EMS FOR INTERCONNECTED O&G OFFSHORE FACILITIES
A SUCCESS STORY

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Abstract

As for any complex facilities electrically driven, and running islanded from a reliable Grid utility, Electrical availability is a key factor for processes' profitability and safety.

It is particularly true for an O&G Offshore structure of which Electrical power is ensured by Gas Turbine Generators fueled by local produced gas,

Ensuring this availability with reliability, sustainability and coherence for two interconnected entities having capability to run independently or coupled, managed by 2 different Yards and accordant EPCs, involving more than 450 apparatus and devices from several manufacturers was a challenge that have been achieved.

The intend of this paper is not to present technological insights linked to disruptive technologies' implementation, but the methodology and lessons learned gained during the realization of a large scale and complex O&G project.

Beyond implemented solutions, it reveals how and why, involvement, rigor, organization, pugnacity, consistency and confidence between teams from different organizations, often in competition, kept all along the project's phases from FEED to Commissioning and Start-up have governed the success.

Ichthys EMS is the first milestone of a complete change of the EMS framework which adequately fits with the recent move of O&G's Companies, from O&G Producers toward Energy Providers.

Index Terms

CPF : Central Processing Facility
Floating platform for Gas processes and compression for export to onshore treatment
ECS : Electrical Control System, focusing on electrical distribution and Load Shedding management
EDG : Emergency Diesel Engine Generator,
EMS : Energy Management System, encompassing PMS & ECS functions within the same structure
FPSO:Floating Production Storage & Offloading Facility
Floating vessels for oil processes and storage
GTG : Gas Turbine Generators, main electrical power generation
IED : Intelligent Electronic Devices
ICSS : Integrated Control & Safety System (Centralized Process Control & Safety)
ISMS: Integrated Security Management System
PMS : Power Management System, focusing of Power Generators sets' coordination and power sharing
SCADA: Supervisory Control And Data Acquisition.

I. INTRODUCTION

For any Oil & Gas Offshore facility, the selection of the electrical control system is usually not straight forward. Besides the level of complexity, the size of the power generation and the associated electrical distribution systems, other key factors such as the contractual strategy, the cost, the schedule and the interfaces of the whole project are contributing to the selection of the electrical control system.

Consequently, it is crucial to define accurately the applications within its project environment, at early stage i.e. during Front End Engineering Design and before drafting the contractual documents for the Call For Tender.

The needs and the functionalities of the Electrical Control System shall be assessed through technical and contractual reviews.

Those reviews shall involve discipline leads (Safety, Process, Mechanic, Electrical, Instrument & Control, Telecom & Security), main equipment package leads (power generation, ICSS/SCADA, ISMS) and Field Ops (operating philosophy) to address the matters related to power management and power distribution control system. Typically:

- ✓ The load acceptance and rejection capability of the main power generation, (Electrical and Mechanic);
- ✓ Active and reactive Load sharing control (Electrical and Mechanic)
- ✓ Busbar synchronization, (Electrical)
- ✓ HV neutral earthing management, (Electrical)
- ✓ Source automatic transfer, (Electrical and Field Ops)
- ✓ Load shedding table (Electrical, Safety, Process and Field ops)
- ✓ Parallel operation with the essential and emergency power generation, (Electrical, Mechanic and Field Ops)
- ✓ Waste heat recovery management to minimize fire heater, (Electrical, Process and Field ops)
- ✓ Remote control start/synch/stop of power generation, (Electrical, instrument & control and Field ops)
- ✓ Automatic black-start recovery sequence, (safety, process, mechanic, electrical, instrument & control and Field Ops)
- ✓ Rationalization of event, alarm and fault list, (Electrical, instrument & control and Field Ops)
- ✓ Power quality monitoring and energy performance measurement (Electrical, instrument & control and Field ops)

- ✓ Cybersecurity, (Electrical, instrument & control and Telecom)
- ✓ Interface with other systems, (safety, process, mechanic, electrical, instrument & control and Telecom)
- ✓ Remote access for maintenance, configuration, update, upgrade, (Electrical, instrument & control and Field ops)
- ✓ Future known and unknown development, extension or tie-in.
  In particular power from shore, wind or solar farm connection or energy storage system (safety, process, mechanic, electrical, instrument & control and Telecom)

The outcome will set the scope of supply and allocate the battery limits (if any) with other packages and systems (power generation, ICSS/SCADA, future tie-in power generations).

Once the boundaries of the scope of supply have been clearly identified, the scope of work shall be developed emphasizing the type of interfaces with other systems and/or packages such as communication protocol, preliminary Input/Output list, IP(Internet Protocol) / MAC(Media Access Control) address, functions, pursued by associated testing sequence such as Hardware Interface Validation Test, Factory Acceptance Test (FAT), Integrated Factory Acceptance Test (iFAT).

Contractual documents shall detail and include sufficient technical interface meetings at the different phases of the project execution. Simulator or “dummy” EMS shall be specified allowing communication, configuration and function tests at other equipment package premises.

Project schedule shall implement the appropriate work break down structure in order to achieve each interface milestone prior triggering the shipment of any related package or system to site.

Whatever is its acronym, an automation control structure, here after named EMS standing for Energy Management System, is in charge to coordinate all electrical apparatus, in order to ensure at any time and under any circumstances, the electrical network’s stability of the facility, especially when running in full islanded configuration.

Long considered as secondary, his role of “electrical control” has evolved along the recent past, to an “energy management” function. It is now a key element to guarantee the permanent electrical power balance and stability of islanded plants, considering that a single black out (or total power failure) leads to a production loss of minimum 18 to 24 hours before full process recovery as well as potential environmental and safety implications.

Indeed, the continuous improvement of the Power Plant’s heat rate of the facility, leads to more accurate control functions to mitigate additional risks linked as example to:

- Reduction of available spinning reserve, driven by a constant quest of the best efficiency set point of the on-line power generators,
- Additional processes improving the Power Plant’s efficiency (Steam production for Combined Cycle electrical generation or for treatment processes),
- Addition of a percentage of Renewable Energy to reduce fuel gas consumption while keeping produced power availability – Hybrid Power Plant,
- Reduction of greenhouse gas and other emissions

Therefore, the EMS concept is born, to provide electrical availability in line with the overall optimization of energy costs and efficiencies. It is based on maximizing integration of former segregated Electrical Control System (dealing with power distribution & load shedding) AND Power Management System (dealing with power generation sets synchronization & load sharing).

However, even if this integrated concept answers to new technical constraints, it is a change in projects’ management approach & realization rules as EMS comprises Power Generation and Power Distribution. Therefore, having a common system compared to usual segregated packages from different worldwide vendors is a new paradigm to be taken into account by End User and EPCs in charge of the project execution, especially when some packages are managed as LLI (Long Lead Item) while the others are not.

In order to illustrate how this new paradigm has been addressed on a large-scale project and associated issues solved, we will take as example, the full hot redundant EMS done for ICHTHYS FPSO and CPF, for INPEX, located in Offshore Australia.

The base case was 2 Offshore facilities fitted with independent power generation and distribution, modeled on a typical marine/Offshore arrangement:

Respectively:

- ✓ 4 Gas Turbine Generators (n+1 configuration, rated at 25MW ISO / 11kV) feeding the normal load;
- ✓ 2 diesel engine generators (rated at 4MW/11kV) feeding the essential load;
- ✓ 1 diesel engine generator (rated at 1MW/690V) feeding the emergency load.

During the course of the FEED phase, an exercise of optimization has been conducted to find a means of uniting both power generations.

Increasing the power generation efficiency and reducing the overall emission of carbon and nitrogen oxide as well as providing a higher reliability and availability rates of the electrical power supply

The selected scheme was to interconnect both facilities via an umbilical composed of fibre optic cables (to facilitate an united EMS control) and power cables (rated at 25MW/33kV equivalent to the power rating of one gas turbine generator).

Leading to a twofold benefit, the power umbilical acting as a virtual Gas Turbine Generator as well as an essential source for either facility.

The arrangement of the power generation for each facility turned into:

Respectively:

- ✓ 3 Gas Turbine Generators (rated at 25MW ISO / 11kV, the n+1 configuration provided by the power umbilical) feeding the normal load;
- ✓ The power umbilical feeding the essential load;
- ✓ 2 diesel engine generators (rated at 2MW/690V) feeding the emergency load.

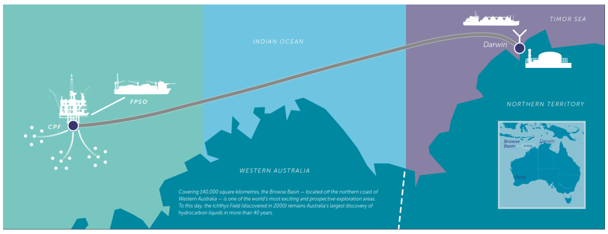
II. PROJECT'S OVERALL CRITERIONS

This section will cover the 3 main aspects of the project, as Operational Offshore facilities presentation, EMS key requirements and Realization structure organization.

A. ICHTHYS Operational presentation

Ichthys LNG is four mega-development projects rolled into one, from subsea wells, through two of the world's largest offshore facilities located approximatively 220 km off the western coast of Australia, linked by a 890 km long subsea gas export pipeline, to onshore LNG processing facilities near Darwin (Northern Territory).

It is expected to produce 8.9 million tons of liquefied natural gas (LNG) and 1.6 million tons of liquefied petroleum gas (LPG) per annum, along with more than 100,000 barrels of condensate per day at peak.



1) Central processing facility - CPF

The CPF is the world's largest column-stabilized offshore semi-submersible production unit. Docked in 250 m of water, it consists of a hull (110 x 110 m) carrying topsides (130 x 120m) as well as living quarters for 200 people. On the CPF, gas is treated, compressed then exported via a gas export pipeline to the onshore liquefaction plant. Two condensate rich MEG (CRM) umbilicals transfer a mixture of liquids from the CPF to the FPSO. This mixture consists of most of the condensates mixed with MEG (Monoethylene Glycol) and water. The remaining condensate is sent to shore through the gas export pipeline.

2) Floating production, storage and offloading facility

Permanently moored on a non-disconnectable turret about 3.5 km from the CPF, the FPSO is 336 m long and 59 m wide and accommodate a workforce of up to 200 people. It is linked to the CPF by subsea umbilicals. It is designed to produced up to 85,000 barrels of condensate per day, to store more than a million barrels and to load the condensate onto tankers at sea. The FPSO also regenerates the MEG, which is injected back into the wellheads to prevent the formation of hydrates and to treat the production water before it is discharged into sea in accordance with Australian Environmental Protection Authority regulations.

3) Electrical Power characteristics
   - FPSO: 3 x GTG 25 MW @ 33°C / 11 kV
   - CFP: 3 x GTG 25 MW @ 33°C / 11 kV
   - Interconnecting link rated 25 MW
   - 19 Electrical rooms (11 x FPSO / 8 x CPF)

B. EMS key requirements

Synthetically, the key requirements were:

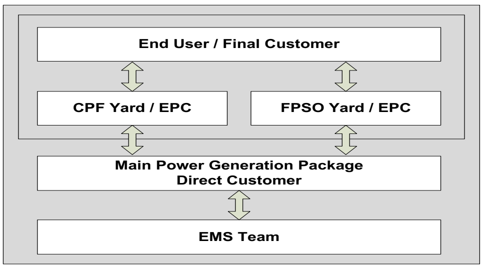
- Electrical network stability & Power sharing,
- Overall energy supervision & Data logging,
- Capability of CPF and FPSO facilities to run independently or as 1 coherent entity.
- When running as 1 entity:
  - Power exchange between CPF & FPSO via subsea interconnector,
  - Maximizing the power produced by FPSO's GTGs to optimize the FPSO's WHRU efficiency,
- Full hot redundant EMS architecture & communication network, keeping process' performance whatever the configuration,
- Marine Class Certifying Authority certification for hardware & software,
- Reinforced Cyber security.

C. EMS Realization structure organization

As for any complex and large-scale projects, numerous companies were simultaneously involved during its realization.

EMS being part of the two facilities, the EMS team was involved with the execution teams:

- The End Users,
- CPF Engineering Procurement Construction & Commissioning Contractors,
- FPSO Engineering Procurement Construction & Commissioning Contractors,
- Power Generation sets' manufacturer,
- Subcontractors / Vendors in charge of the 450 electrical apparatus managed by / linked to the EMS, and mainly composed of:
  - Gas Turbines & Generators,
  - HV and LV switchgears,
  - On Load Tap Changer,
  - Uninterruptible Power Supply,
  - ICSS,
  - Emergency Diesel Generators,
  - Waste Heat Recovery Unit,



EMS Project Organization chart

III. EMS CHARACTERISTICS & FUNCTIONS

A. *EMS key objectives*

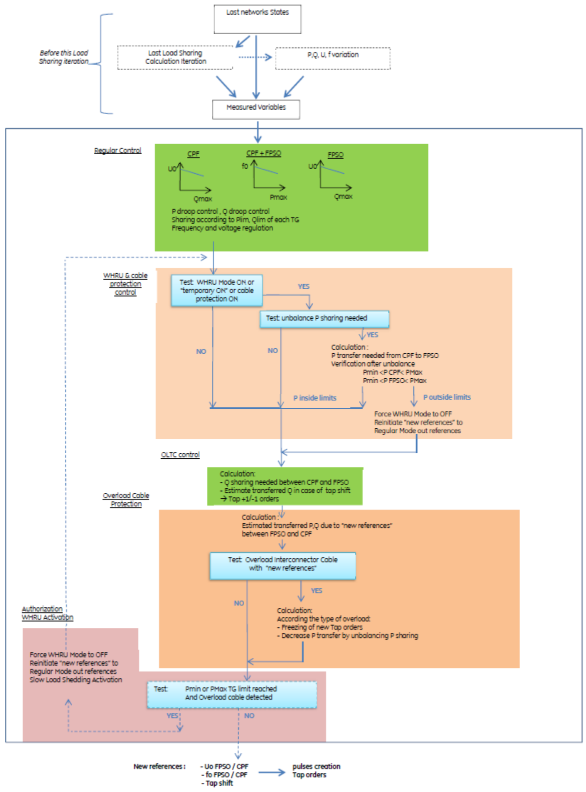
The main objectives of the EMS are:

1) Availability of the FPSO & CPF power supply and distribution network, by means of automatic Frequency & Voltage regulation (Load Shedding, Load Sharing...)
2) Centralizing, displaying and recording the alarms and events of the whole electrical network, for analysis by electrical maintenance operators after the occurrence of a fault,
3) Supervising and remotely controlling the equipment of the power supply network, from EMS Operator workstations,
4) Communicating with the Integrated Control & Safety System (ICSS), feeding it with general information on the electrical network and generators status; as well as specific control (Process loads starting authorization),
5) Configuring online and remotely, the load shedding steps
6) Live bus bar Synchronizing, local 11kV and 33kV/11kV Power Interconnector,
7) Either in “Islanded mode” (CPF & FPSO independently) or in “Interconnected mode” (overall CPF & FPSO considered as one entity among which the electrical energy is shared)

B. *EMS Main Functions*

To reach above objectives, the EMS ensures:

1) Main Generators individual Management,
   - Start / Stop / Coupling requests orders,
   - Load Sharing, by Speed & Voltage adjustment setpoints,
   - Unload / Disconnect / Stop requests orders,
   - WHRU (Waste Heat Recovery Unit) control,
   - OLTC (On Load Tap Changer) control,
2) Emergency Diesel Generators supervision and individual Start / Coupling / Return to normal & Stop request orders,
3) Dynamic Load Shedding,
4) Manual Source Transfer initiating; Functions of Automatic & Manual source transfer being directly managed by dedicated switchgears’ devices
5) Neutral earthing resistor management
6) CPF & FPSO GTGs’ synchronizing, to allow local 11.5 kV & interconnection Busties closing (Manual / Automatic)
7) CPF-FPSO Power interconnection control,
8) Monitoring and Control of the Electrical Equipment (fault discrimination with 5ms accuracy)
9) Large load start authorization.
   Even if loads start / stop decisions are ensured by the ICSS as per Process’ needs, the EMS authorizes / inhibits the starting of large loads, depending on the GTGs’ Active & Reactive power reserve vs the loads’ Active & Reactive power demand.

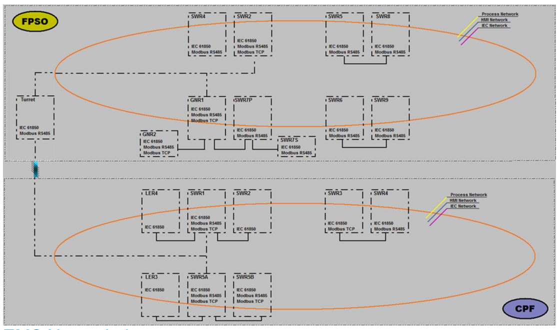

EMS Typical Logic Diagram for Power Management and Load Control

C. *EMS Main Characteristics*

1) Data base: 12000 I/Os,
   - 4 500 wired I/Os
   - 7 500 Serials
2) From 900 electrical equipment, including 400 devices by smart communication (Modbus TCP/RS, IEC61850 [1], Open Platform Communications)
3) 20 supervisor workstations including 2 servers in redundant configuration
4) 22 EMS cabinets located in electrical substations embedding PMS and PDCS management system including local supervision,
5) 26 hot redundant EMS active devices (Controllers, gateways Remote Gateways and Remote IO concentrators)
6) GPS time acquisition and distribution system for time synchronizing of EMS equipment and Ethernet connected smart devices (Protection relays) through Network Time Protocol,
7) Marine Class Certifying Authority certification for hardware and Software.

D. EMS Structure

1) Three-level automation architecture
   - L2: Supervision, Alarm recording & Archiving,
   - L1: Automation functions & Data server for supervision,
   - L0: Data acquisition & event data server for supervision.
2) All active devices in full hot redundancy, under Real Time Operating System,
3) Interconnected by Optical Fiber ring Networks to link all CPF & FPSO's electrical & control rooms.



EMS Network ring structure

IV. MAIN REALIZATION CHALLENGES AND SUCCESS APPROACH

Even if an EMS is not an "off the shelf" product but a System, it is based on a structured & field proven architecture embedding experienced functions, to be customized to act as an "Anti-Black-Out" system of a dedicated facility.

Therefore, the present section will not cover all above expressed architecture & functions' details but will focus on the ones for which collaborative approach & deep involvement from each party were key to turn out successfully each phase of the project, leading to an overall success.

A. EMS Data Base / Operational Functions Equipment List – Equipment Type – Functional entities Document

To allow the EMS to match with its automation control and supervision objectives, a clear definition and count of exchanged data including the associated functions with the "electrical world" of the facility are fundamental.

The first action was to issue a credible and representative list of devices / equipment to be connected to the EMS, considering that too many data affects speed and reaction time whereas not enough data affects accuracy:

1) Undersized list: Risks of unreachable functionalities by a lack of data,
2) Oversized list: Risks of Operators' disturbance (over complexity), un-affordable costs and increase of cabinets' footprint impacting electrical room layouts,

It was crucial, considering that both interconnected facilities were manufactured by:

1) Two different yards & EPCs, each with their own realization rules & experience,
2) Switchgear manufacturer also sub-segregated by 4 teams [(HV & LV) x (CPF & FPSO)],
3) EMS team was interfaced to above electrical teams through our BHGE mechanical colleagues of the power generation package, also segregated by 2 teams CPF & FPSO.
4) Numerous sub-sub providers, as for Thrusters, UPS, Emergency Diesel Engine Generator…

This was solved by:

a) A close collaboration and regular face to face meetings with Client and Vendor representatives, held all along the project, from FEED phase to Startup, allowing:
   - Mutual pooling of expertise & experience,
   - Clear definition of End User's expectations,
   - Never questioning of past decisions,

b) Co-location of teams during the FEED phase allowing CPF – FPSO coherence,

c) Co-location of EMS core teams, for both CPF and FPSO, kept all along the project, from FEED phase to Startup,

d) Accurate and mutually agreed definition during the FEED phase, of all key EMS principles, functions, Data base, interfacing, based on:
   - Deep analysis of INPEX FEED's document, as mainly, CPF and FPSO:
     - EMS specifications,
     - Main Power System Generation & distribution philosophy,
     - Load Shedding philosophy,
     - Electrical Loads Schedules,
     - Single Line Diagrams,
     - …
   - Ranking of each data as per their processes' importance,
   - To reach an agreed "90%" EMS data base and accordant functions, composed by:
     - CPF and FPSO <u>Equipment List</u>, focusing on the 900 main devices to be considered,
     - Accordant approved <u>Equipment type,</u> describing the matter to characterize each similar equipment, by a standardized:
       - IO type and number,
       - Acquisition and Control principle (Hard / Serial)
       - HMI representation,
     - IO List, consolidation of IO list with equipment's details provided by the Equipment type.

e) Relocation since the beginning of commissioning phase, of the Head of the EMS engineering team, close to the CPF & FPSO yards in Korea.
This has been key to ensure and check the coherence between initial decisions and results & adequacy with facilities' real needs.

f) Continuous data cross-checking between EMS team and all the electrical systems involved, through meetings and document's centralization, ensuring that any modification to the Data Base and/or associated functions were captured and updated in due time:
   - EMS cabinets advancement status, with CPF / FPSO manufacturing constraints, to allow cabinets installation within electrical rooms,
   - CPF & FPSO EMS Homogeneity for similar devices, "BD, HMI, Functions" despite "one side" philosophical evolutions,

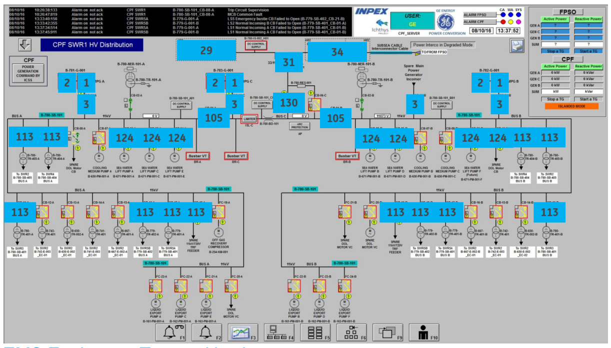
At the beginning of the execution phase, it was known that "agreed 90%" was not realistic to be kept all along the realization, but has been used as common guide line to guarantee consistency beyond EPCs, Yards, Switchgears and Packages suppliers (GTG, EDG, UPS…)

As result, the project successfully kept this homogeneity for the main devices by limiting the number of different Equipment Types from CPF vs FPSO, and limiting the differences when not kept:

Switchboard / System	Item number	Item Description		Items quantity CPF
	1	11kV Generator Control Panel		3
	2	11kV Gas Turbine Control Panel		3
	10	11kV Fault current limiter		1
	14	Bus Riser for Is-Limiter		1
	29	11kV/33kV Interconnector Transformer NER Feeder (CPF)		1
	31	11kV/33kV Transformer AVR OLTC		1
	34	11kV/33kV Transformer Power Circuit Breaker (33kV)		1
	40	690V Incomer		10
	43	LV bus coupler		4
	45	690V Switchboard Interconnector Feeder		11
	47	690V UPS Main Supply Feeder		28
	48	690V UPS Bypass Feeder		10
	50	400V Incomer		6
	51	LV Transformer Outgoing Feeder (ACB Feeder Type)		6
	55	690V Incomer 1 to GSP Aux SWB		3
CPF & FPSO	56	690V Incomer 2 to GSP Aux SWB		3
	60	690V EDG Unit Control Panel (CPF)		2
	67	690V Main Emergency Incomer		4
	70	400V/230V Small Power & Lighting Distribution Board Feeder		132
	71	230V Small Power & Lighting Distribution Board		57
	72	400V Emergency Power Distribution Board		33
	76	110VDC/24VDC Battery Charger (HV/LV SWBD)		14
	77	AC UPS		8
	79	Navigational Aids AC UPS		2
	80	UPS Sub-Distribution Board		25
	83	DC UPS Switchboard Control Supply		34
	86	690V Main emergency switchboard bus-tie		2
	89	690V Bus-tie		3
	90	400V Bus-tie		2
	100	690V incomers to heater/thyristor panels		7
	103	11kV Gas Turbine Generator Incomer		4
CPF	105	11kV Bus Tie		2
	106	11kV Bus VTs and ES		1
	112	11kV Bus VTs		2
	113	11kV/720V Transformer Feeder		12
	115	11kV Earthing Transformer Feeder		2
	118	11kV/720V Captive Transformer Feeder for process heater		7
	120	11kV Package P2 type / HV Motor ≤ 1000kW		6
	121	11kV Package P2 type / HV Motor > 1000kW		4
	122	11kV Package P3 type / HV Motor ≤ 1000kW		4
	124	11kV Sea water lift pump		7
	130	11kV/33kV Transformer Incomer/Feeder		1
	133	11kV Pre-Insertion Resistor Feeder		1
	162	690V EDG Incomer		3
	163	690V Bustie A/B (between both EDG)		1
	177	AC UPS (Helideck Lighting)		2
	187	LV Emergency Bus-tie/Interconnector		2
	188	LV Bus-tie/Interconnector		1

EMS Equipment Types' Definition & List

Operators' satisfaction and Maintenance team feedback are the key homogeneity and coherence KPIs as the EMS is a central point for the 2 facilities even if engineered by segregated teams.



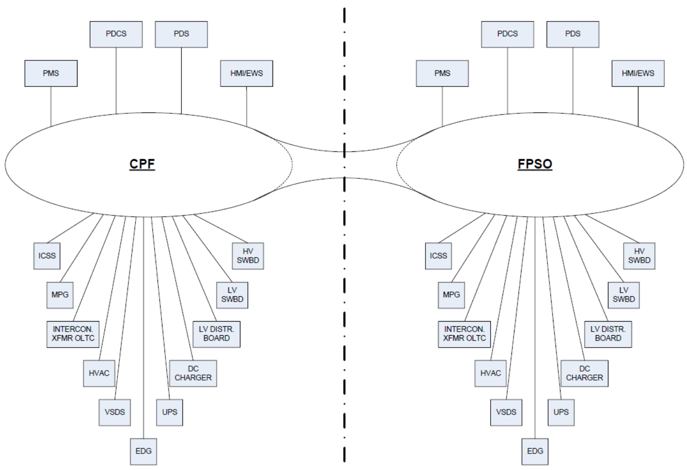
EMS Equipment Type unitization

B. EMS IO Interfacing - Coordination

Considering that an average of 60 % of the Data base is issued from 400 external devices, a high integrity of the communication networks is the backbone of the EMS, and key for efficiency and sustainability.

Coordination with equipment suppliers was done by issuing, consolidating and centralizing interfacing document, to be discussed with all involved parties, until reaching agreement by:

a) Interconnecting Lists definition: List of the external wiring and network connection with EMS cabinets,
b) Acquisition / Control principle, hardwired versus Serial link depending on data's criticalities,
c) Establishing communication protocols between EMS and interfaced devices respecting devices' capabilities (HV relays by IEC 61850 [1], GTG UCP by Modbus TCP, UPS UCP by Modbus RS…)
d) IP Address document: List of IP addresses of EMS system and interfaced Ethernet devices' Class addresses,
e) Updating above document until startup phase – As built document version.,



EMS Interfacing structure

C. EMS IO Interfacing – Communication Network Structure

The EMS efficiency, meaning its capability to ensure key functions to avoid blackout risks & Gen sets power sharing, is directly linked to the guarantee of its reaction time.

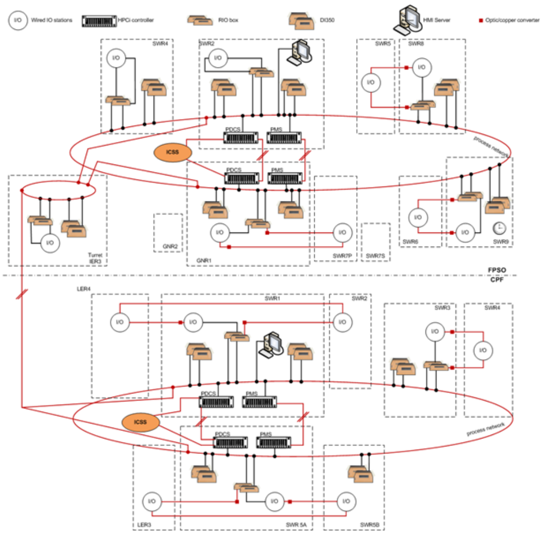
Considering the number of devices simultaneously in communications, not all mastered by EMS, and not all dedicated to EMS functions (as the IEC 61850 GOOSE messages [1] between some Protection Relays), Independence of Data Flux is key success factor to avoid networks' saturation risks.

This segregation is ensured by using six dedicated Ethernet mono-mode optical ring Networks to link all CPF & FPSO's electrical & control rooms (FPSO x3, CPF x 3) while limiting maintenance complexity.

a) EMS Process Networks

Dedicated to level 1 (Processes), these rings are used for Ethernet communications between Process' main real time controllers, RIO concentrators and Gateways.

MRP (Main Ring Protocol) is used for the rings.

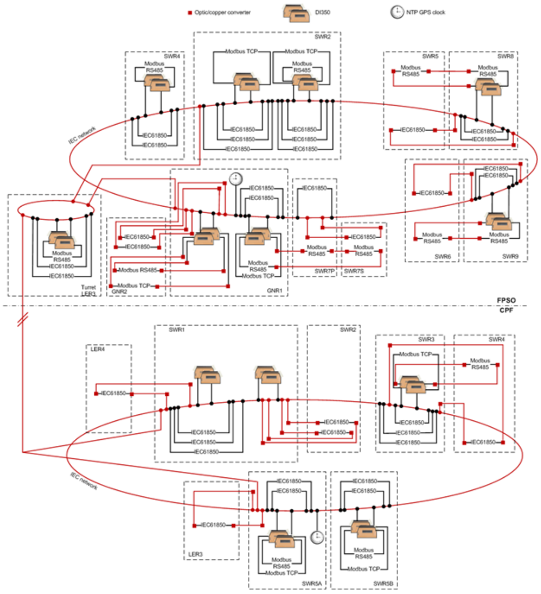


EMS Process network structure

b) IED communication Networks

Dedicated to level 0, these rings are used for Ethernet communications between IEC 61850 devices [1] (protection relays…) & EMS gateway and between IEC 61850 devices [1] & accordant configuration tools.

MRP is used for the main ring, completed by RSTP (Rapid Spanning Tree Protocol) within the sub chains between relays organized as "Daisy Chain".

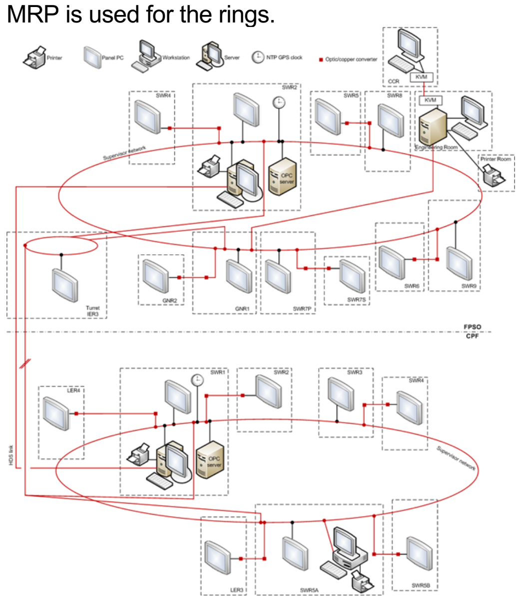


EMS Data acquisition network structure

c) EMS Supervision Networks

Dedicated to level 2, these rings are used for Ethernet communications between HMI servers PCs, client workstation PCs and panel PCs.

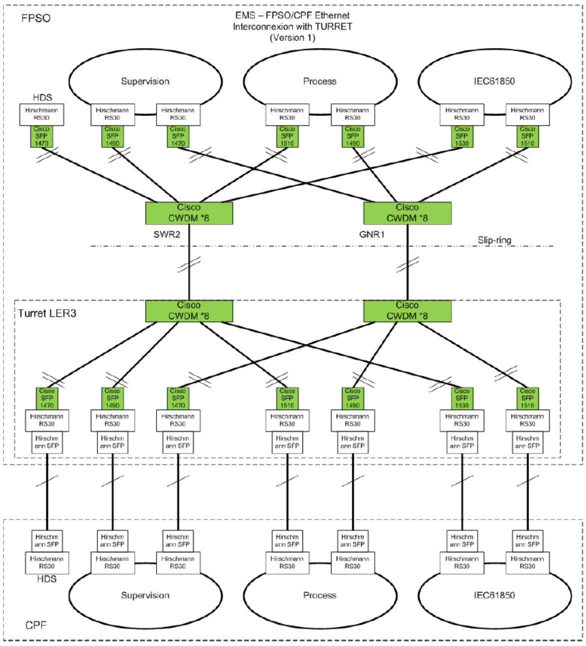
MRP is used for the rings.



EMS Supervision network structure

d) Rings Coupling

Rings' coupling between CPF and FPSO are done through the turret slipring of which the number of available optical fiber cores are limited. A Multiplexer / Demultiplexer device is used to enable the transmission of up to 8 Ethernet link over one single-Mode fiber strand.



EMS Ring coupling FPSO - CPF network structure

Demonstration of above structure efficiency has been assessed during commissioning phase when the interconnection between CPF & FPSO, has been established. 2 HV protection relays (1 on CPF and 1 on FPSO) with the same MAC @ have communicated through GOOSE messages triggering protection and unexpected trip on the opposite facility.

D. EMS IO Interfacing – IEC 61850 Interfacing [1]

Using IEC 61850 protocol [1] provides key communications' improvements between Intelligent Electronic Devices (IED) operating in electrical substations, in terms of interoperability & sustainability & capex reduction.

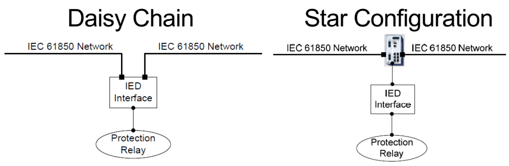
However, huge attention must be paid to avoid jeopardizing of IED's network functioning by saturation.

It is true for configuration risks (as above example and particularly with spare parts), but also during exploitation when IOs' state change occurs.

Indeed, thanks to digitalization progress, IEDs have huge capabilities to also provide additional contextual data (time stamping, status of associated IOs, measurements, etc.), which can unexpectedly multiply network's load at each process' data state change if not correctly managed. All capabilities and IED's available data are described within IED's ICD (IED Capability Description)

Therefore, to consolidate and ensuring the coherence of IEC 61850 communications [1] while keeping IEC 61850 [1] network's availability despite the numerous devices, ranges, manufacturers…, we established a dedicated document describing the basic configuration capabilities that each IED must have, and the philosophy that have been applied during project execution :

a) Daisy chain connection capability as preferred, with star connection as fallback, for media redundancy purpose,



b) Availability in Device's "Public Area" of Logical nodes & Datasets configuration in accordance with EMS database, for accordance with operating philosophy & service life purposes,

c) Multi "consumers" capability, to communicate with two EMS Gateways for Control redundancy purpose.
It means capability to integrate each Dataset into 2 separated Report Control Block (RCB), each controlling the exchanges with the 2 EMS devices of the redundant Gateway.

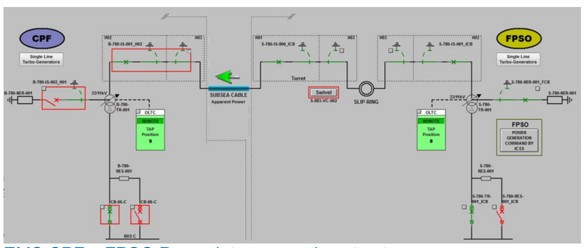
d) Capability of IEDs to be time synchronized by EMS time servers (GPS clock) through SNTP (Simple Network Time Protocol), for time stamping accuracy purpose,

e) Assignment by EMS team of main network parameters, as IED name, Ethernet IP address & subnet mask,

f) Assignment by EMS team of CID (Configured IED Description) configuration rules, including the customization of DataSet in order to limit the exchanged data to those declared in the EMS I/O schedule.

E. CPF-FPSO 11kV/33kV Power interconnection

Each facility's 11kV switchboard are interconnected by the 11/33kV Power Interconnector subsea cable, through a dedicated 11kV/33kV transformer including an OLTC device (On Load Tape Changer) on the 33kV side.



EMS CPF – FPSO Power interconnection structure

For Interconnection purpose, EMS ensures following functions:

a) Open/close control and supervision of the CPF-FPSO 11/33kV Power Interconnector distribution devices (Manual / Automatic), including synchronization of live bus bar.

b) The 4x 11kV CB (2 in CPF + 2 in FPSO) and the 3x 33kV CB (1 in CPF + 2 in FPSO)

c) NER (Neutral Earthing Resistor) CB Control, Automatic by EMS / Manual, on CPF or FPSO side

d) OLTC (On Load Tap Changer) control, to ensure the best Reactive Power sharing between facilities regarding WHRU set-point and 33kV cable maximum power.

e) “Black start” function to allow re-energizing of one facility since local black-out (CPF or FPSO) by the other remaining safe. This function has been required by Marine Class Certifying Authority to mitigate a potential failure of the local Emergency Diesel Generator and associated emergency switchboard.

Not particularly technically complex, the main difficulties to be solved during their realization, were linked to :

a) The impossibility of real testing during the commissioning & Site Acceptance Tests on the fabrication yards, as the 2 facilities were erected on separate locations.
b) The segregation by dedicated teams (1 for CPF and 1 for FPSO), with the EMS as only common node (for electrical energy purpose)
c) Late Black start function’s requests during Offshore commissioning execution, meaning far from EMS development facility and to be done by tight schedule while keeping EMS sustainability.

Once again, factors leading to “Plug and Play” interconnecting success for EMS purposes, were due to:

a) Close collaboration between involved teams (Power Generation package, Yards teams, main Switchgear providers and EMS teams, on behalf of Client representatives,
b) High degree of testing, including on simulation tools, from FAT done in EMS facility in France, until the 2 Yards’ SAT.
c) Collaborative approach and confidence between involved teams for Black start definition & realization & testing.

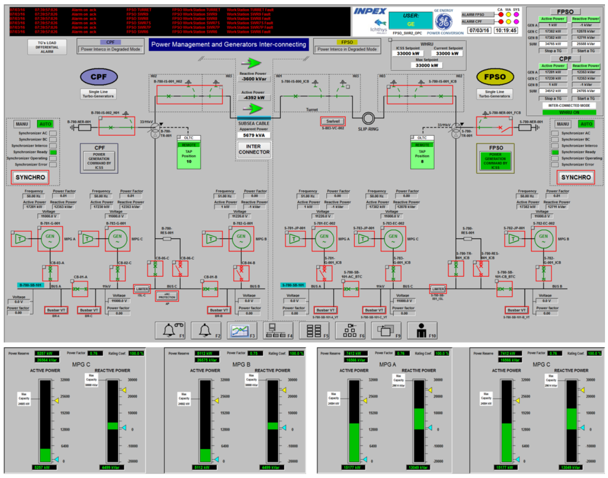
F. *Waste Heat Recovery Unit (WHRU) control*

The purpose is to minimize the use of the fire heaters by recovering maximum waste heat generated by the FPSO MPG’s (combined cycle). To achieve the best efficiency WHRU/Fire heaters, the FPSO GTG shall be loaded as much as possible without impairing the integrity of the FPSO/CPF power generation

WHRU control, is part of Load Sharing functions. It modifies the regular Active Power sharing to drive the FPSO Power Generation to a dedicated active power set-point sent by ICSS.

Hence, WHRU control will unbalance the active power sharing, to increase the active power supply by the FPSO and to decrease proportionally the active power supplied by the CPF.

WHRU control is then in charge to maintain the level of FPSO active power equal or above the ICSS set-point (depends on global power consumption) while checking to not reach the minimum load off CPF Gas Turbine Generators and to not reach the overload limits of the 11kV/33kV subsea interconnection cable.



EMS Power Sharing control view

G. *Cyber Security*

Cyber Security is probably one of the main challenges to be addressed in the coming years, to guarantee the availability, safety, integrity and productivity of industrial facilities.

Even though Cyber-attacks are long story against IT infrastructure (Information Technology), they are fairly new and few against OT infrastructure (Operation Technology), with first SCADA attack in 2010 (Stuxnet), 2015 (Black Energy) …

However, they quickly evolved from basic interference with the HMI via the Graphical OS, to serious disturbance via the process and /or the safety PLC like in 2017 (Triton).

Therefore, huge attention must be paid to secure our OT architecture facing our uncertain world, especially for safety purpose.

Indeed, even though the EMS is not a safety critical element of the facility, being the focal interface point with electrical protection devices and power generation systems, it is a key contributor to the reliability of the electrical power generation and distribution.

Consequently, securing data exchanges concurs to the safety and availability of the components constituting the OT infrastructure.

As mentioned, it is fairly new, and well-known tools and rules focusing on IT security cannot directly apply to OT, because objectives and priorities are not the same, exploitation and maintenance teams are different. Even though main HMI are using the same Graphical OS for both OT & IT, the difference resides in the version, IT operates with the latest version while OT operates with the “FAT” version (except for security patch).

IEC 62443 [2] defines Risk as combination of Threats x Vulnerability x Consequences. Feared events and potential impacts for IT and OT are different whatever the cause (intentional or not), therefore risk analysis shall be used to define appropriate cyber protection (Security Level Target / Tolerable risk / Mitigation Plan).

Even if the 3 basis objectives are common,

a) Their precedence is in opposite order:

- IT: Confidentiality / Integrity / Availability,
- OT: Availability / Integrity / Confidentiality,

b) A fourth key objective, which doesn't exist for IT, has to be added to the first priority for OT, as a complement to Availability: Safety.

Together, they guarantee that crucial EMS functions of Load Balancing:
- Will be **Ensured** = Availability
- In **Due Time** (Deterministic) = Safety.

Even though the Ichthys EMS realization started before the latest cyber-attacks, the Information Security have been addressed by permanently keeping in mind these 4 key aspects, including the Maintainability as part of the Availability.

Indeed, it would have no sense to "over-secure" the architecture, if the EMS became non-operational at the first device or interfacing failure, especially with 400 devices in communication.

In other words, high availability is a paramount attribute and secured design is a permanent balance between performance and security, including fallback mechanism like degraded mode.

In close collaboration with Client inspectors in charge of Cyber security until validation, added to our Power Conversion's rules for the purpose, Cyber aspects were addressed by:

a) EMS devices location
To ensure physical security, thus to mitigate unauthorized access, all operators' HMI & Servers and all EMS devices are installed:
- In secure, accessible only by authorized users locations. i.e. Electrical Rooms and Central Control Room,
- Housed within EMS key lockable cabinets, including the electrical rooms local HMI which are panel door mounted.

b) EMS main active devices (Process Controllers, Gateway, Remote IO Concentrators):
- All running under Real time Operating System,
- Managed as per rules for cyber security,

c) Segregated communication networks

As explained in section 4-C – The communication structure is composed of 3 main segregated networks, completed by sub-networks generating physical network segmentation, which provides high availability as well as safety.

d) Graphical Operating System for HMI (Human Machine Interface)

- All provided PC are featuring Antivirus software,
- During EMS HMI PCs boot and HMI application loading sequences, the Graphical Operating System are not accessible to any operator
- After the PC boot sequence and during HMI application normal operation, only duly "high access level" authorized operator can access to the Graphical Operating System,
- All the EMS HMI PC external mass storage devices including CD/DVD reader/writer and USB ports are disabled (Auto-play mode disable).
- All EMS PCs are equipped with an automatic log-off session in a time delay of 15 minutes when no operator action is detected (mouse nor keyboard)
- …

V. OPEN-ENDING TO THE FUTURE

As introduced, the paradigm of O&G companies is changing from O&G producers to Energy providers. It essentially means for EMS to actively participate to the transformation of End Users' operating model by allowing seamless:

a) Fossil fuel Power Generation's heat rate optimization by loading power generators to their best efficiency point and in parallel providing a substitute such as renewable energy and/or energy storage capacity offering sufficient spinning reserve in event of fossil fuel power generator failure. Resulting to lower the emission of carbon and nitrogen oxides without jeopardizing operating availability and reliability of the power plant

b) Interfacing with Digital Assets Performance tools, to provide risk identification before failure and remote diagnosis, to achieve significant gain in operational efficiency, (Periodic maintenance - inspection program and local maintenance team optimization…)

c) Power import/export from/to local Utility Grid when cost effective, allowing a win-win benefit, Companies' additional revenues by selling electrical energy in excess, as well as Utilities' capex reduction (Energy Peak period management…)

d) All above complementary functions and interfaces will have to be implemented taking into account the Cyber-Security constraints and challenges ensuring devices' interoperability in a safe and efficient operational context.

Obviously, Ichthys EMS doesn't fit all new above purposes yet, but its realization approach & philosophy pave the way for, reason why its completion can be considered as the first milestone of the future Energy Management.

VI. CONCLUSIONS

The Electrical automation management system, whatever is its acronym (ECS, PMS, EMS, ENMCS…), is no longer to be considered simply as an Operator's help, but as an active, influential and key system, for smooth and economical electrical availability and reliability, especially in the new O&G paradigm.

Therefore, this evolution implies a change in automation approach, to realize the benefits of new system capabilities, in terms of performance, redundancy, cyber security, sustainability, interfacing, etc.

This requires:

a) Teams' close collaboration beyond the Companies, merging and sharing knowledges and solutions for mutual business benefits and End Users' satisfaction, thus overall growth,

b) Independence from proprietary platforms for sustainability, including the total cost of ownership,

c) Independence from "One-sided" package solutions:
   - Neither Power Generation, of which electrical power supply is the core business,
   - Nor Power Distribution, of which electrical power distribution, control and protection is the core business,

d) Independence from the Process Control system, of which process instrumentation, control and safety is the main purpose,

Regardless the efforts of Engineering teams, money spent and the intrinsic qualities & performance of above-mentioned systems:

A formula 1 car will never win a rally race in the desert and a rally car will never win the Formula 1 cup;

It is not a question of devices' performance, but a question of accordance between the needs and solutions.
The project EMS realization pro-actively embeds this paradigm changes, reason why it is a success story of Peoples and Companies doing the right things to deliver a purpose driven solution.

VII. REFERENCES

[1] IEC 61850 International Electrotechnical Commission – Communication networks and systems for power utility automation Standard.

[2] IEC 62443 International Electrotechnical Commission – Industrial communication networks - IT security for networks and systems

VIII. VITA

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He started his activity in the Automation Team and moved in 1994 to management position of Automation Maintenance Team for Services activity.
Focused on the reliability and the safety of Automation architecture, he moved to Oil & Gas Department in 2006 in which he was involved with R&D and Engineering teams, in the design and development of the new Electrical Energy Management Architecture for Oil & Gas facilities, later extended to Power for any off-grid facilities energized by heterogeneous fossil & renewable sources, and Water activities.
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