and improve proper operation of the plant, utilizing lessons learned by incorporating updated standards. An integrated system on a common control network allows access to all necessary signals for startup and shutdown of the power plant.

Operator interface permissives provide descriptive feedback on conditions required to operate a pump or valve. These permissives are first configured in the controller,based on the necessary logic for operation. Once configured in the controller, the operator interface permissive is automatically configured from the controller and is viewable from the operator interface without the need to view controller logic. For example, once logic has been added in the controller to require greater than 400°C steam temperature prior to opening the block valve, the permissive information and associated description is automatically passed to the operator interface permissive faceplate. Additionally, device descriptions displayed on the operator interface are inherited from the controller description. *(Figure 4.)*

Tight coupling of the controller and operator interface eliminates the configuration and mismatches that are typically found during FAT and commissioning. Personal computer (PC) based controller and operator interface emulation allow for generation of operator interface screens and logic validation by the engineering partners in their local office prior to factory acceptance testing (FAT). *(Figure 5.)*



HP STM HDR ISOLATION MOV

HP STM HDR ISOLATION MOV Lockout
HP STM HDR ISOLATION MOV Not avialalbe alarm
HP STM HDR ISOLATION MOV Open Circuit Fail
HP STM HDR ISOLATION MOV Close circuit failure alarm
HP STM HDR ISOLATION MOV Congrueny alarm
HP STM HDR ISOLATION MOV Failure to close alarm
HP STM HDR ISOLATION MOV Failure to open alarm
HP STM HDR ISOLATION MOV Manual reject

Figure 4. Controller to operator screen integration

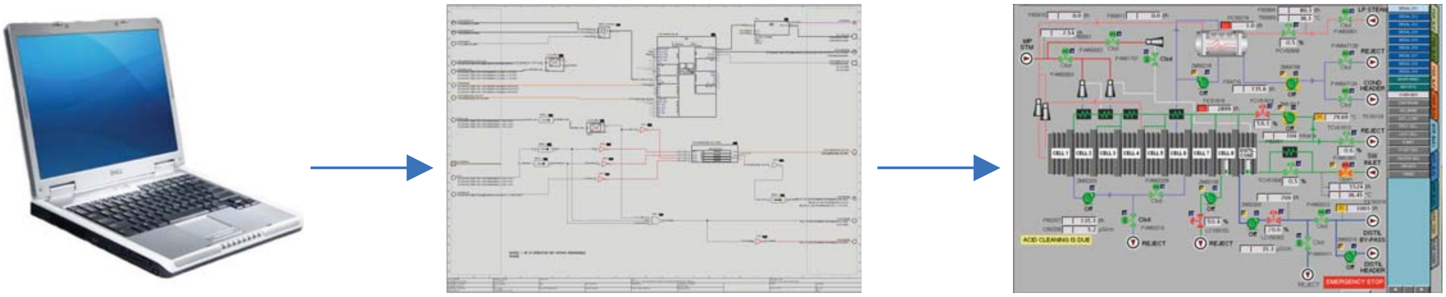


Figure 5. PC based controller emulation allows development of logic and screens

II. Testing and Commissioning Phase

Process simulation and stage testing of the full plant control system—as it will be configured on site—play a key role in verification of the system prior to shipment. This verification process validates the implementation of control system algorithms, network connectivity and provides a high degree of confidence in the complete integrated system before shipment; reducing installation time and risk during commissioning. When required for early shipment, IO panels are downloaded with the applicable configuration and validated prior to leaving the factory. Operator interface equipment and controllers remain in the factory for software testing, allowing IO cabinet placement at the site and its associated field wiring earlier in the project cycle.

Factory Testing

During FAT, turbine controllers and operator interfaces are validated with the plant control equipment, ensuring total system integration and validation. *(Figure 6.)* Operator stations are integrated allowing seamless screen navigation and operation through the entire plant control system. Structured FAT tests that match site-acceptance tests used in commissioning are conducted to ensure that systems operate properly in the field. Turbine to BOP logic configuration and functionality is improved and validated in an integrated system. Signal names are automatically associated between devices, eliminating the need for signal mapping and verification. Having a common control network for the turbine and BOP equipment eliminates the number of hardwired signals between individual controllers; only critical signals between controllers need to be hardwired. Additionally, peer-to-peer controller signals can be transmitted at 25 Hertz, allowing closed loop control across the network when required.

The FAT is improved by using a field-proven standard plant design, resulting in a reduced testing period. Since the majority of the logic is standard and during test has fewer failures, fewer corrections are required. Field engineers are familiar with control algorithms, tuning, and system behavior, which reduce the startup commissioning effort. The elimination of the interface between the plant control and turbine control systems removes the testing and commissioning issues associated with third party interfaces.

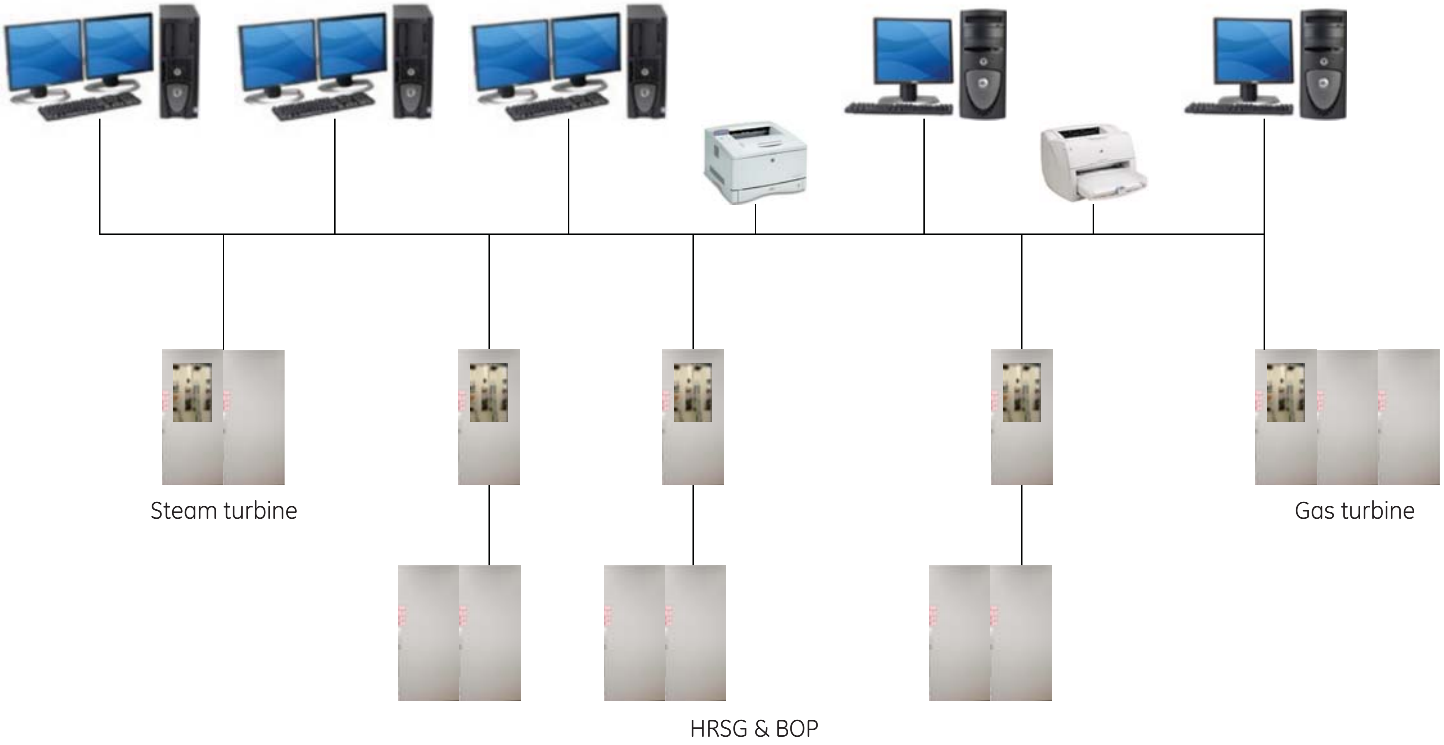


Figure 6. Full system FAT

Advanced Data Collection

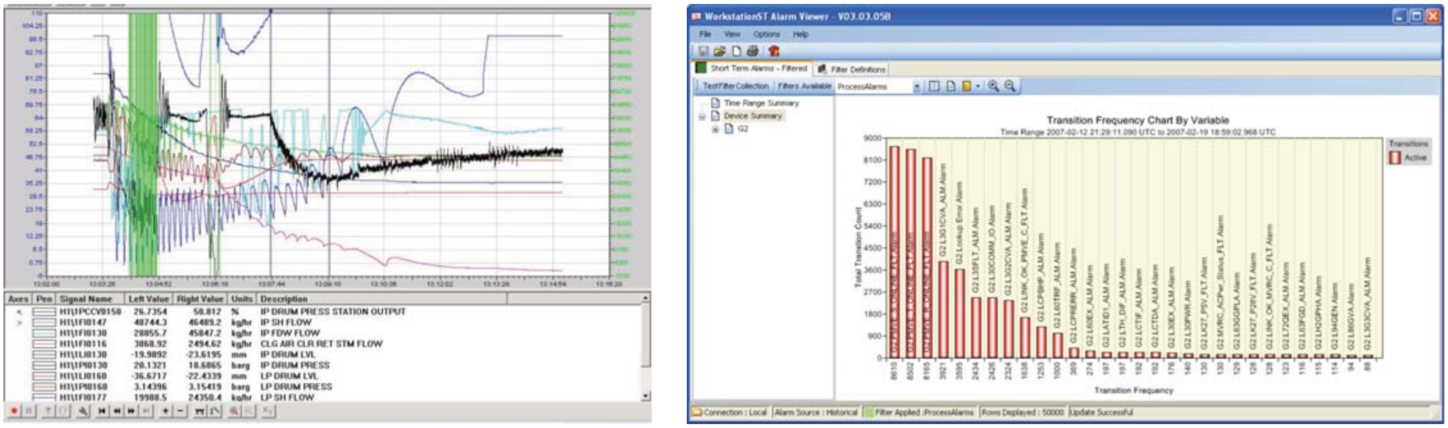
During FAT, event-triggered data collections, high-speed data recording and trending are also verified. Event-triggered data collections are configured with the signals critical to post trip data analysis across the entire system. Additionally, high-speed data recording is available to view system-wide operation. Trending can be accomplished with real-time controller data and backfill data from historical archives. An operator can use a common trend to view signals from the gas turbine, steam turbine and BOP. For example, gas turbine exhaust temperature, attemperation and steam metal temperature can be viewed on one trend with real time and archived data. These advanced engineering and operation tools based on a single database are made available in a common toolset with access from each operator interface. This type of data collection and analysis tool—coupled with system-wide time-coherent data—eases system analysis providing both reduced commissioning time and better long-term operation. *(Figure 7.)*

Third-party interfaces are reduced in this architecture. The communication and associated actions of remaining third-party interfaces are tested with either actual or virtual devices. Factory configuration and testing of the data links reduces both risk and commissioning time for the project.

Remote Diagnostics Support by Factory Engineers

Having a single control system for the turbine and BOP equipment increases the value of many of the commissioning and operating support tools. As an example, remote connectivity and virtual site support via GE's OnSite Support* provides problem resolution, data analysis, remote software deployment and remote tuning capabilities for the control system. *(Figure 8.)* A team of experienced power industry engineers is available 24 hours per day, 365 days per year to assist a user with problem resolution during both the commissioning and operating phases of the project. Once connected, the remote engineer has access to the same control system data and diagnostic tools as the site personnel. Their troubleshooting skills coupled with a database of previous site support issues and resolutions allow quick problem solving of controls-related issues. Remote deployment of software enhancements is also capable with the remote connection. When required, tuning analysis and remote tuning can be coordinated with the site team—improving the quality and consistency of plant operation.

Figure 8. OnSite virtual site assistance 24x7



Axes	Pen	Signal Name	Left Value	Right Value	Units	Description
<		H1\1PCCV0150	26.7354	50.812	%	IP DRUM PRESS STATION OUTPUT
>		H1\1FI0147	48744.3	46489.2	kg/hr	IP SH FLOW
		H1\1FI0130	28855.7	45847.2	kg/hr	IP FDW FLOW
		H1\1FI0116	3868.92	2494.62	kg/hr	CLG AIR CLR RET STM FLOW
		H1\1LI0130	-19.9892	-23.6195	mm	IP DRUM LVL
		H1\1PI0130	20.1321	18.6865	barg	IP DRUM PRESS
		H1\1LI0160	-36.6717	-22.4339	mm	LP DRUM LVL
		H1\1PI0160	3.14396	3.15419	barg	LP DRUM PRESS
		H1\1FI0177	19988.5	24350.4	kg/hr	LP SH FLOW

Figure 7. High speed trending and alarm analysis tools

As indicated in the risk mitigation plan, throughout the course of the project, actions are taken to reduce risk. Each risk area is identified, evaluated and reduced through the use of collaboration, structuring, integrated testing and remote monitoring. *(Figure 9.)* This detailed validation and integration reduces surprises typically found in power plant commissioning and diminishes vendor-to-vendor issues.

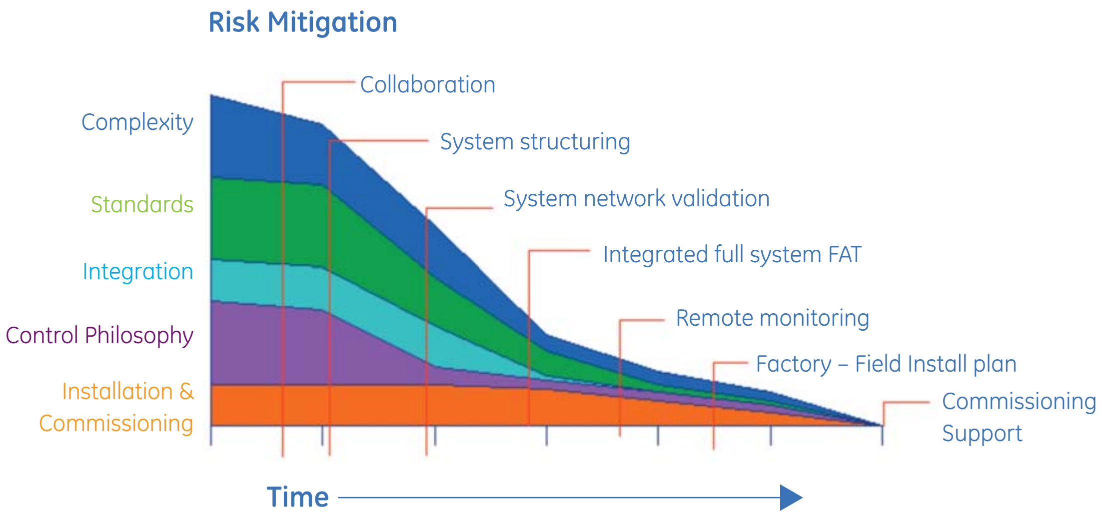


Figure 9. Risk mitigation

III. Operational Phase

Operator productivity and operational awareness are increased through a common interface provided by a single hardware and software platform. This allows the operator (from one single operator station) to access and perform critical operations for all systems of the plant—including BOP, electrical, gas and steam turbines. Problems can be identified more quickly and resolved sooner with all of the process data, alarms and events and trend data in a single time-coherent database that is coupled with advanced system tools. *(Figure 10.)* The single database with time coherent data in an integrated platform contributes to simplified life-cycle maintenance.

While most systems provide the information necessary to operate a plant, the ease of use and the time to identify and resolve issues are critical to proper operation. The common look and feel of operator screens, total plant access and advanced operation tools are enabling technologies for the plant operator. Integrated alarm, diagnostic and sequence of event (SOE) presentation and management contribute to the enabling technologies. The single time-coherent database adds to the richness of data and its associated management.

A single platform control system provides lower life-cycle cost with savings in training, software, hardware and maintenance. The training required is reduced, as the product knowledge needed for the plant control system is the same as for the gas and steam turbine control system. Additionally, the maintenance and operations personnel become more knowledgeable in a single system than in a system requiring separate expertise in two distinct control systems. Both product and application software updates are easier to implement in a single platform versus two different platforms. The unique hardware is reduced in a single common control system requiring less inventory and reducing its associated costs. Plant operations decisions are improved with better quality data in a single unified database. The unified database also allows for shorter mean-time-to-repair with direct access to all diagnostics with high-resolution time tagging.

Advanced Technologies Improving Plant Performance

By incorporating advanced control technologies, plant operation and productivity are improved. Advances in modeling capabilities of gas turbines, steam turbines, and BOP equipment allow for better control within operating envelopes, which increase equipment life, and reduce start-up times and emissions. Model based control (MBC) and advanced algorithms focused

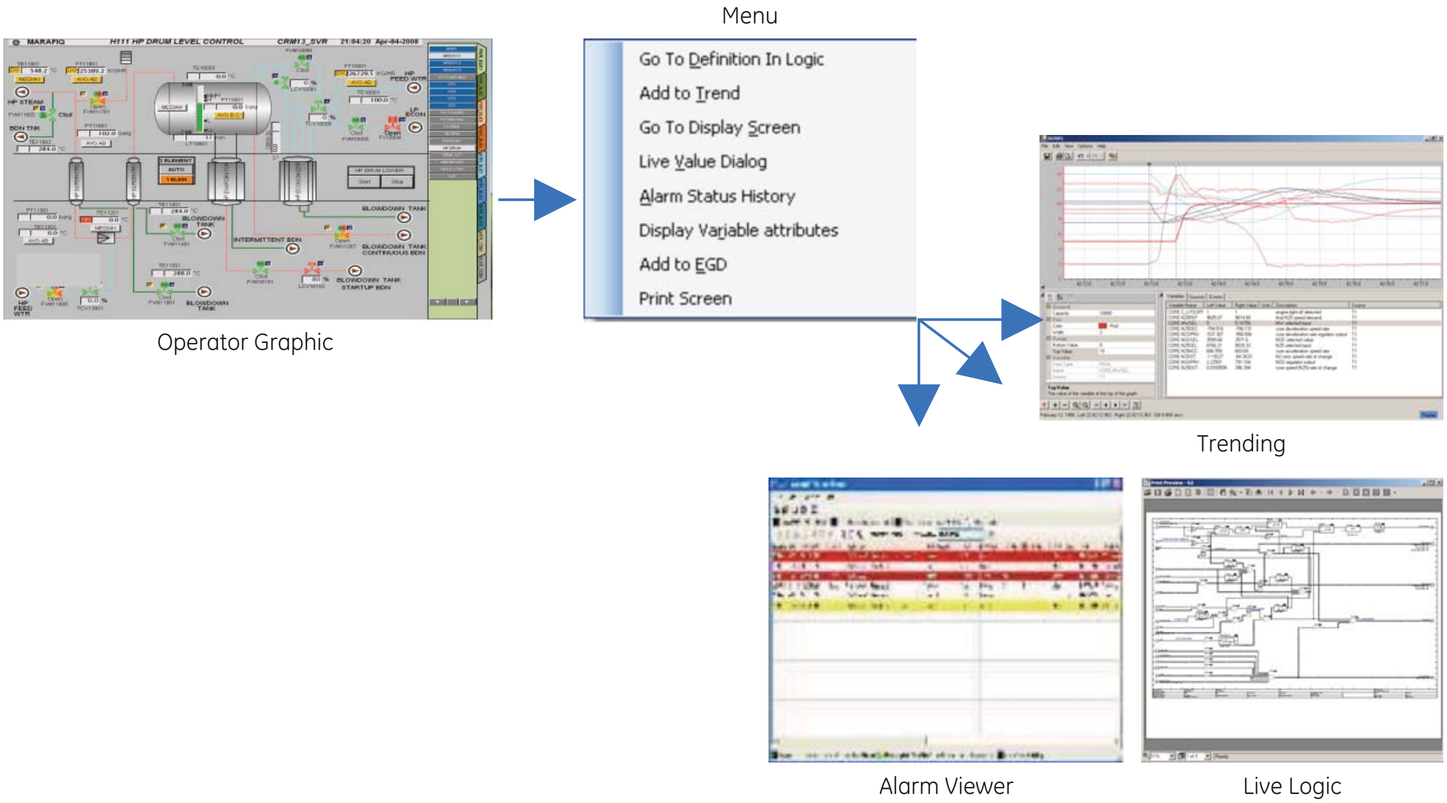


Figure 10. Operator tools

on key plant operating processes offer reduced operating cost and improved plant responsiveness. An example of this is illustrated in *Figure 11*. Using model predictive control coupled with original equipment manufacturer (OEM) equipment design knowledge, the plant can be controlled to start up quicker while maintaining critical stresses within allowable levels. By predicting the future stress levels in the steam turbine during warm-up, the control system can allow the gas turbine to increase load quicker, offering fuel savings and reduced emissions. It also allows the plant to respond more quickly to load demand during start-up.

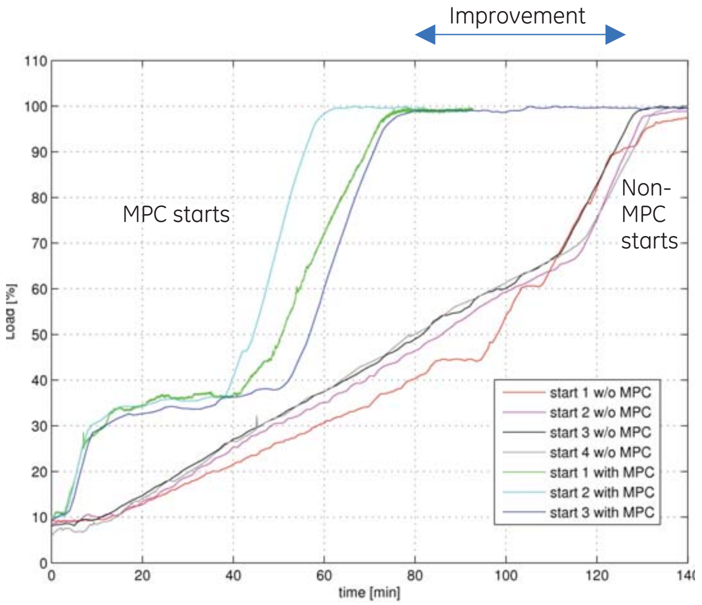


Figure 11. Application of Model Based Controls

IV. Case Study – Lares Site

The Lares Power Plant in Portugal built by Energías de Portugal (EDP), the national electrical producer, is a GE standard plant design. The plant has two, single-shaft, combined-cycle power blocks (2x109FB). The standard plant pre-designed control architecture allowed for updates, incorporating EDP's requirements in terms of hardware and software while also including adding specific third party interfaces for electrical, gas and environmental systems. This project included a control enhancement to the standard plant to incorporate functional groups in the control hierarchy. The structured design allowed for easy adoption of the new hierarchy by adding the functional groups and building the corresponding permissives. Additionally, this option is now a tested feature of the standard plant going forward, which demonstrates how the system can be improved and be incorporated in all future projects.

The Lares project was based on the single power block design of the standard plant design. The remote IO locations were part of the pre-designed architecture and therefore available from the very beginning of the project. This was helpful to Engineering for various reasons; the development of the input/output assignments was able to be done earlier and with less rework, and the wiring and cable routing design was well understood, which led to less engineering and better estimation of installation cost and labor. The schedule required that the IO cabinets ship four months before the software FAT to allow the site to begin cable terminations and verification of the field wiring. Shipping the IO cabinets was easily accomplished while still having full system software FAT.

Operator interface screens were available for customer review early in the engineering cycle. The single control system and database improved report generation for the Lares project. Having all plant-wide data in a single database provided for more robust reports, especially where single reports span across different equipment. Reports were developed without the need for special configuration.

The plant control engineers had implemented knowledge gained from previous projects based on standard plant design, improving the productivity and quality of the project. The standard design validated through previous installations and commissioning made the FAT testing more robust. Factory testing included the gas and steam turbine control and tested the interaction of the plant processes in addition to the standard software validation.

Using set standards helped provide more consistency when the control system reached the site. During commissioning the site engineers will work with logic that has been previously confirmed in field operation, resulting in fewer issues. When an issue is identified the logic is familiar to the engineer because it is similar to other standard plant sites.

Continued evolution for the standard plant includes continual cost comparison of additional remote IO locations and the use of bus technologies. Evolution of the standard plant is continually optimizing the design, as in this case reducing the cabling, erection time, and providing easier hot loop checks and commissioning.

V. Summary

In response to market requirements from the power industry, GE, along with partners, have developed a standard plant design incorporating a single plant-wide GE control system. This structure includes a pre-designed power island, collaborative engineering, structured control libraries and field-proven lessons learned. The end result is a project with a shorter cycle time, reduced project risk, and better cost containment. Operations and engineering receive benefit over the life span of the power plant. By combining GE OEM plant design knowledge, a single plant control system philosophy and advanced controls, GE is also improving plant operability.

List of Figures

*Cimplicity is a trademark of the General Electric Company

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