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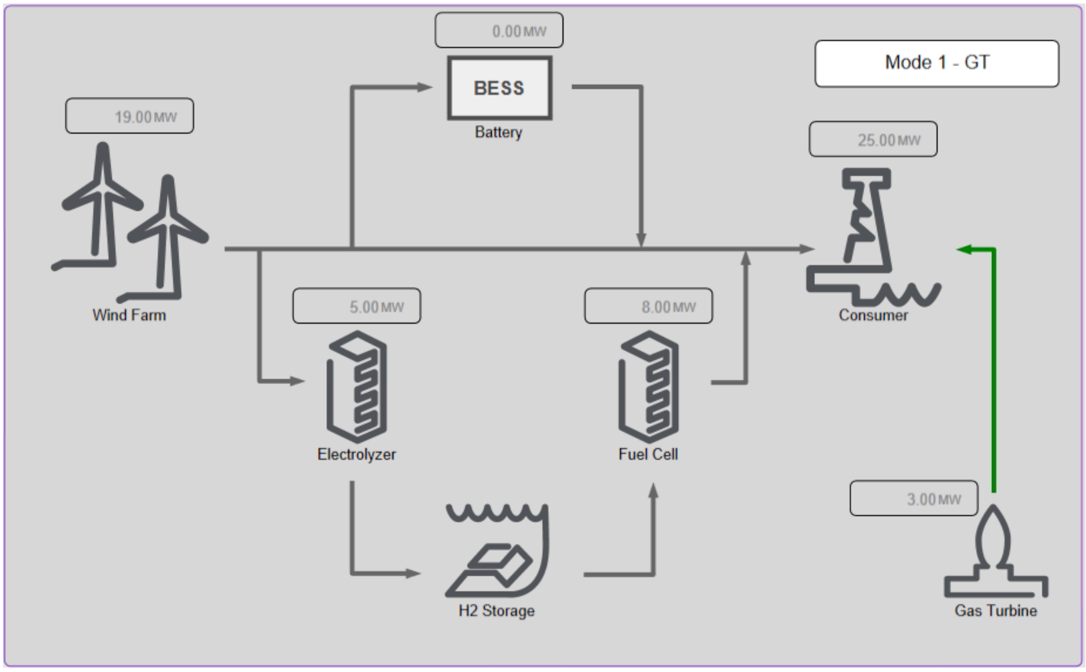
M. Sc. Industrial IT and Automation

Design and Implementation of Control System Prototype for Offshore Oil & Gas Using Renewable Power



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Summary:

Offshore Oil and Gas production has high CO2 emission and there are many initiatives looking into how to reduce the emissions. Renewable energy sources such as Offshore Windfarms are planned to be feeding power to oil platforms but inconsistency in the power output remains a major concern. Deep Purple project tries to overcome this problem by excess wind energy stored as Hydrogen in subsea. The generated Hydrogen will generate power via Fuel Cells to balance the power need during when the wind energy is not meeting the demand. The solution maximizes the usage of renewable energy and effectively reducing carbon gas emissions.

The Deep Purple Control System will control subsystems such as Electrolyzer, Fuel Cells, Water Treatment, Load sharing and mode management. The Deep Purple system is an autonomous system with remote operations, but remote override is catered for.

This thesis identifies basic building blocks for the SCADA/Control System, requirements, and philosophies to develop the system from scratch. As part of the thesis a prototype SCADA system was created against a Simulink model for the Deep Purple System using OPC DA.

Preface

This thesis, titled 'Design and Implementation of Control System Prototype for Offshore Oil & Gas using Renewable Power', is carried out in partial fulfillment of the requirement for the award of Master of Science degree in Industrial Information Technology and Automation at the University of Southeast Norway, Porsgrunn Campus.

I wish to thank my supervisors Fredrik Johan Østheim, TechnipFMC and Hans Petter Halvorsen from USN for sharing their knowledge and taking time to attend to my questions and discussions during this Thesis. I thank David McLernon, TechnipFMC for support and recommendations with regards to the development of the prototype.

Finally and most importantly my gratitude goes to my wife Dayana and kids for their support and encouragement throughout the thesis and my studies.

Porsgrunn, 14 May 2020

Jose Tharayil John

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Abbreviations

The following abbreviations are used throughout this document.

Abbreviation	Definition
AEM	Anion Exchange Membrane - Electrolyzer
API	Application Programming Interface
AWS	Amazon Web Services
BES	Battery Energy System
CAN	Controller Area Network - Protocol
CAPEX	Capital Expenditure
DA	Data Access
DMZ	Demilitarized Zone
DP	Deep Purple
ERP	Enterprise Resource Planning
FAT	Factory Acceptance Test
HIL	Hardware In Loop
HMI	Human Machine Interface
HSE	Health Safety And Environment
HVAC	Heating Ventilation And Air Condition
HW	Hardware
IACS	Industrial Automation And Control Systems
IMS	Information Management System
MES	Manufacturing Execution Systems
MTBF	Mean Time Between Failures
NTP	Network Time Protocol
OPC DA	OLE for Process Control - Data Access
OPC UA	OLE for Process Control - Unified Architecture
OPEX	Operational Expenditure
OT	Operations Technology
PEM	Proton Exchange Membrane - Electrolyzer
PMS	Power Management System
PTP	Precision Time Protocol
REST	Representational State Transfer
RIO	Remote I/O
RTU	Remote Terminal Unit
SAS	Safety And Automation System
SCADA	Supervisory Control and Data Acquisition
TFMC	TechnipFMC
TRL	Technology Readiness Level
UPS	Uninterrupted Power Supply
UWHP	Unmanned Wellhead Platforms
ZMQ	ZeroMQ Protocol

1 Introduction

TechnipFMC is developing a concept to power offshore platforms using renewable energy. Hydrogen will be used to store energy in order to stabilize the power production. The project is named Deep Purple as the color of Hydrogen is purple in the emission spectrum and Hydrogen shall be stored subsea.

Deep Purple is a system that aims to utilize renewable energy sources and energy storage to provide CO2-free and stable energy to consumers.

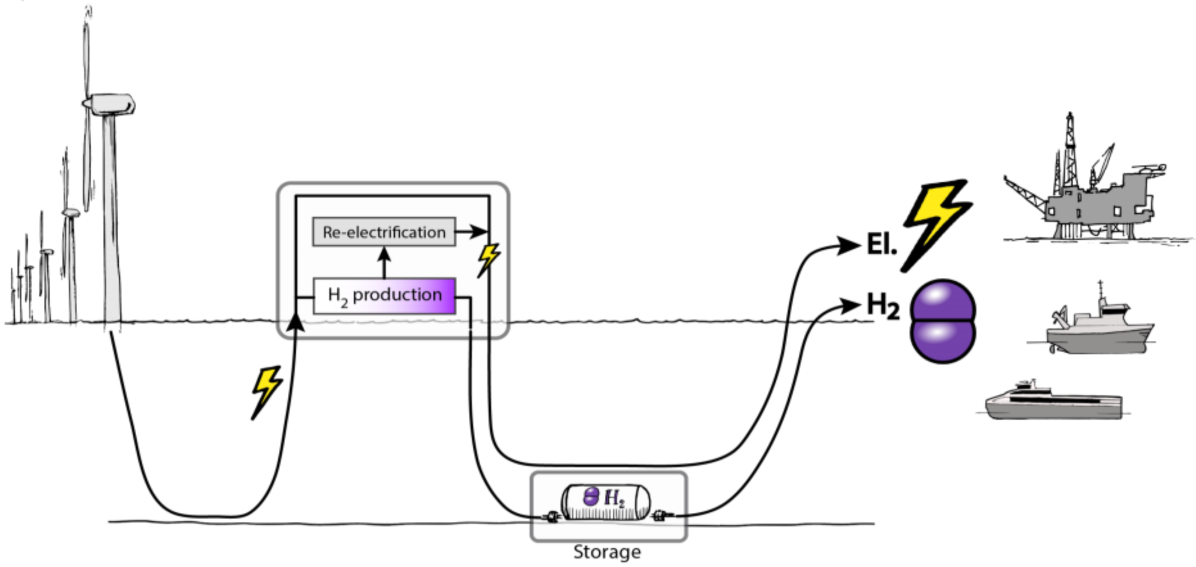


Figure 1-1: Deep Purple Concept

Current applications of the system are:

- Supply of stable CO2-free electric power to remote off-grid consumers
- Supply of CO2-free hydrogen to onshore or coastal consumers of hydrogen

The Deep Purple project partially is funded by The Research Council of Norway and led by TechnipFMC with partners.

1.1 Background

In order to eventually phase out CO2-emitting power sources the problem of the intermittency of renewable power sources has to be overcome. Energy storage is a way to do this. While the use of electrical batteries is proven and well developed, so far it is not practical to store large amounts of energy to stabilize seasonal variation in power consumption.

Alternative approaches to store excess energy from intermittent sources have been proposed and are currently under research or testing. Similarly the Deep Purple project is looking into using the excess electric energy to produce hydrogen through water electrolysis, and producing electricity through the use of hydrogen fuel cells.

1.2 Objective

Deep Purple project is currently in its second phase where it needs to develop a robust technical solution for offshore production, storage, usage, and transportation of hydrogen-carried energy to supply electric energy to O&G platforms.

The objective of the thesis is to identify the high-level requirements for the SCADA system for Deep Purple and act as an input to the design and development of a SCADA system adhering to the current requirements, focusing on unmanned offshore operation.

The Thesis will also create a high-level design of the control system and prepare a prototype of the SCADA system that will interface the existing MATLAB Model.

1.3 Case Definition

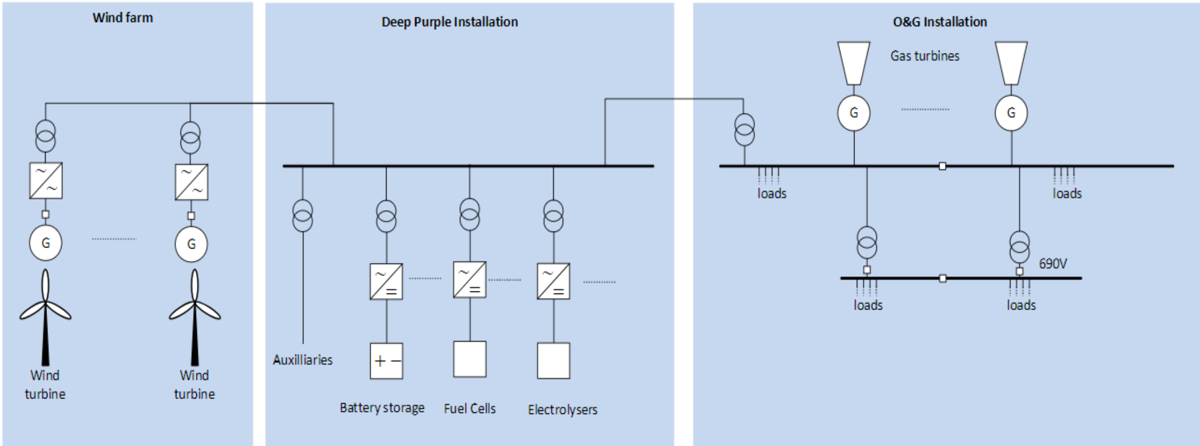


Figure 1-2: Principle power system single line diagram [1]

The system to be used as the basis for the work is described in this section. A principle single line diagram of the Deep Purple concept for powering O&G installations is illustrated in Figure 1-2. An O&G installation with a number of onboard gas turbines is connected to an alternative source of power consisting of many wind turbines combined with a number of electrolyzers to produce hydrogen when there is excess power and several fuel cells to supply electric power when there is a shortage of wind power. Additionally, battery system is included to improve transient capabilities and to allow stable operation in all desired modes. [1]

The case is defined by the main component sizes as given in Table 1.1. The case is designed to target an 80% reduction of emissions.

Table 1.1: Deep Purple, Energy to Offshore Installation, Rated power of main elements [1]

System	**Total capacity**	**Number of units**
Consumer power demand	33 MW	NA
Wind farm	56 MW	7
Electrolyzers	25 MW	~10
Fuel cells	18 MW	~100
Gas turbine rated power (on O&G installation)	15 MW	1

2 Deep Purple Sub-Systems

This section will discuss on the different subsystems in Deep Purple and their ability to handle power flow and change in power need and how voltage and frequency control capabilities are used.

2.1 Battery System

The main electrical characteristics of a battery storage system is the maximum useable energy storage capability (kWh) and maximum charge and discharge power (kW). A larger, short-time peak power capability can also be specified. The maximum values are usually much larger than the recommended operating conditions since large power flow typically causes accelerated degradation.

Power flow in and out of battery systems connected to AC grids are controlled by power electronic converters. The converters can control power flow from maximum in one direction to maximum in the other direction within milliseconds. Batteries can handle very fast changes in power flow within their given maximum limits for charge and discharge power. The battery system with converter is therefore ideal for stabilizing power grids the Deep Purple project. The battery system can provide or absorb power whenever there are load transients that the other power sources and sinks cannot follow. The peak power will typically only be needed for rare contingencies and accelerated degradation due to high power will therefore not necessarily be a problem in this application. [1]

A battery system can be brought on-line in a very short time (within seconds) if it has been turned off. It can also be kept on-line in stand-by with zero power flow such that it is instantly available on demand.

2.2 Electrolyzer

The Electrolyzer is interfaced to the power system via power electronic converters. Power converters can instantly change both active and reactive power flow. A cold start-up of the Electrolyzer will typically take five minutes and a typical warm ramp-up time from 0 to 100% load is 10 seconds. [1]

The cold start-up time will have to be considered in the mode change control, while the limitation in ramp-rate have the implication that the electrolyzer cannot handle the need for fast active power balancing on its own. In modes without running gas turbines, less battery storage power rating will be required if Electrolyzer response time is lowered.

There should be no reason to set restrictions on the reactive power response for the Electrolyzer converter since fast changes in reactive power will only affect the power converter and not the rest of the Electrolyzer system. There will however be restrictions in the amount of reactive power that can be supplied or consumed by the converter. The maximum reactive power flow will depend on the rating of the converter and the current power consumption of the Electrolyzer.

One potential Electrolyzer is PEM (Proton Exchange Membrane) Electrolyzers, where the electrolyte is a thin, solid ion-conducting membrane, which is used instead of the aqueous solution.

2.3 Fuel Cell

The fuel cells are interfaced to the grid in the same way as the Electrolyzer. It will therefore also for the fuel cell be the power converter controller that dictates the rate of change in power flow. The converter controller will typically be implemented such that change in power flow is kept below recommended maximum values given by fuel cell supplier.

The ideal scenario for the fuel cell is to run with limited dynamics and a low number of startup/shutdown cycles. This will be beneficial for fuel cell lifetime. Typically, cold startup time will be in the range of 2- 3 minutes to reach 100% power. Ramp-up of a warm system can be done much faster, 0-100% power in 0.1-1 minute depending mainly on air compressor dynamics. [1]

The ramp rate of the fuel cell will be too slow to let the fuel cell alone take care of the instantaneous active power balancing. It needs to be operated together with sources with faster response to maintain a stable power grid.

2.4 Windmill/Wind Farm

The maximum production from the wind turbines is always limited by the prevailing wind conditions. Also, there will be no production at all if the wind speed is less than the cut-in or higher than the cut-out wind speed. Ref. Figure 3-7. The turbines can be controlled to produce less than maximum by using the pitch control of the turbine.

If the farm consists of several turbines one has also the option of shutting down one or more turbines to reduce the total production. Also there are methods such as wake control to maximize the efficiency of the wind farm, by adjusting the wind deficit in wake and hence increasing the power yield.

A reduction in production to prevent a power surplus is always possible. A controlled increase in production is however only possible if initially the turbine is not fully utilizing the prevailing wind. A wind turbine that produces less than what is possible for a given wind speed can contribute to power balancing both with an increase and a decrease in power production. The penalty is that less wind energy can be utilized.

The controllability of wind turbine active power will not be sufficient for operation with wind turbines as the only source of power. It will have to be operated together with the gas turbine or a battery storage in order to maintain stable voltage and frequency. [1]

2.5 Gas Turbines

Gas turbine generators are the most common source of power on the O&G installations in the North Sea. These have proven to have the robustness and the dynamic capabilities that are required for the type of loads on O&G installations.

The gas turbine generator is connected directly to the AC power grid. The power flow is therefore, unlike wind turbines, Electrolyzers, and fuel cells, not controlled by power converters. The initial response to a load change will for this reason be given by the intrinsic behavior of the generator rather than the control loops for the gas turbine fuel injection. However, after some tens of milliseconds the gas turbine controller will dominate the power transient response. The initial response is more or less instant. There will be an instant increase in power output if someone adds a load to the generator. The energy for the initial response is taken from the rotating mass of the gas turbine generator. The consequence is a decrease in frequency until the gas turbine controllers have adjusted the fuel injection to bring the speed back to the desired level and balance the new load.

One major disadvantage of gas turbines is their long start-up times. It can take 40 minutes or even more from initiating a start-up until it is connected to the grid and can be fully loaded. Another disadvantage is the poor efficiency at low load and the fact that it cannot run stable at very low loads. This implies that the gas turbine may have to run with some significant load even if the load can be covered by other zero emission power sources, or it has to be shut down with the penalty that it will not be available on short notice. [1]

3 SCADA System

3.1 SCADA - A brief History

SCADA(Supervisory Control and Data Acquisition) system or early forms of SCADA were in use from the 40's in electrical utility systems to operate equipment located in remote substations. These solutions started with two-wire communications and quickly switched over to multiplexed communications lines between the nodes. The term SCADA was more popular after the use of a computer-based master station became common.

During the 60's the remote station of the SCADA systems took the nomenclature, Remote Terminal Units (RTU’s). Since most RTU’s operated on a continuous scan basis, and since it is important to have fast response to control operations in the event of a system disturbance, the communication protocol had to be both efficient and very secure. Security was a primary factor, so sophisticated checksum security characters were transmitted with each message. [3]

The HMI functionality in the early versions of SCADA was very limited, which changed with the introduction of CRT which were black and white. In the 80's Full Graphic CRT’s became available. The operators were able to provide inputs using keyboards.

During the 80's the Fieldbus protocol developed as national standards and availability of these communication protocols such as OPC enabled communication between equipment from different vendors. [4]

Late 90's the major functionalities of SCADA was getting more standardized to Remote Monitoring and Control, Alarm Monitoring and Data Collection. More critical and sophisticated control actions were handled by the RTU/PLC. SCADA was also acting as a bridge between ERP/MES systems and the plant/process. [3]

The latest generation of SCADA systems utilize web solutions to achieve same functionalities as on the previous generations while accessing the HMI over a web browser, which will be backed with secure networking and cybersecurity. This allows to use SCADA from any part of the world over the internet and device-independent.

3.2 Standards Applicable

Deep Purple project is an innovative concept which means there are no standards defined by any regulatory bodies at present. Standards allow technology to work seamlessly and establish trust so that markets can operate smoothly. They: [5]

- provide a common language to measure and evaluate performance,
- make interoperability of components made by different companies possible, and
- protect consumers by ensuring safety, durability, and market equity.

TechnipFMC has been developing and delivering control systems to subsea and surface oil and gas fields and this experience shall be benefited towards identifying standards from Oil and Gas fields towards Deep Purple. The equipment is meant to be operating in a very similar environment to offshore oil and gas platforms supporting the power needs of and offshore platform. Though the project can be redesigned to generate and distribute Hydrogen using supply chains, the current scope is to support offshore platforms. A set of applicable standards are provided in Appendix C

An important consideration with regards to the use of these standards is that many of these standards have been developed with focus on HSE for manned platforms. These will increase the requirements and hence the design cost of the system. Since Deep Purple is designed to be operated unmanned, a careful re-evaluation of these standards needs to be done to eventually design a set of standards for projects and products similar to Deep Purple.

3.3 Deep Purple - Control System

The Deep Purple Control system will consist of different functionalities and SCADA will be one major component in the control system. As mentioned in Chapter 2, Deep Purple is comprised of a number of subsystems which has their own control systems. But to coordinate and supervise these subsystems a SCADA system needs to be in place along with Advisory Control and Safety System.

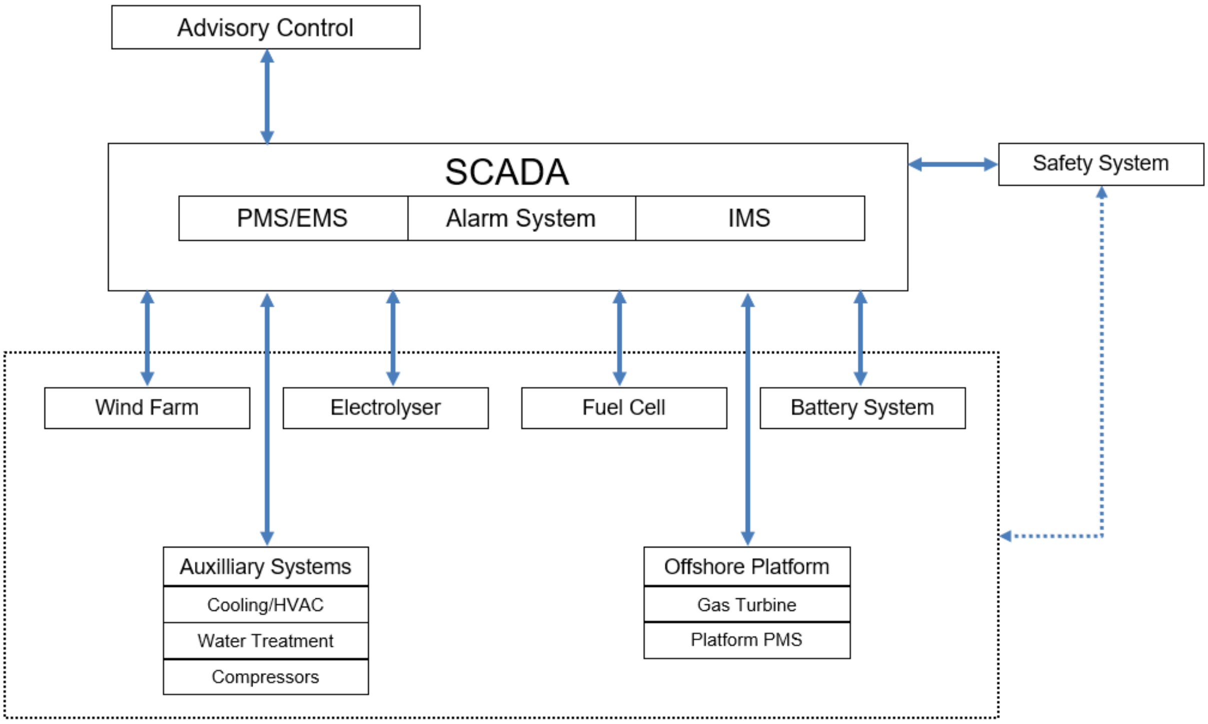


Figure 3-1: High-level block diagram of control system

In addition to the systems shown above, auxiliary systems such as Water Treatment, Cooling and HVAC shall also be interfaced to the SCADA.

The key functionalities that need to be in place for a Control System for Deep Purple can be listed as

- Power management System/Energy Management System
    - Active/reactive power balancing
    - Load sharing
    - Load shedding
- Mode Transition Control
- Alarm Monitoring
- Advisory Control
- Data Logging & Reports
- Operation and Monitoring of Subsystems
- Safety/Shutdown System
    - Fire & Gas

    - PSD/ESD
- HMI

Another important functionality to be considered for a Deep Purple control system is remote control access.

3.4 SCADA Subsystems

3.4.1 Alarm & Event Server

Alarms will warn operators of any abnormal operating conditions. The alarms will be triggered based on a limit and the operator needs to acknowledge an alarm. Events are normally generated when a system status is changed such as new operator login and these do not require acknowledgment.

Alarms shall be grouped to represent the area/equipment where they are generated from and shown in an aggregated view so that the operator can understand and track the errors easily. Some possible alarm groups for Deep Purple Project will be :

- System - Showing System/Housekeeping Alarms
- Electrolyzer Alarms
- Fuel Cell Alarms
- Wind farm Alarms
- Auxiliary Alarms
    - HVAC Alarms
    - Water Treatment Plant Alarms
    - Compressors Alarms
- Battery System Alarms

It shall be possible to link alarms to HMI pages in the SCADA system so that the operator can easily navigate to the respective page and take action immediately.

Alarms generally can have three states as follows:

- Alarm has triggered
- Alarm has acknowledged
- Alarm has returned to normal

Also Alarms shall have the possibility to set priorities as High, Medium, and Low. It shall be possible to set access rights on acknowledging more critical alarms.

Alarms can be set to various states such as suppressed or disabled. Alarm is disabled based on the project requirement during configuration so that the alarm does not occur. Alarm suppression is normally used by the operator to suppress an alarm based on some faulty equipment or maintenance which will stop the alarm from coming into an alarm list. It shall be possible to see the suppressed alarms count from an overview page and an alarm suppression list shall be available to the operator.

Alarms shall be stored historically for making it available in the future for maintenance and fault finding. It shall be possible to sort, search and filter the alarm list to make the analysis simpler for the operator. IEC 62682, Management of alarm systems for the process industries can be used as basis for specifying Alarm and Event Server.

The event log can also typically show who and when acknowledged or suppressed and alarm in the system. Also event logs shall be stored historically for traceability and root cause analysis.

It shall be possible to export the alarms from Deep Purple to other systems using a suitable standard protocol.

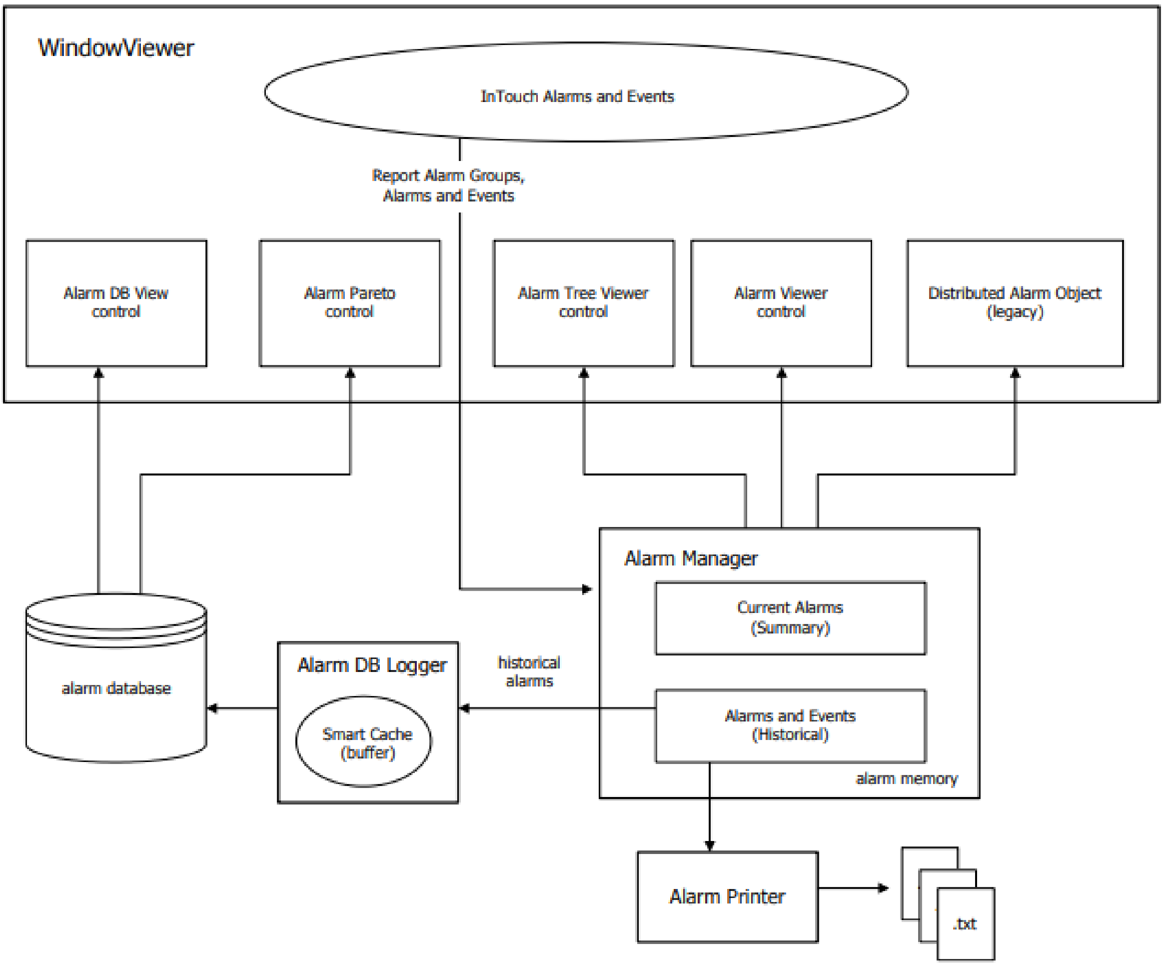


Figure 3-2:A typical layout of Alarms and Events Server solution [6]

3.4.2 SCADA Software

The HMI Software acts as a front-end visualization of the process and assists the operator to easily monitor and control the plant from a remote location. It is assumed for Deep Purple that the SCADA system will also run the control algorithms for PMS, Mode Control, and other automation functions in the background. While a cycle frequency of 10 Hz should be considered more than good enough for most of the functions, some functions, like load shedding, might require a higher cycle frequency.

Though the monitoring of normal operations will be performed from a control station located onshore, an HMI is required offshore for maintenance purposes. HMI shall comprise of symbols with minimum visual details to show only relevant information to the operators.

Most of the SCADA systems are designed and developed for Microsoft Windows Platform. A platform-independent SCADA solution is desirable due to the cost of the operating system licenses as well as maintenance. Also OPC UA is platform independent which makes it much simpler to integrate the SCADA on a non-windows platform today. The advantages of using a Linux OS are: [7]

- Security -Less Targeted
- Stability and Reliability - Compared to Windows
- Lower Cost - No license Cost

To get the best of both worlds, a possibility of accessing the SCADA over a web-browser could be a solution. Typical examples of this would be Indusoft Web Studio, Advantech WebAccess /SCADA. This will allow the operators to access the HMI from any HTML5 enabled device irrespective of the OS. Also "thin clients" for SCADA can be hosted on the cloud to reduce the CAPEX as long as cybersecurity risks are assessed.

The SCADA Software shall support other major functions in SCADA such as Alarm and Event Viewer and Historian. The SCADA Software shall have the ability to speak common industrial protocols such as OPC UA, OPC DA, CAN Bus, Profibus, and Modbus to interface with subsystems. At the same time it shall have ability to transfer data to a remote location efficiently (Lossless compression and encryption) so that remote operations can be performed on the Deep Purple System.

3.4.3 Historian Server

Historian primarily records and retrieves process and non-process data by time. The data is typically stored in a time-series database which can be retrieved to:

- A trending tool
- Exporting interface such as OPC DA/UA
- CSV/excel sheet
- Proprietary data formats

Historian can also be used as a source of real-time data to third-party clients outside the control system.

A historian solution provides an overview from individual sensors to whole plant level data over a period which can be utilized for analysis, troubleshooting, and optimizing the process and operation. Typical Historian examples are:

- Wonderware Historian
- OSISoft InfoPlus 21
- Siemens Process Historian
- TechnipFMC Field Recorder

A subset of requirements for a historian server is available in Appendix B.

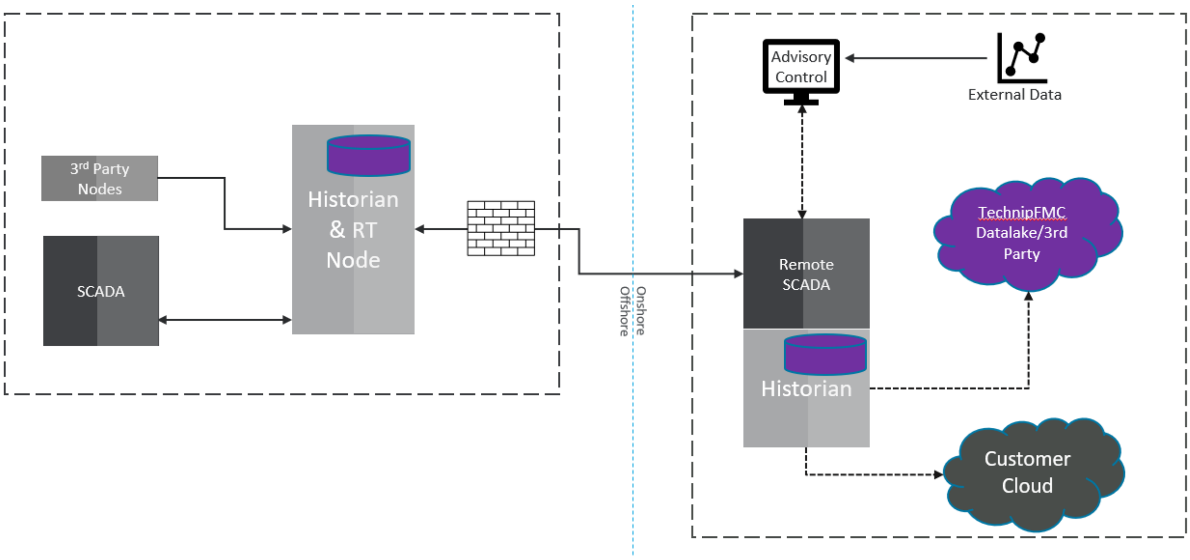


Figure 3-3:Typical block diagram showing Historian with SCADA

3.4.4 Hardware

The Deep Purple system is planned to be installed offshore on an unmanned platform. Hence the hardware components required for SCADA System shall meet marine requirements based on standards such as IEC 60945:Maritime navigation and radiocommunication equipment and systems –General requirements –Methods of testing and required test results.

The major components of the control system will include industrial PCs, Network devices and PLC/RTU.

The hardware components shall be selected based on:

- Stability and reliability
- Ruggedness
- Performance and expandability
- Availability of spares over long time

These components shall withstand the harsh environments such as humidity , salinity, vibrations, temperature variations and dust for a long period.

For onshore control stations off the shelf products can be used as the challenges with the environment is more controllable and the access for maintenance is simpler.

Figure 3-4:An example Industrial Computer [8]

A few examples for the hardware can be found [8] [9].

3.4.5 Network and Cybersecurity

Network is the backbone for every control system enabling communication between different nodes and layers. Communication in the system shall preferably be LAN based, utilizing the industry-standard Ethernet technology. The network shall be divided into appropriate LANs. Remote I/O (RIO) shall be employed to reduce the amount of hardwiring.

Access to the SCADA from the outside shall be strictly controlled by a firewall. Only pre-approved network nodes shall be able to control or extract data from the SCADA.

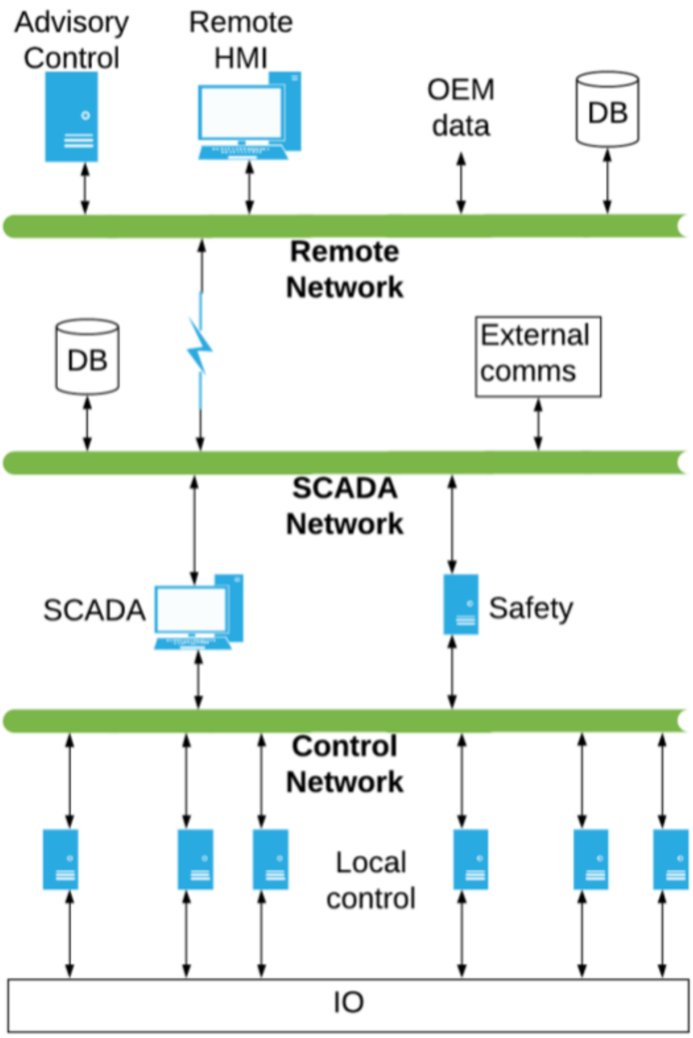


Figure 3-5:Network Bus Topology for Control System

There needs to be a connection between different subsystems and many of the sub-systems currently does not support encrypted protocols. This calls for a holistic approach to capture cybersecurity issues. This holistic approach will provide efficient, cost-effective technical validation to provide “bottom-up” proof that proper security measures have been taken for a complete system from an end-to-end perspective. The results include: [10]

- secure network design principles
- physical cyber defenses and intrusion prevention
- data stream analysis
- policy and procedures for prevention, detection, mitigation and recovery.

Defense in depth is a philosophy supporting the holistic approach to identify the security state of the whole system. This will even cover the physical access to the system such as fences and locks.

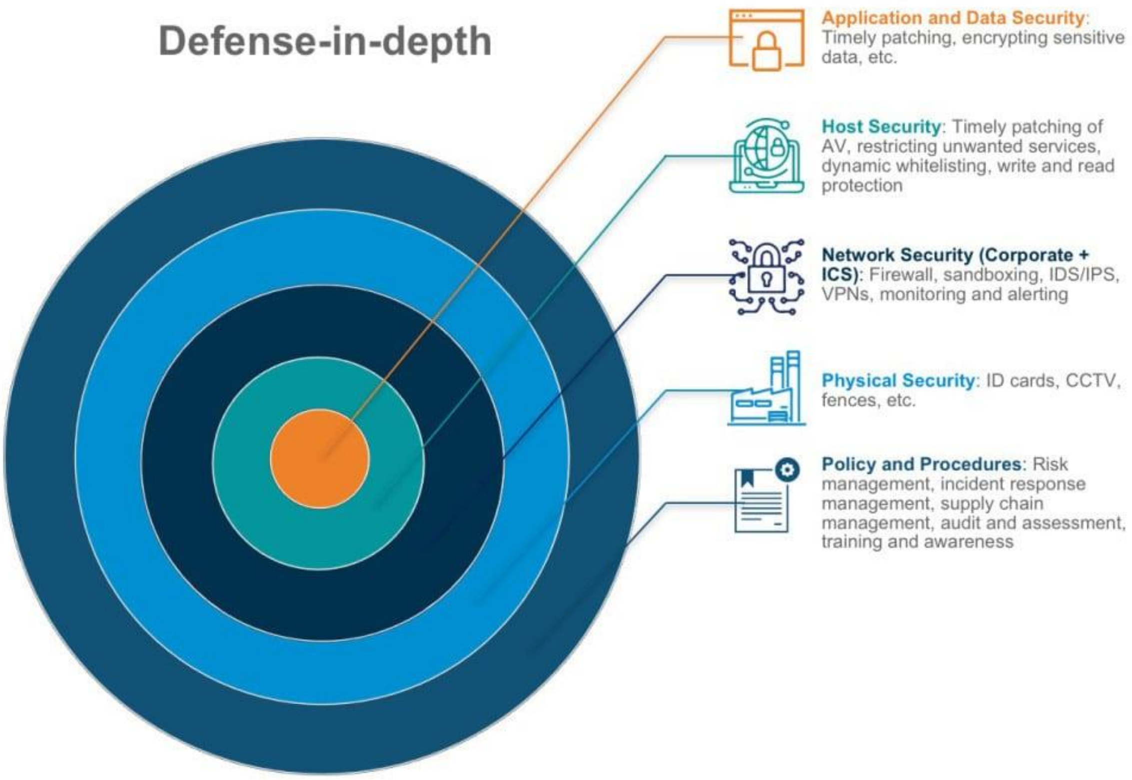


Figure 3-6:Defense in Depth approach for security [11]

The network needs to be layered to make sure that devices with lower security are least exposed to threats. The communication between the layers shall be filtered using a firewall to avoid any unnecessary/threatful communication. This will require combined system design between SCADA, Network, and Cybersecurity domains.

Following points are to be focused while designing Operational Technology(OT) systems: : [10]

- Availability, Integrity and Confidentiality
- Real-time process
- Component lifetime up to 15-20 Years
- Modest Throughput and Time Critical
- Many connections with few messages
- Engineers and Technicians
- Very diverse landscape and architecture
- Possibly high costs due to incidents are difficult to predict

Client will require the implementation of cybersecurity for Control System based on IEC 62443: Security for Industrial Automation and Control Systems and client specific requirements.

3.5 Advisory Control

Advisory Control is a set of mechanisms to support the operation of Deep Purple in the most optimum manner. The two overarching services in Advisory Control is

- Predictive Maintenance
- Operation Optimization Support

3.5.1 Predictive Maintenance

Predictive Maintenance is gathering data from the control system and other sources and based on patterns and trends predicts possible future failures be addressed. This will assist to maintain the system in a preventive manner and avoid stopping production in these possible scenarios. Wind Farms already have a condition monitoring system and Deep Purple and Wind Farm operators can benefit by exchanging or integration of both systems.

It is also to be noted that the Conditional Performance Monitoring can be applied to recognize device deterioration, fault patterns, device failures, over-engineering and provide feedback to product designs to achieve design and cost optimizations and subsequent product improvement.

The Predictive Maintenance shall reduce the OPEX by optimizing the maintenance as well as increasing the efficiency of the system.

3.5.2 Operation Optimization Support

Deep Purple operation is dependent on the available wind and the advantage of Deep Purple is to use Hydrogen as an energy storage during periods of excess energy. Hydrogen needs to be used as a fuel at periods when the wind energy does not meet the power need. The challenge is that the windspeeds can drop or increase very sharply making the generated wind power to zero. Figure 3-7 shows the variation in windspeed along with power generated.

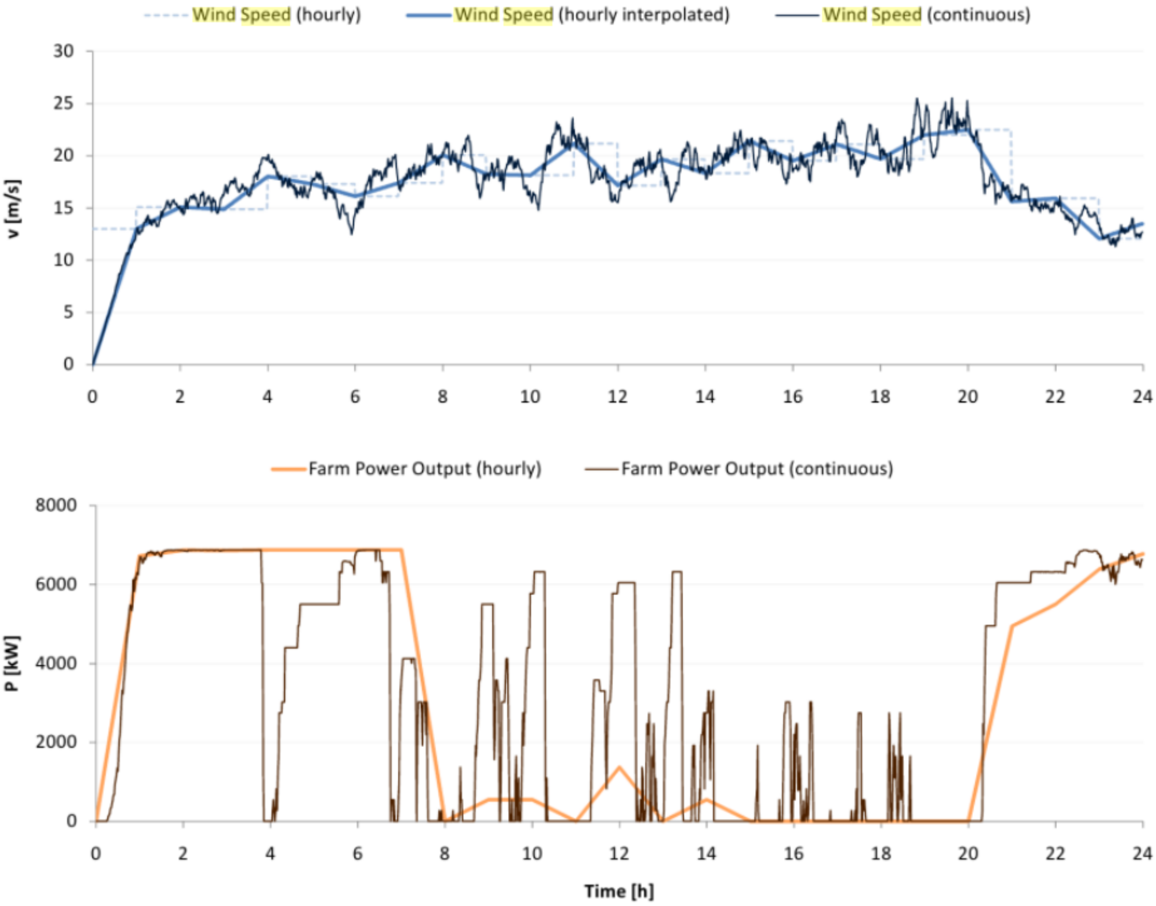


Figure 3-7:Comparison hourly and continuous power outputs(bottom) and corresponding wind speeds(top) for a day [12]

This sharp changes in wind speed will cause sudden fluctuations in the frequency and this needs to be compensated using the battery. In some other scenario the wind might be dropping from maximum wind to no wind in matter of seconds, where the gas turbines(which typically takes 40 minutes to start) have to be started. This will increase the requirement of the battery system which will directly affect the cost. To overcome this, wind predictions can be used from sources such as Meteomatics, which provides a REST 1 -style API to retrieve historic, current, and forecast data globally. This includes model data and observational data in time series formats. [13]

Based on the weather prediction data and customer need an optimal operation plan can be obtained using an algorithm. This plan will be presented as an alternative to the operator and the operator can decide to update his current operating plan.

The Operation Optimization Support shall also suggest operation routines to reduce fatigue on a single instrument to reduce the chance of failure.

4 SCADA Requirements

The purpose of requirements is to define and document system, interfaces and the functionality for DeepPurple control system. The following general factors should be considered during SCADA design: [14]

High Availability by,

- selecting high-reliability components
- providing component redundancy
- providing back-up or secondary systems;
- providing spare units (modules) for replacement

Maintainability by,

- designing equipment for accessibility and easy maintenance;
- designing control system assemblies to be retrieved independently

The SCADA System shall have the following capabilities to: [15]

- operate safely in the sited environment
- respond to the host and other safety sub-systems
- provide effective operational interface
- display and warn of out-of-limit (fault) and alarm conditions
- load balancing based on power requirement
- display operating status
- provide a shutdown capability.
- sequenced operation of valves
- software interlocks
- process-control interconnections with host facility
- data collection, storage, analysis and presentation
- remote communication to onshore control center
- interface with remote shutdown system on oil rig

4.1 Generic Functional Requirements

The requirements on the HMI/SCADA systems are extracted from NORSOK I-002 which is the engineering basis for Safety and Automation System Design. Additional requirements which deemed to be applicable for Deep Purple control system are incorporated below.

4.1.1 Design

a. System hardware shall be designed as fully redundant.
b. It shall be possible to operate the Deep Purple from multiple locations. It shall be possible to operate from only one station at a given point in time. It shall be possible to transfer operation access from one station to another using a handshake. In case of failure of one station, the operation access shall be transferred automatically to a station next in line. It shall also be possible to override operation access with higher access levels.
c. The system shall comprise 2 independent control systems for software redundancy. The system shall be designed to ensure that no single failure will cause a total system shut down.
d. All objects shall be identified by tags based on a tagging philosophy. The tagging philosophy must distinguish between different categories of displayed data.
e. It shall be possible to modify the application without stopping the Control System.
f. The number of colors used should be kept to a minimum.
g. Different access levels shall be configured for the system to prevent unauthorized access.
h. Time in the system and subsystems shall be synchronized to enable logs and alarms correlated. It should be possible to sync the system time towards an external Master Clock with high resolution and encrypted.
i. It shall be possible to exchange data with Advisory Control System and recommendations from Advisory Control shall be available for operator in the SCADA System.
j. A spare capacity of 15% shall be used while designing the SCADA system.

4.1.2 Display

a. The HMI shall display a mimic featuring a general layout of the system, equipment to be operated and all associated functions.
b. Easy navigation between displays /HMI Pages shall be possible.
c. Indicator lamps or symbol graphics shall provide function activation status.
d. The process shall be divided into functional standalone sections on each display area.
e. A standard display element(Symbols, Icons, Texts, and graphic elements) library shall be used.
f. A text label should accompany the display element with information to identify the physical object.

g. The symbol shall display an indication for various statuses and alarms of objects it represents. The detailed information shall be easily accessible.
h. Labels shall be consistent throughout the display screens.
i. The display system shall allow for a minimum of three levels - overview, system and sub-system displays.
j. Clock, Server Name and Logged in Operator name shall be always visible in the display.
k. Latest Alarms and most important statuses shall be always visible to the operator.
l. There shall be an overview of server statuses.

4.1.3 Operations

a. Unintended operations shall not be possible. Commands shall be confirmed by the operator.
b. It shall be possible to initiate shutdown of the DeepPuple system and subsystems from the HMI.
c. The system shall give feedback to the operator that a command has been registered, and that processing has started.
d. The display screen shall present necessary and sufficient information for task completion.
e. It shall be possible to interlock functions to avoid risks to HSE. It shall be possible to override the interlocks with sufficient access rights.

4.1.4 Alarms Events and Reports

a. An Alarm management philosophy shall be applied where Alarm Masking, Filtering, and or/ Suppression shall be applied based on a logical hierarchical structure to prevent Operator Alarm flooding and to rationalize the number of alarms. It shall be only possible to acknowledge/filter/suppress an alarm with sufficient access rights.
b. Alarms shall be categorized using different colors based on priority. It shall be possible to filter alarms based on priority, group, and status.
c. Its shall be possible to visualize active alarms per process area/equipment.
d. It shall be possible to navigate to related display pages from alarms in the alarm list.
e. It shall be possible to generate reports for process data, maintenance data and Alarm system.
f. It shall be possible to collect operation logs and events.
g. All alarms, values, and system events shall be logged with timestamp.

4.1.5 Trends

a. It shall be possible to trend all the process variables in real-time and historically.
b. The time windows and sampling intervals shall be user-selectable.
c. It shall be possible to show several process variables in the same trend display.

4.1.6 Interface Requirements

a. The SCADA shall be able to acquire and send data in real-time.
b. The protocols used shall have value, quality, and timestamp.
c. Data shall be transferred on change to reduce the amount of traffic.
d. The protocols shall be possible to be encrypted.
e. Different subsystem data shall be gathered using an integration unit to be used by the SCADA.
f. It shall be possible to export data to customer networks or third party clients. The operational system shall be isolated in such a manner that external faults cannot impact operations.
g. The exposed interface shall be secure, i.e. only approved external servers shall be able to access the export server.
h. It shall be possible to expose different signal lists to different external servers. These signal lists shall be independent.
i. Deep Purple network shall provide a transparent communication interface for 3rd party subsystems.

4.2 Non-Functional Requirements

4.2.1 Automatic start

a. The Application shall start at power-up of the servers

4.2.2 UPS

a. A UPS shall be equipped to keep the control system and relevant communications running for a minimum of 30 mins in case of a blackout.

4.2.3 Language

a. Text occurring on the operators VDUs shall be in English.

4.2.4 Printing

a. The operator shall be able to generate a hardcopy print of any display screen.
b. The operator shall be able to generate a hardcopy print of alarms, events, and reports.

4.2.5 Security

a. Firewalls shall by default be closed, and only open for specified ports/IP addresses

4.2.6 Maintenance

a. The Deep Purple system shall be designed to operate unattended and maintenance should be performed from onshore. The system shall have remote access and backup solutions for maintenance.
b. Conditional Performance Monitoring shall be implemented to predict potential risks and plan maintenance with offshore maintenance campaigns.
c. Operator manuals shall be provided for all systems having an operator interface.

5 Unmanned Operation for Control System

The purpose of this chapter is to define the unmanned operation and a philosophy to achieve unmanned operation offshore.

Unmanned operation for Deep Purple SCADA can be seen same as Remote Access and Operation with other control systems except the Deep Purple will have no personnel attending operation or maintenance at the platform in normal circumstances. Security is a major concern with regards to any remote control system. The unmanned situation drives the need for a control system that is more autonomous, robust, and redundant compared to traditional control system deliveries from TechnipFMC.

5.1 Secure Remote Access

The Deep Purple Control System is designed to be operated from a remote location such as the onshore operations room for the wind farm or the offshore platform control room. Remote access solution must provide easy and secure access to critical information and essential services to those who require it to perform their duties.

A typical example of a remote access solution based on Wonderware InTouch Access Anywhere is shown in the figure below. This solution enables the remote user to use SCADA Applications with an HTML-5 compliant web browser running on mobile devices or a desktop. It uses a secure gateway server in DMZ which will provide authentication and authorization services as well as data encryption.

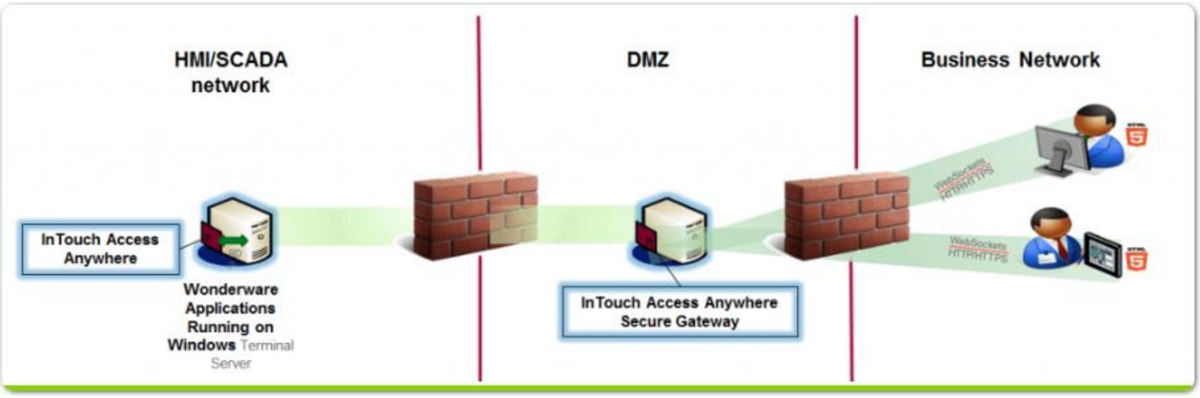


Figure 5-1:InTouch Access Anywhere solution for Remote Operation [16]

A detailed assessment of the cybersecurity requirements shall be performed by security experts and major points to be considered are only discussed below.

A remote access solution shall be planned from the early phases of the design of control system. Unplanned remote access solutions shall be strictly prohibited as these are a major cybersecurity risk. So all scenarios with remote access shall be already foreseen and catered for. These may include, but not limited to:

- Remote Monitoring

- Remote Operation
- Remote Support
- Remote Support from Third Parties

All possible users of the control system shall be authenticated and defined with access levels. An example user set is shown below: [17]

- Operators
- Supervisors
- System Integrators/Specialists/Maintenance Engineers
- Reporting/Enterprise (Read-Only) Users
- Data Interface Users(OPC/SFTP)
- Third-Party Users

Authentication is the process of verifying who the user is and authorization verifies to what the user has access to. A multi-factor authentication shall be chosen for remote access solutions. The SCADA system shall have the possibility to add, modify, and remove access to its users and revoke access immediately in case of a breach.

The network shall be segregated in layers as per cybersecurity and all communications between layers shall be encrypted. Firewalls and DMZs shall be used to segregate business and control architectures. As preventive measures anomalies shall be detected, logged, and responded appropriately to identify attacks.

5.2 Unmanned Operation

Unmanned operation shall permit monitoring and control of Deep Purple SCADA from a remote operation center. Unmanned operation will mainly benefit from cost savings(both OPEX and CAPEX) as well as reducing HSE risks to a significant level. This can be achieved by sharing the infrastructure and resources from the host(windfarm) or a nearby oil platform to simplify the design.

Offshore windfarms and oil platforms have been already been working on the same concept but being a complex process and new technology with no real field data drives the requirement for a philosophy for unmanned operation of Deep Purple. These philosophies will apply to the whole Deep Purple System.

5.3 Operation and Maintenance Philosophies

5.3.1 Design

The Deep Purple System shall be designed to minimize the manning frequency and the hours spent on board. Equipment and systems shall be kept at a minimum, and equipment requiring periodic inspection or re-certification shall to the extent possible be avoided. A modular design shall be used to simply replace the modules rather than repairing offshore. Equipment with proven reliability and high MTBF shall be used. [18]

Access to the system is an important factor and the following scenarios shall be considered.

- System with access from a host facility(such as an offshore platform)
- System with access from a nearby platform(using a boat)
- System with access using a supply vessel

Compared to a manned platform where there is a full focus on manning, elements to meet HSE requirements can be reduced on an unmanned platform.

Also following factors shall be considered during design and planning:

- Distance to host facility
- Complexity of the system
- Maintenance requirements

During the design, it shall be focused to identify critical elements and achieve redundancy as well as backup solutions. For example: Hot standby for the control system nodes which can be reconfigured to any node remotely in case of a failure.

5.3.2 Strategy

A set of points to define the strategy towards unmanned operation is stated below.

- The Deep Purple system shall be autonomous even if the link to the operator station onshore is lost. Manual intervention shall be always possible from the shore.
- Condition monitoring and predictive maintenance shall be actively utilized to capture any early warnings/indications and deviations.
- Operations that can be performed remotely and those needs local personnel shall be identified and planned.
- Tests to be performed to verify the integrity of the system shall be recognized with optimum frequency.
- Competence on the team operating remotely shall be high with a higher priority access(at least for initial deliveries) to the development team for support.
- Spares, backup solutions, and hot stand by shall facilitate high availability and reduce the risk of losing functionality
- Frequency of the maintenance visits shall be adjusted to the trust on the system.
- Video/visual access to the plant using cameras/drones shall be planned to observe the physical condition of the system remotely.

5.3.3 Development

The Deep Purple project shall be developed in the following stages to achieve trust and operation data to establish an unmanned operation offshore.

1. Test Deep Purple Control System against simulator in the lab. During this stage the control system shall use HIL Simulation by utilizing models for the different processes and models for the windfarm based on available data.

2. Test Deep Purple System and Control System against real process similar to operating environments. At this stage the control system shall connect to the real process which might be located at an easily accessible location such as onshore windfarms.

3. Test control system offshore along with an offshore platform. For example: Hywind Tampen [19] is planned to support Snorre and Gullfaks offshore operations and the Deep Purple system can be placed offshore on one of these platforms. The SCADA shall be operated from a remote control center such as the windfarm operation center. This will ensure that the Deep Purple can be operated remotely from shore and also access to the Deep Purple system will be easier as the platforms are manned.

4. Test control system unmanned with accessibility planned for support anytime. With enough experience and data from stages 1,2 and 3 Deep Purple System can be put on an unmanned windfarm with possibility to access the system from a nearby platform or a support vessel.

5. Install Deep Purple unmanned with scheduled maintenance. Stages 1-4 builds confidence in the system and at this stage the Deep Purple shall be able to run unmanned for longer periods with scheduled maintenance visits. The time interval between the scheduled visits can be reduced as the confidence in the system increases.

The stages above are a proposal from a technical point of view and needs to be re-evaluated with feasibility and practical challenges for the whole system. Duration for each stage above shall be defined after closely studying risks. This will be very closely related to the TRL(Technology Readiness Level) of Deep Purple System and external audits and certifications shall be applied to validate the system. It is also very important to use conditional performance and monitoring systems to predict possible failures and maintain the system based on this information during each maintenance campaign

5.3.4 Challenges

- Capex can be high due to the better quality of products used, but this shall be compensated by a low OPEX.
- Manual operations shall be minimum/none.
- Extended design control checks and verifications are required to avoid any design errors. It is extremely expensive to rectify such design errors on an unmanned installation.
- Extended commissioning checks are required.
- Visiting crew shall be familiar with the Deep Purple installation.

6 SCADA Prototype

A prototype SCADA system with HMI and data collection is developed as part of this thesis. The platform selected was Aveva Wonderware as TechnipFMC already has development licenses for this platform and inhouse competence is available to continue the development. The prototype is made against the MATLAB model and it helps to visualize the Deep Purple system.

An alternate SCADA System Cogent WebView was initially evaluated as an alternative. The advantage with WebView was that it is hosted and driven by the Cogent Datahub running on network computers and the installation was very minimal and it has zero deployment. The data sources can be easily bridged with Cogent Datahub user interface.

After investigating further and trying this product it was found out that the product was better used as an additional SCADA HMI to a major delivery due to

- Lack of Alarm Server
- Lack of own Historian
- Use of Silverlight technology(outdated)

Based on these considerations, the development with WebView was dropped and Wonderware System Platform was chosen as the solution for building the HMI Prototype.

6.1.1 Model

Deep Purple project developed a model with SINTEF to run simulations and verify the concepts and operation philosophies. The model was developed in Simulink and it simulates power generation and consumption with components as:

- Wind Turbine
- Battery Storage System
- Fuel Cells
- Gas Turbine
- Electrolyzer
- Load(from Platform)

The model reads a load profile and wind profile and runs the plant against the variations to see if a power balance failure is occurring.

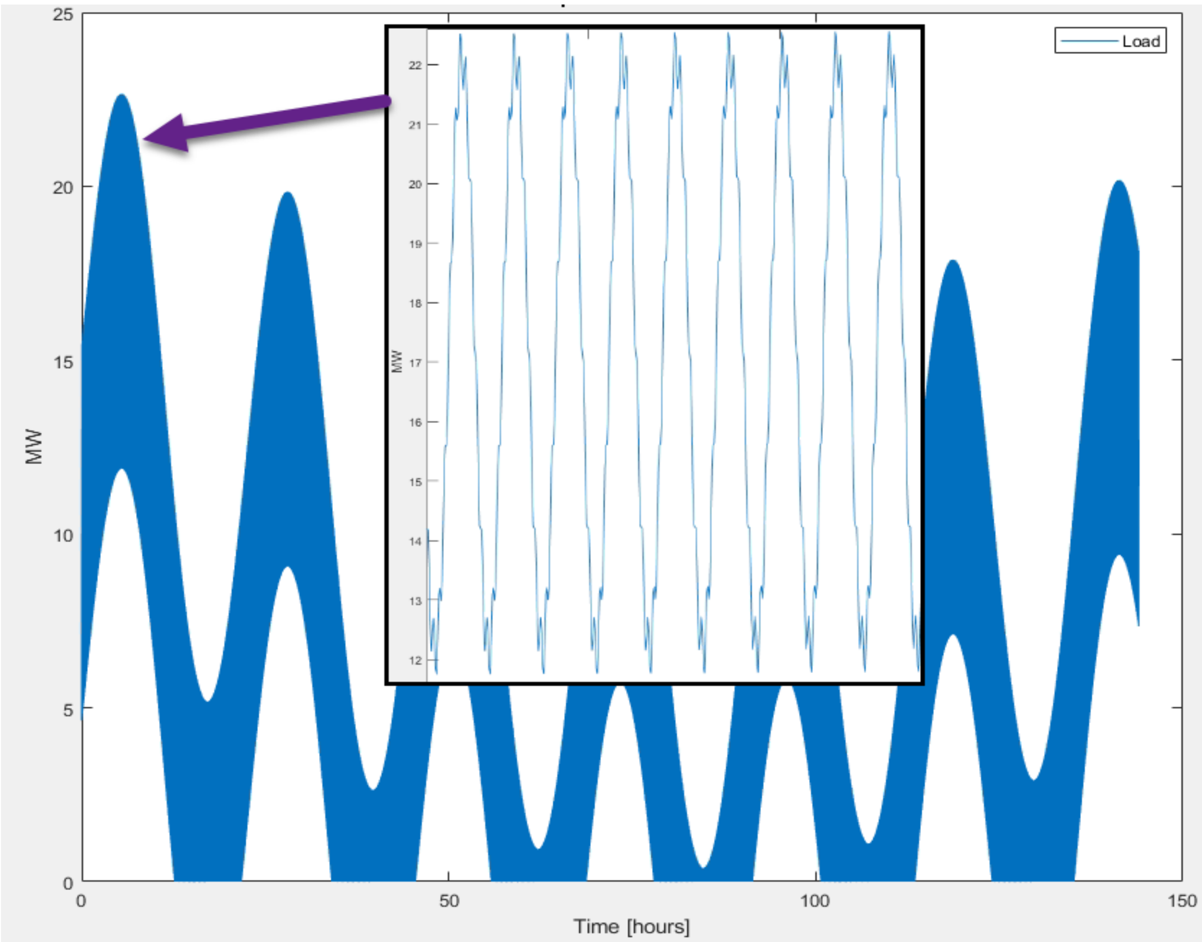


Figure 6-1:Simulated Wind Power Profile over 150 hours

The WindPower profile in Figure 6-1 is generated using four sinusoidal waves with different amplitude and frequency added together.

The model currently handles the mode control logic and the modes are defining which power sources shall be used based on the load and wind power available. The mode control logic shall be handled by SCADA as well as the load sharing in the real systems. A mode transition diagram showing the different combinations and possible future scenarios is shown in Figure 6-2. The optimal running situation is when the Wind Turbine is generating excess power and Hydrogen is produced. The Battery Energy System will be used to adjust the fluctuations in the frequency. When wind is decreasing the stored hydrogen will be used to generate power to the load along with BES. The Gas Turbine(which has a slower starting period) will have to be started for the periods when the wind is minimal and Fuel Cells are not meeting the power demand. Advisory Control shall be used with weather prediction to proactively switch between these modes to meet the power demand of the consumer at any point of the time.

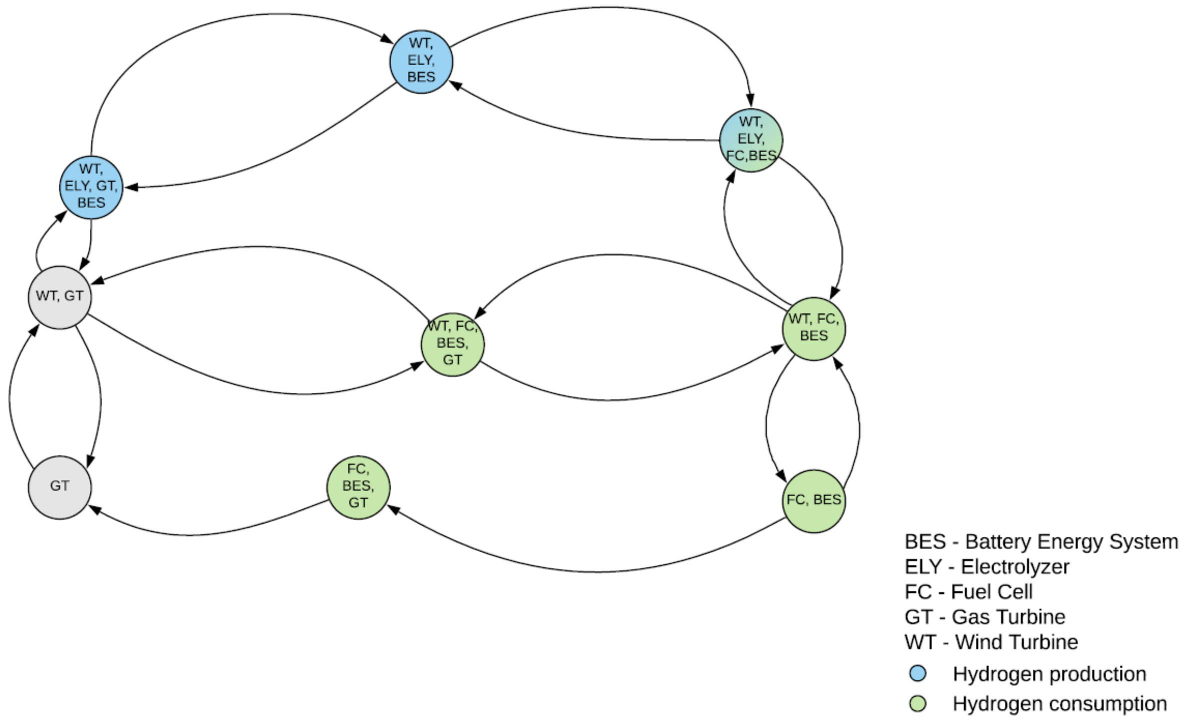


Figure 6-2:State transition during normal operation of Deep Purple

6.1.2 Interface

The prototype uses an OPC DA interface between Simulink model and the SCADA Software.

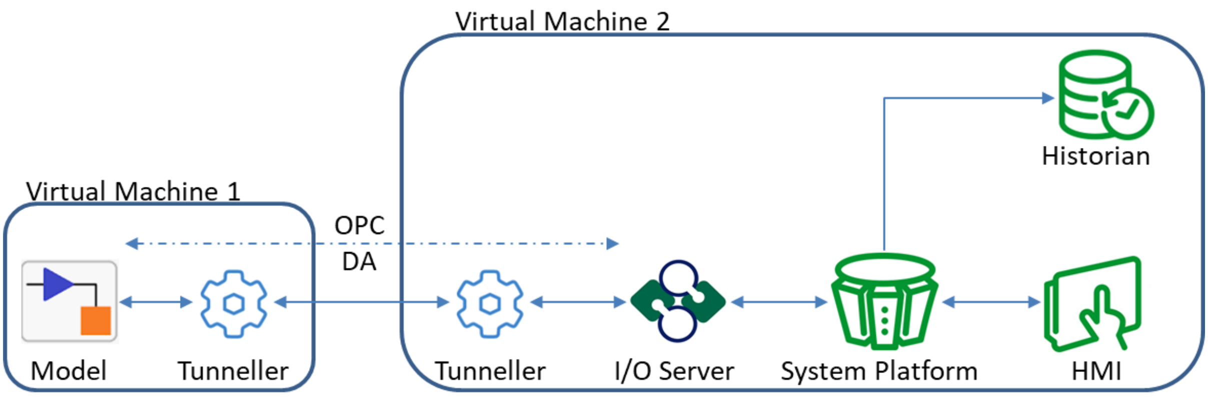


Figure 6-3:Current interface to the model from SCADA

The interface required OPC Tunnellers(Cogent Datahub Tunnellers) due to OPC DA and an IO server on the SCADA machine(Topserver from Software Toolbox) is used as an OPC Server towards Wonderware System Platform. The I/O Server is not required but it is helpful to simulate process values during the development of the HMI Templates in System Platform.

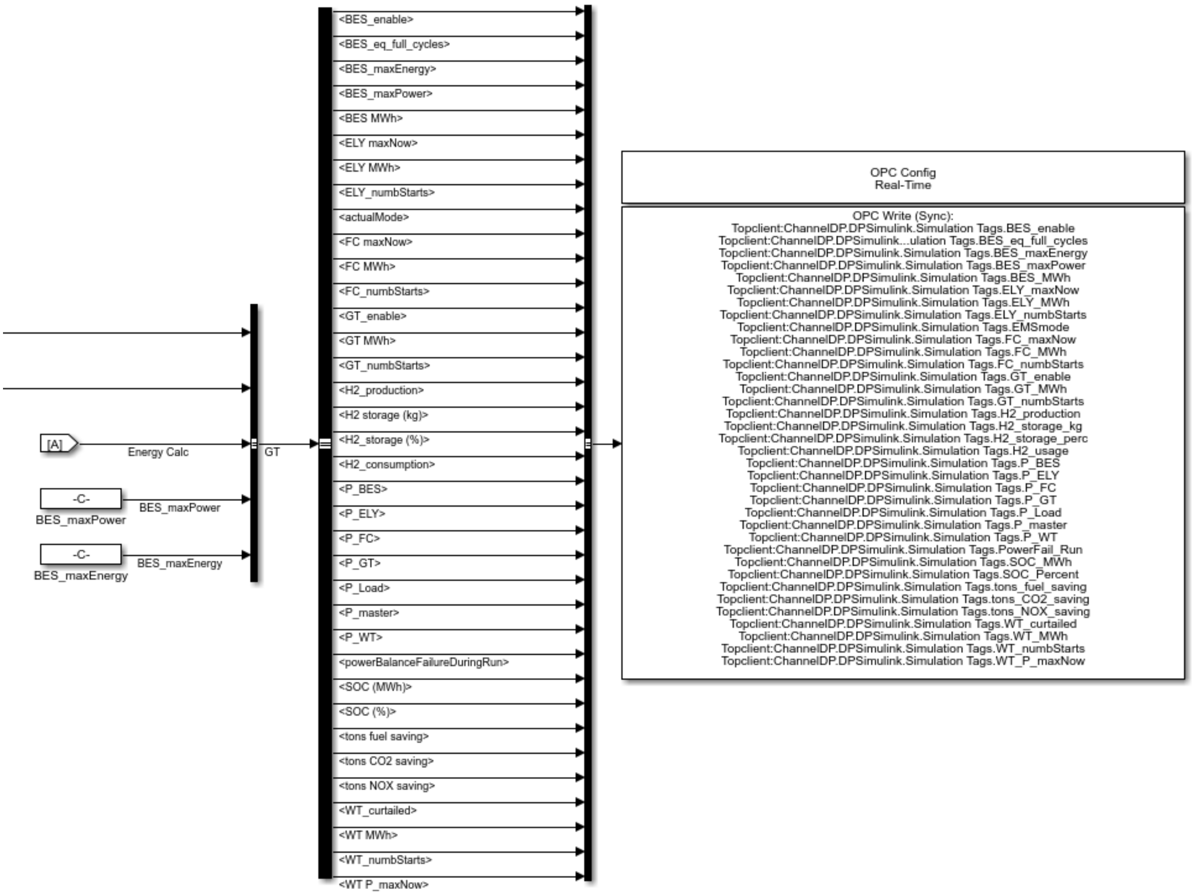


Figure 6-4:OPC DA Interface to the tunneller from Simulink

In further development on the prototype OPC UA connection shall be used against the model. This allows encryption and platform independency. Also OPC UA does not require any tunneller functionality. This will reduce the amount of components adnd layers in the interface. A test was performed to verify OPC UA interface between Simulink model and and the SCADA.

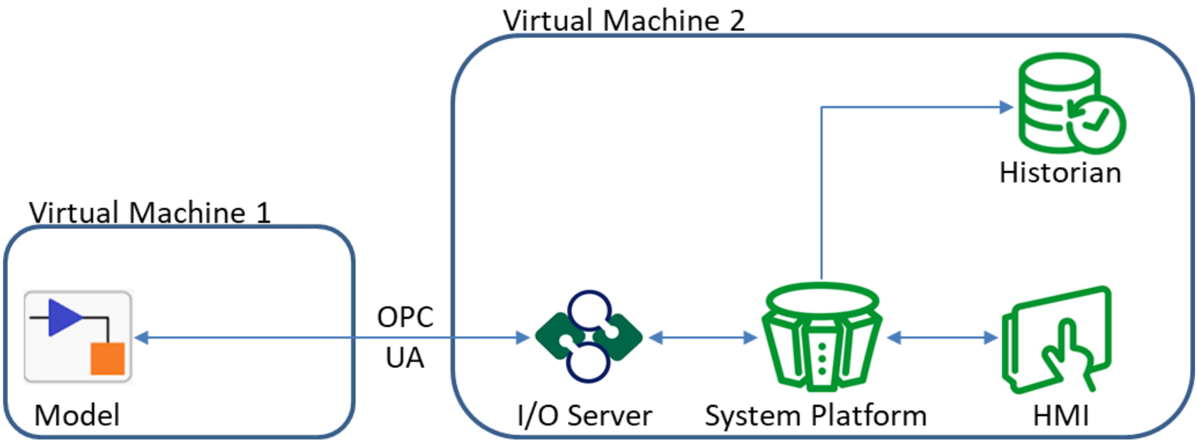


Figure 6-5:Interface to the model using OPC UA from SCADA

Once the control system is tested against the model, the different subsystems can be connected with respective I/O devices either via the I/O Server or directly to the SCADA and developed further.

6.1.3 HMI Software

The HMI Software chosen is Aveva Wonderware System Platform. This has been used in the delivery of Workover Control Systems for TechnipFMC and a development software was provided by TechnipFMC to develop a prototype for Deep Purple SCADA. It is possible to choose an alternate solution/platform to realize the SCADA after evaluation of the requirements and the approach TechnipFMC would like to use for development.

Wonderware System Platform uses templates and Archestra graphics to create template objects which is very similar to many of the other vendors. The Wonderware base template $UserDefined is used to create a Deep Purple specific master template $DP_$UserDefined. The master template will contain all the basic functions for different instruments/objects in SCADA and the functions and graphics will be inherited by the child templates.

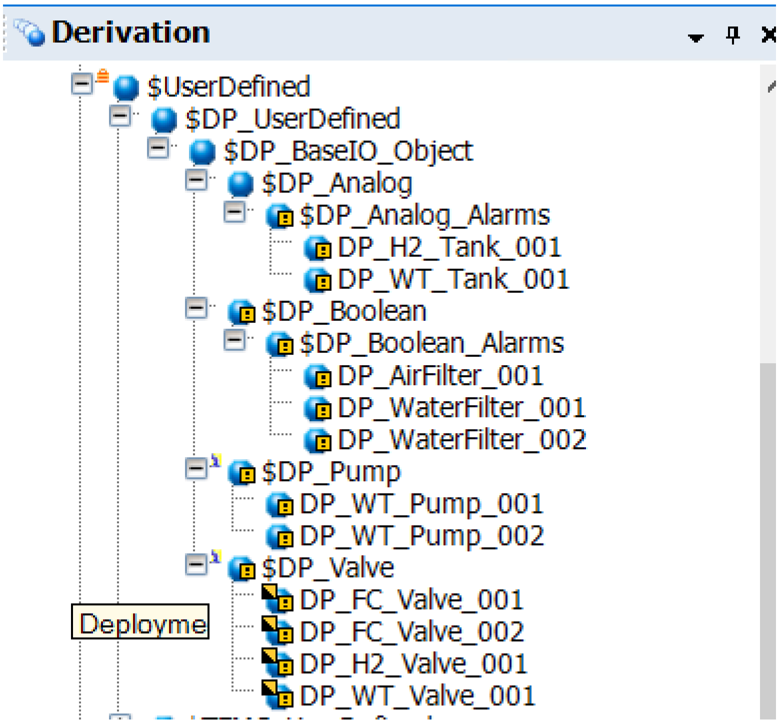


Figure 6-6:Template Hierarchy for Deep Purple SCADA

The field instruments and actuators can be generated as instances from respective templates and represented in the HMI providing status and command possibilities for the SCADA.

The System Platform also allows creation of variants by which a template can be used with different attributes to enable and disable functions and graphics.

For example: A Pump template can have Pumps with only status or Pumps with status and commands. By using variant choice the Status only, all command signals and functions can be disabled in the instance which will reduce the number of required templates.

6.1.4 HMI Pages

For the prototype, an HMI Hierarchy is designed with the lead engineer and a number of pages are developed to provide a visualization.

The hierarchy of pages are aligned with the Process and provides the operator an easy understanding of the process. In addition to the process pages, additional housekeeping pages for Servers and communication is provided showing status for all the servers and communication interfaces to the SCADA.

The Logs page will gather all the pages with information such as Alarms(including Historical Alarms), Trends and Reports.

The Process pages have possibilities to zoom and scroll since the graphics are vector-based. It is possible to navigate to the pages using the navigation map on the left-hand side as well by clicking on the process objects in other pages.

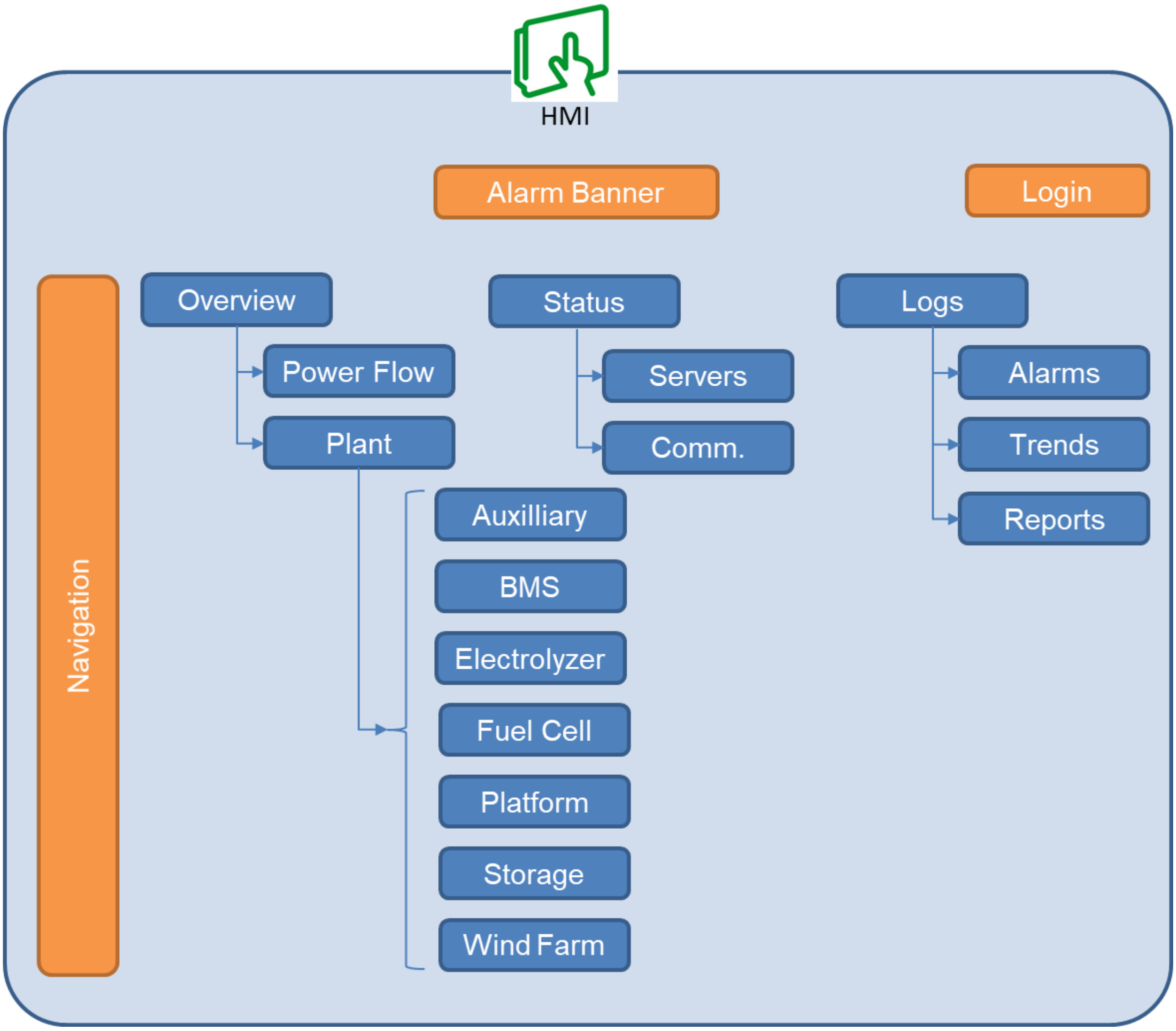


Figure 6-7:HMI Hierarchy for Deep Purple SCADA

A number of screenshots from the HMI is shown below.

The Overview page provides a pie-chart showing the power balance diagram showing the amount of consumption of power against generation from various systems. It also shows the Quick overview of the whole system with power flow from systems and power generated/consumed on each subsystem. The lines indicate active mode by changing color to the line between equipment used in the mode. The Login pane enables access for users of the system with possibilities to visualize alarms in the navigation pane itself for each process area. Alarm Banner presents the latest Alarms in the system with possibilities to navigate to related pages and acknowledge alarms. An alarm Page showing historical alarms from the Deep Purple System is provided with possibilities to navigate to related pages and acknowledge of alarms.

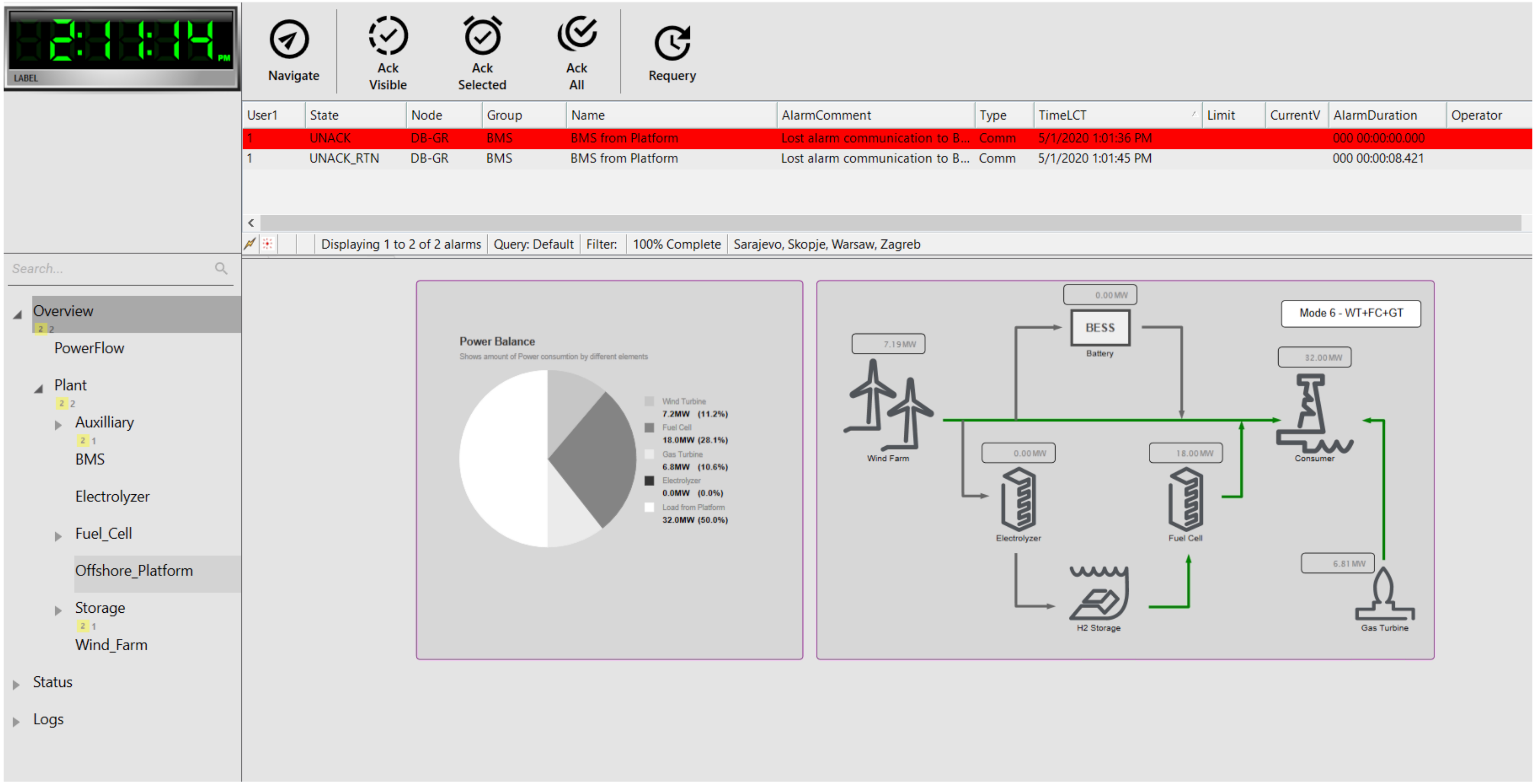


Figure 6-8:Overview Page for Deep Purple SCADA

PowerFlow page shows the electrical power substations showing the distribution of power through 10 kV and 400V switchboards including information on the transformers and converters.

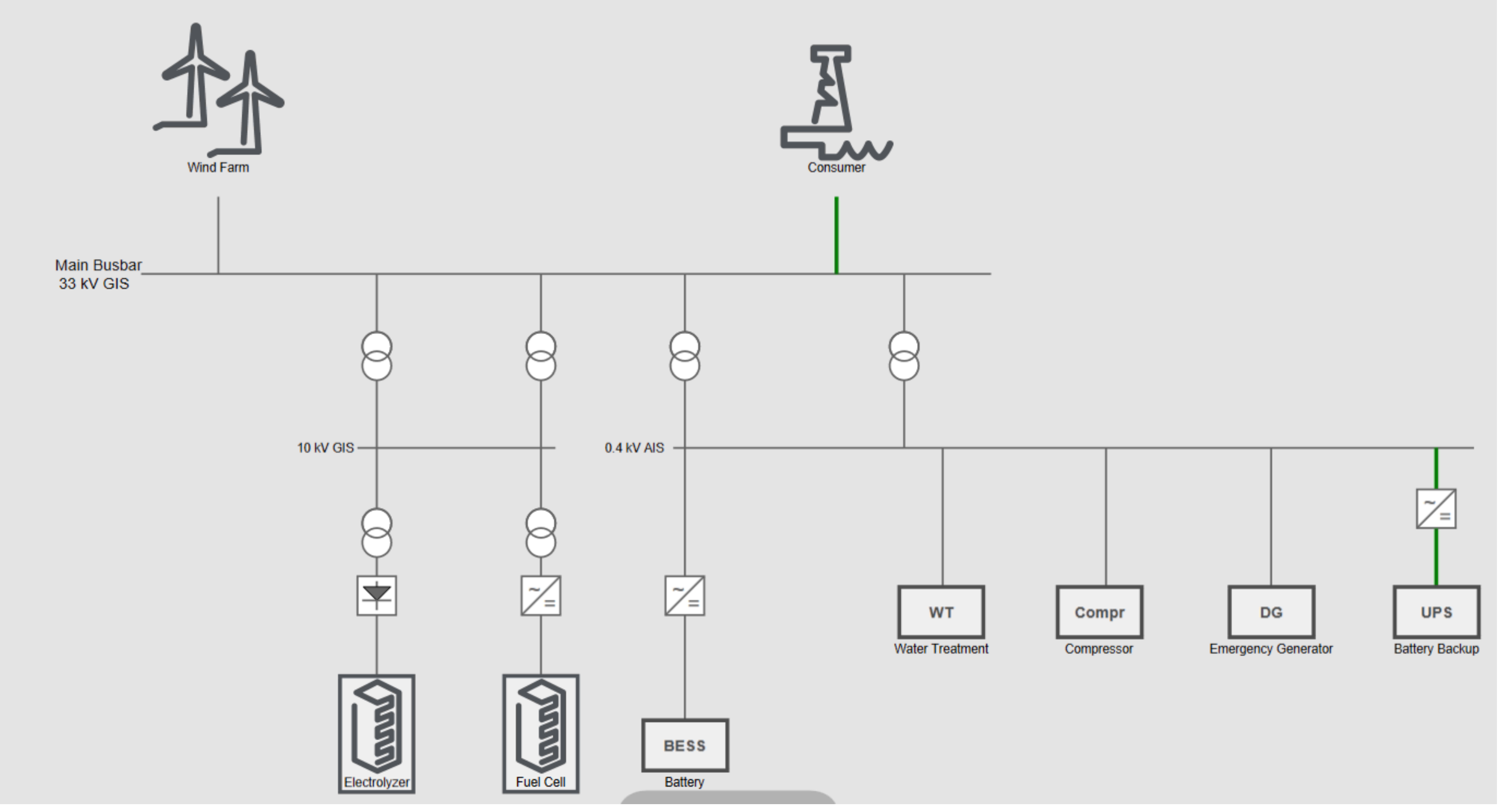


Figure 6-9:Plant Page for Deep Purple SCADA

Currently the plant page shows an example of the process where the seawater enters into the process, filtered and de-ionized, generation of Hydrogen, and re-use of Hydrogen into fuel cells with compressed air. This is an example of the whole process and it can be seen how symbols, indications, and alarms are presented in the HMI. It shall be possible to navigate deeper into the sub-systems for control and monitoring.

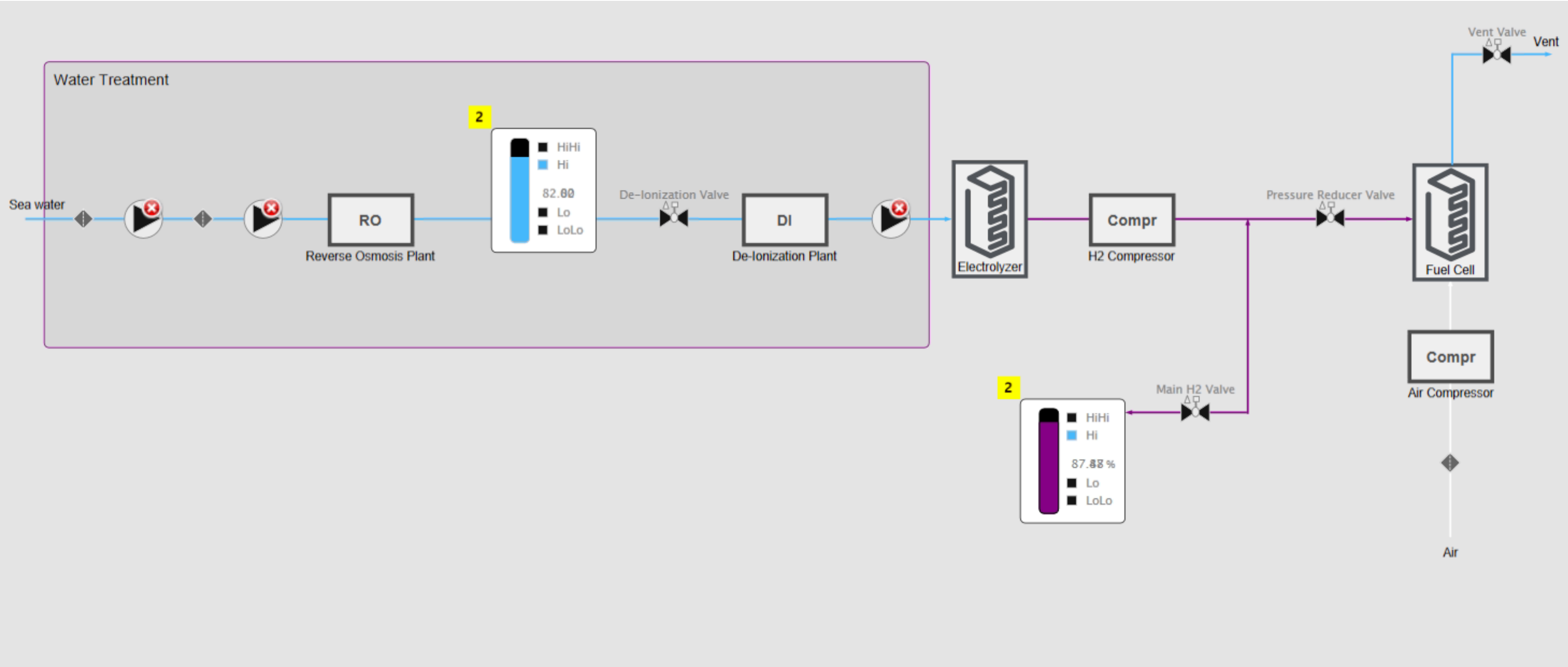
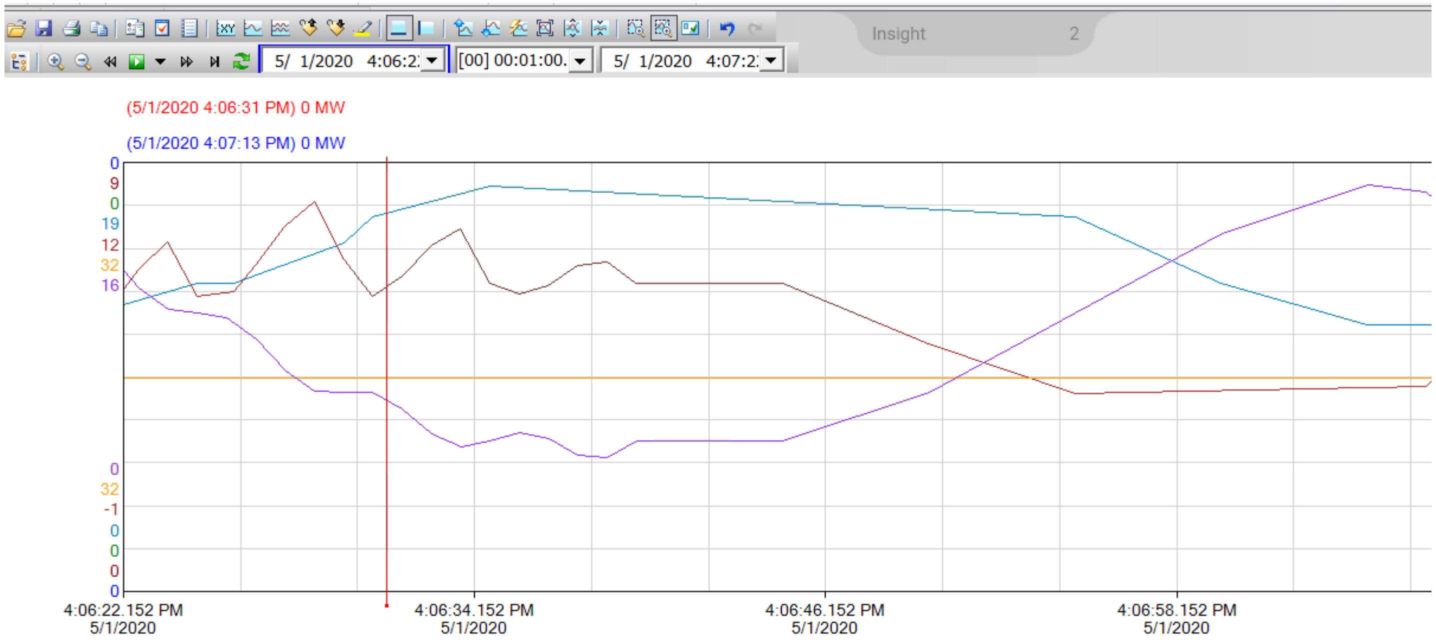


Figure 6-10:Plant Page for Deep Purple SCADA

The Trend page provides plotting functionality to the SCADA with the possibility for real-time as well as historical data. It has also possibility to save plots and use cases for convenient access during operation. It is also possible to embed the plots in other HMI pages.



Tag Name	Description	Num...	Server	Color	Units	Mini...	Maxi...	IO Address	Time O...	Source Tag	Source Se...	Value ...	Value ...
DP_P_Aux.PV		1	DB-GR		MW	0	0	\\DB-GR\InSQL_...	0:00:0...			0	0
DP_P_BES.PV		2	DB-GR		MW	0	9	\\DB-GR\InSQL_...	0:00:0...			0	0
DP_P_ELY.PV		3	DB-GR		MW	0	0	\\DB-GR\InSQL_...	0:00:0...			0	0
DP_P_FC.PV		4	DB-GR		MW	0	19	\\DB-GR\InSQL_...	0:00:0...			17	12
DP_P_GT.PV		5	DB-GR		MW	-1	12	\\DB-GR\InSQL_...	0:00:0...			8	9
DP_P_Load.PV		6	DB-GR		MW	32	32	\\DB-GR\InSQL_...	0:00:0...			32	32
DP_P_WT.PV		7	DB-GR		MW	0	16	\\DB-GR\InSQL_...	0:00:0...			7	11

Figure 6-11:Trend Page for Deep Purple SCADA

7 Conclusion

This thesis aimed to be an initial development phase for Control System for Offshore Oil & Gas Installations using Renewable Power called Deep Purple. A study of the Deep Purple system has been performed as part of this thesis and necessary blocks required to realize a control system for Deep Purple has been identified. While major functionality of the control system is fulfilled by the SCADA system, a set of additional systems are required to support Advisory Control, Predictive Maintenance, Safety, and Shutdown.

Since Deep Purple is a novel solution, there exist no explicit standards or requirement for such a system. A set of requirements are identified for SCADA and these shall provide an acceptable level of safety with cost-effective solutions to strengthen the competitiveness of Deep Purple. The requirements identified shall be taken to a separate documentation and broken into detailed requirements with IDs for traceability during design and verification. It shall also be considered to digitize the requirements and promoting them as standards in the future.

Advisory control is an integral part of the system which will bring intelligence into the system. Unmanned operation of the system with the advisory control can be extended to realize digital twin concepts, which can be used to run simulations and scenarios offshore to identify optimal operation plans.

A prototype SCADA solution has been built based on Aveva Wonderware. This involved a quick learning of Wonderware System Platform tool developing templates, symbols, and HMI hierarchy and layouts. Though Aveva Wonderware is used for developing prototype for this thesis, alternate solutions shall be explored with other vendors and suppliers to identify the best combination of technology, easier project engineering, and cost.

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Appendices

Appendix A : Thesis Task Description

FMH606 Master's Thesis

Title: Design and Implementation of Control System Prototype for Offshore Oil & Gas Installations using Renewable Power
USN supervisor: Hans-Petter Halvorsen
External partner: FMC

Task background:
Deep Purple is a project focusing on refining the concept of powering an offshore oil & gas installation with stable renewable power.
This will be realized with the use of offshore wind turbines and a seasonal energy storage where the energy carrier is hydrogen.
Hydrogen will be produced utilizing electrolysis of water using the curtailed power from the wind turbines. During periods of little or no wind the hydrogen will be used to generate electrical power through fuel cells.

Task description:
This project will be used as an initial development phase of a control system for the Deep Purple Project. It will also look into philosophy to operate an unmanned control station from shore.

The Deep Purple project has developed a MATLAB/Simulink model that can be used to investigate different operation philosophies.

Suggested Project Activities
The following activities are relevant in this project (which tasks that shall be part of this project will be decided by the student in collaboration with the supervisors and external partners when the project starts):

- Make an overview of the Deep Purple project and process by
    - Performing interviews and meeting with stakeholders to collect information.
    - Investigate operational philosophies based on the MATLAB/Simulink model.
- Make Definition of SCADA for Deep Purple project
- Design a high-level architecture for the control system or a dedicated part of the system
- Define a philosophy to establish unmanned offshore operation
- Identify high level requirements for control system
- Make high level design of the overall control system or a dedicated part of the system
- Finally, make a prototype for the overall system or a dedicated part of the system.

Student category: IIA Online Student working at FMC

Practical arrangements:
Communication and supervision will be executed on Email and Skype.
Regular meetings can be done on Skype.
The student should at least be present at USN Porsgrunn for the final presentation.
FMC will provide an external sensor used for the assessment of the final work.

Open Access: All results of this project will be open for the public, meaning the results and report should be open access and will be public available on Internet and the results may be used in research and publications, etc.

Supervision:
As a general rule, the student is entitled to 15-20 hours of supervision. This includes necessary time for the supervisor to prepare for supervision meetings (reading material to be discussed, etc.).

Signatures:
Supervisor (date and signature):
Student (write clearly in all capitalized letters):
Student (date and signature):

Appendix B: Historian Requirements

A set of requirements are mapped for Deep Purple Historian below. These are preliminary and subject to change depending the design and need of the control system.

1.0 Historian Requirements

Requirements for Historian is divided into functional and non-functional requirements.

1.1 Functional/Design Requirements

1.1.1 Centralized Point of access

Historian system shall be the Central point of access for all Deep Purple Field Data to all clients outside control system network.

1.1.2 Capacity & Capability

The Historian System shall be scalable and configurable. The Historian System shall be designed to handle different Field Sizes and Layouts. It shall also be possible to make changes to configuration along with changes to original delivery.

1.1.3 Tag Groups

Historian software shall be able to create groups of tags to segregate tags belonging to different clients or devices. For each device group it shall have a status tag indicating if the group is connected/disconnected with time and a number of tags online/offline.

1.1.4 Access Lists

It shall be possible to setup an access list for different clients for different groups of tags.

1.1.5 Resolution of data

Historian System shall store and handle in the resolution the data are sent in to avoid loss of data.

1.1.6 Time-Stamping

All data received shall have an arrival time stamp in addition to its original time stamp if available so that lag and synchronization issues can be identified and mitigated.

1.1.7 Tag names

It shall be possible to assign at least one alias to data points so that a TechnipFMC and Customer tag philosophy can be followed. It shall be possible to assign unique TechnipFMC identifier for a sensor/data point between projects delivered from TechnipFMC.

1.1.8 Complex data

Historian System shall have capability of forwarding complex data from all instruments as received. Some examples are:

- Logs, events and reports.
- Syslog from network devices
- Vibration data from Pumps

Each data type shall be possible to visualize/open on the Historian offshore.

1.1.9 Multiple Projects

Historian System shall be able to store and transfer data from multiple projects. It shall be possible to identify data from different projects by using an identifier.

1.1.10 Data Handling

1.1.10.1 Data Properties

Following properties of data shall be available in TechnipFMC Historian as minimum.

- Timestamp
- Quality
- Data Source/Project Identifier
- Resolution
- Aliases
- Access Level

1.1.10.2 Database

Database is the main component of the Historian System where collected data is stored. The selected database for Historian shall facilitate following functionalities:

- Visualize data
- Export data
- Backup data
- Import data
- Replicate(Example: to itself via DMZ to cloud)

1.1.10.3 Real-time data

It shall be possible to view, plot & print real time data offshore on the historian node. Also it shall be possible to share real-time data with clients through interfaces specified in interface requirements section.

1.1.10.4 Historical Data

All historical data for at least one year shall be available offshore. It shall be possible to view, plot & print historical data for one year offshore on the historian node. Historian System shall have capability of storing and monitoring data from TechnipFMC equipment's for the lifetime of the field. Non TechnipFMC data shall be stored for minimum one year period.

1.1.11 Transport/Export of Data

Data referred can be of tag values, logs, files from Control System.

1.1.11.1 Order of Data

Export of Data from Historian System shall be in chronological order according to the Historian arrival time so that data can be analyzed and stored as a data stream.

1.1.11.2 Buffering of data

Historian System shall have ability to buffer data for minimum 30 days when the communication link between nodes are interrupted. Connection/disconnection status between nodes shall be logged in the historian for a minimum of one year period. The Historian shall activate an alert when not storing data or tag groups to the database. And when loss of communication to offshore or onshore occurs a notification shall be logged in both tiers of Historian.

1.1.11.3 Data Compression

Historian shall compress data(Lossless compression) transferred to onshore so that minimum bandwidth is used.

1.1.11.4 Secure data transport

Historian shall transfer data to onshore in a secure manner(either encryption or secure channels) so that data can be exported safely.

1.1.11.5 Cloud Solution

It shall be possible to export the data from two tier solution to a TechnipFMC Cloud solution without a manual intervention. The Historian system shall be designed with functionalities to interface to other cloud solutions such as Azure, Google Cloud or AWS.

1.1.11.6 Data Export

A local user shall be able to export the stored data per agreement with Operator and upload it to an external device. E.g. Internet storage, USB hard drive etc. depending on availability in each project. The procedure shall be automated to minimize impact on the Historian uptime and database integrity.

1.1.12 After market update

An upgrade to existing delivery shall be backwards compatible. The update shall not initiate upgrade of software versions from previous delivery. The upgrade/update shall have minimal impact to dataflow.

1.1.13 Interface Requirements

Historian shall only be able to monitor/read data from various data sources, except in conditions where Historian will be used as a data source to transfer data to other consumers.

1.1.13.1 Automatic update of new data points

The historian shall automatically identify new data available from the data source given that the protocol supports it so that new extensions in number of instruments, or data points made available in the instrument, are automatically made available.

1.1.13.2 Interface Protocols

Historian shall be able to interface with following protocols to read data.

- Modbus RTU/TCP
- OPC DA
- OPC UA
- KAFKA/ZMQ
- File Transfer
- Syslog

1.2 Non-Functional Requirements

1.2.1 Operating System

Historian system shall be tested against latest release of Windows Operating System and Windows Patches(including patches for previous version) once a year to generate a compatibility report.

1.2.2 Service Mode

It shall be possible to run the Historian Software as a service to make sure the application is running continuously in the background. It shall be possible to run the software as program for configuration and maintenance. The software shall not require administrator rights to run.

1.2.3 Cybersecurity

Architecture and design of Historian system shall meet cybersecurity requirements from IACS. Refer to requirements

1.2.4 Anti-Virus Programs

Historian system shall be tested against default TechnipFMC anti-virus solution and shall be retested when new version is adapted by TechnipFMC.

1.2.5 Time Synchronization

Historian System shall be able to synchronize time with an external time source with protocols. The system shall continue to perform the functionalities covered by functional requirement even when there is a significant change in time.

- NTP
- PTP

1.2.6 Updates

Historian System shall be able to connect to a server provided by the client to update operating system and virus definitions. The patches shall be tested before they can be applied.

1.2.7 Dimensions

The physical size of the TechnipFMC Historian HW, including the HW for server and HW for Firewall, shall be evaluated based on where the HW shall be installed.

More than one option for HW shall be defined to be able to meet the different limitations for each of the field's offshore facilities. Which of these pre-defined HW options that shall be chosen for each of the relevant fields will be outlined upfront the installation offshore. And HW selection criteria's shall be defined in a selection guidelines document.

1.2.8 Performance

Shall be evaluated case by case based on where the HW shall be installed (depended on field size, field complexity, the amount of sensors, instruments etc.).

1.2.9 Location

The TechnipFMC Historian shall be installed offshore. It shall be able to work as a two tier solution where data can be transferred to onshore.

1.2.10 Redundancy

The historian shall have full redundancy so that data will not be lost with a single failure. The Historian servers shall have redundant disks in a RAID solution for data storage. Virtual machines shall be configured to meet the desired RAID level.

1.2.11 Maintenance

Historian shall have possibility to access remotely and perform update and maintenance provided customer allows remote access. A yearly check of the system shall be sufficient if remote access onshore has not been granted. Historian shall be designed as a "stand-alone" robust offshore system collecting subsea and topside data continuously and shall not require any maintenance from service personnel beyond tuning, startup and reset.

1.2.12 Backup and Recovery

A documented recovery plan shall be available and executed before, during and after an event. The plan shall describe procedures, roles and competence that are available to recover systems. A backup of the system shall be performed after FAT, commissioning and periodically and be available in need of performing a recovery.

Appendix C: Standards applicable for Deep Purple

Standards	**Section/Description**
IEC 61892-2:2019	Mobile and fixed offshore units – Electrical installations – Part 2: System design
IEC TS 61400-21-4 ED1	Wind energy generation systems – Part 21-4: Measurement and assessment of electrical characteristics - Wind turbine components and subsystems
IEC 61400-25	Communications for monitoring and control of wind power plants, TC 88
IEC TC57	Power system management and associated information exchange
IEC 60870-5:2020	Telecontrol equipment and systems - Part 5: Transmission protocols
IEC 60092-504	Electrical installations in ships – Part 504: Automation, control and instrumentation
IEC TS 61400-25-41	Communications for monitoring and control of wind power plants - Mapping to communication profile based on IEC 62541 (OPC UA)
IEC 62443-3-3: 2013	Industrial communication networks – Network and system security – Part 3-3: System security requirements and security levels
IEC 60945	Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required test results
ISO 13628-1:2005	Petroleum and natural gas industries — Design and operation of subsea production systems — Part 1: General requirements and recommendations
NORSOK I-002	Safety and automation system (SAS) - Rev 2