Base Load Power Hub (BLPH)

EMCS Software Functional Design Specification (FDS-SW)

Document Number: 1724000594-IN-SP-00019

Supplier Document Number: E366772C00-EMCS_FDS_SW

Document Class: 2

03	29/01/2025	Accepted For Construction (AFC)	CF	AB	SC
02	15/09/2024	Issue for Review (IFR)	CF	AB	SC
01	15/07/2024	Issue for Review (IFR)	CF	AB	SC
00	31/05/2024	Issue for Review (IFR)	ADL	AB	SC
Rev.	Date	Description	Prepared	Reviewed	Approved

YOKOGAWA Co-innovating tomorrow™

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

BaxEnergy Company Details

Legal Entity:	BaxEnergy Italia s.r.l.
Address:	Free Mind Foundry innovation hub Via Sclafani 40/b 95024 Acireale (CT) Italy
VAT:	04880720877
Legal Representative	Dr. Eng. Simone Massaro

Trademarks

Energy Studio Pro® and AssetStack ® are registered trademarks of BaxEnergy. All rights reserved.

Business Value Monitoring™, Industrial HUD™, Universal Data Engine™ and FarSight™ are trademark of BaxEnergy. All rights reserved.

All other trademarks in this document are property of the respective owners.

Confidentiality – Commercial Confidence

This document is proprietary to BaxEnergy. It is supplied in confidence and should not be disclosed, duplicated, or otherwise revealed in whole or in part without the prior written consent of BaxEnergy.

Whilst every care has been taken in preparing this document, the content is subject to formal contract negotiations. All conditions and warranties whether express or implied by statute, law or otherwise, are hereby excluded. This document shall not form part of any contract.

This document was prepared on the instructions and information available to BaxEnergy at the time of preparation: no responsibility is accepted for any inaccuracy or error, or any action taken or not taken in reliance on this document.

Any comments on, or opinions stated in this document regarding the functional and technical capabilities of any software or other products proposed or referred to in this document, whether expressed as being those of the end user, are based on the information provided by the product vendors to BaxEnergy or provided by the end user. While BaxEnergy does not have reason to believe that this information is in any way inaccurate or incomplete, responsibility for its accuracy and completeness does not rest with BaxEnergy.

These limitations are not in any way intended to restrict continuing business discussions between BaxEnergy and the customers of BaxEnergy.

Contents

1. Scope of Document 7
2. Context – Crosswind BLPH 8
2.1 Project Overview 8
2.2 Project Location 9
2.3 Electrical Distribution 10
2.4 Production Units and Loads 10
2.5 Operational Constraints 11
3. Reference Documents 12
3.1 Definition & Abbreviations 14
4. Functionalities of the EMCS 16
4.1 Enable Supervision and Control by CCS SCADA HMI 16
4.1.1 Supervision 17
4.1.2 Command 18
4.1.3 EMCS Flow Chart 19
4.1.1 EMCS Status Machine 21
4.2 Power Control & Energy Management 22
4.2.1 Energy Management 22
4.2.2 Management Under BLPH Internal Communication Failures 51
4.2.3 Power Control 51
4.2.4 Forecasts-based Control 56
4.2.5 Coordination with the Process Control System 56
4.3 Load Shedding 58
4.4 Management of Electrical Distribution Equipment 60
4.5 Wind Farm Grid Connection and BLPH Synchronization After Emergency Mode 61
5. Data Interoperation 63
5.1 BESS Data Interface 63
5.2 Electrolyzer Data Interface 63
5.3 Fuel Cell Data Interface 63
5.4 Solar farm Data Interface 63
5.5 Wind Farm Data Interface 64
5.6 Electrical Distribution Equipment 64
5.7 OLTC/AVR Data Interface 64
5.8 PCS and LV Loads 65

On HOLD	
HOLDs	Description
HOLD 1	~~To the aim of reducing the issues about the fuel cell dynamics, it is assumed that for the current version the EMCS is sufficient to implement a generic rule in the control policy (as a deviation-vs-time filter on the set-point signal).~~
HOLD 2	~~An operator shall be able to set and hold the Supply Guarantee request status on NOT REQUIRED manually.~~
HOLD 3	~~For the EMCS, the BLPH shall be considered off-grid (i.e. not grid-tied) exclusively on the basis of the related hardwired signal. The latter is supposed to be an OR of the open condition of the INCOMMER 6.6kV CB and the GIS Q0(A1). This holds independently from the presence of grid signal and the status of the INCOMMER 6.6kV switchgear and any upward disconnector.~~
HOLD 4	~~(Under analysis, information arrived in May 2024): the "BESS charge level" and the related BESS.MINIMUM-EMERGENCY-RESERVE (and the others parameters about "BESS charge levels") are supposed to be expressed in SoC. However, such thresholds may need to be based on absolute values of energy, expressed in MWh, instead of SoC %: According to the meetings in held May 2024 with the BESS vendor, the BESS expose over the data interface the absolute value of energy available to the discharge, and this value is representative of the BESS ability to produce power and hence to sustain the isolated grid, while SoC value is not.~~
HOLD 5	~~The fuel cell, electrolyzer, BESS, solar farm will each provide a signal, or a set of signals, over the data interface with the EMCS which univocally identify the package status of ready to operate; the package vendor will document a static set of values of the mentioned signals for which such condition is met.~~
HOLD 6	~~the solar farm will provide a signal over the data interface with the EMCS, signaling that the solar farm is not able to guarantee the respect of the set-point from the EMCS (within the declared tolerances).~~
HOLD 7	~~The BESS is healthy is not a mandatory condition to enter in EXPORT MODE, if the fuel cell can produce power.~~
HOLD 8	~~EMCS shall constrain the range among positive set-points only (discharge), so to prevent power flow inversion (with the aim to avoid consequent possible stress on the BESS).~~
HOLD 9	~~The solar farm is able to guarantee the strict respect of the active power limit provided by the EMCS, or the respect of the limit with a maximum upward tolerance (supposed within 10%) in normal operating conditions.~~
HOLD 10	~~In grid-forming mode, if the BESS is not fully charged, it is always able to adsorb up to 1 MW (charging).~~
HOLD 11	~~It is supposed that the "BESS charge level" will be based on the SoC. HOWEVER, according to the BESS vendor, to assess the actually available margins of the BESS to charge and discharge, the energy margins shall be used instead of the SoC. In such case, it is also supposed that it is preferrable to operate around a point were energy margins in charging and discharging have similar values, instead of using the SoC as a reference (for the SoC, the optimal operational point was reported to be 50%). This affects the definition of any parameter related to the BESS stored energy level.~~
HOLD 12	~~BESS, electrolyzer, fuel cell, solar farm vendor will provide a heartbeat/watchdog allowing the package and the BESS to verify the presence of communication between the two systems.~~

HOLD 13	~~The suggested trade-off is the architecture with Fuel Cell in feedforward and BESS in feedback~~
HOLD 14	~~It is assumed that (in EMERGENCY MODE), to prevent the (potential) power overload of the BESS, the sum of the fuel cell set-point and the solar farm set-point shall be less than the BESS charge power in any moment in time, which is assumed to be always more than 0.6 MW.~~
HOLD 15	~~The synchronization procedure shall be required by the EMCS to the BESS, using a dedicated command signal exposed in the data interface of the BESS. The BESS shall start and execute the procedure only if the command is True, stop otherwise.~~
HOLD 16	~~The BESS expose a signal that is True when it is running the synchronization procedure, false otherwise~~
HOLD 17	~~The BESS perform the parallel closing request to the INCOMMER CB automatically after the synchronization, without waiting any input from the EMCS.~~
HOLD 18	~~Time-sync among EMCS and electrical equipment (protections and relays) will be done by PTP protocol.~~
HOLD 19	~~EMCS shall constrain the range among negative set points only (charge), so to prevent power flow inversion (with the aim to avoid consequent possible stress on the BESS).~~
HOLD 20	~~Definition of the condition for Supply Guarantee OFF (by Crosswind).~~
HOLD 21	~~Definition of BESS healthy no more required.~~
HOLD 22	~~To enter in EXPORT MODE, it is allowed to stop the Electrolyzer, i.e.; Able-to-Export shall consider also the possibility to use the ImperativeStop transition of the Electrolyzer. EMCS will allow to disable this possibility parametrically (Default: ImperativeStop allowed)~~
HOLD 23	~~Tanks are full~~
HOLD 24	~~Minimum ON-time inertia~~
HOLD 25	~~Minimum OFF-time inertia~~
HOLD 26	~~Waiting from Crosswind~~
HOLD 27	~~waiting from Crosswind~~
HOLD 28	~~As per the document provided, "HKN1-02-REG-341 Manual for Controlling the Solar Farm via the Client Connector REV A," , mentioned in response to TQ 55, it also consists of a signal list. However, clarification/confirmation about the "availability to control" of the park controller from Crosswind is still required.~~
HOLD 29	~~The electrolyzer PLC requires a custom time synchronization interface, based on dedicated signals (specifically: year, month, day, hour, minute, second) to be updated by the EMCS; it is assumed that the precision required is equal to the resolution.~~
HOLD 30	~~The provided response Fuel Cell Signal Analysis, sent document " TQ-0008 – Signal Analysis Response" lack in item. 2.4, 2.6 and 2.8, awaiting for the updated "Crosswind Modbus Table - Main PLC - External Cut"~~
HOLD 31	~~In consequence conversation with vendor Electrolyzer~~
HOLD 32	~~It is assumed that preventing the hydrogen level to overpass a pre-defined threshold is a sufficient condition to prevent protective/emergency reaction of the PCS and any other~~

	~~safety system~~
HOLD 33	~~Power Surplus formula is WTG.Power - 1 MW~~
HOLD 34	~~CW must provide the signal/s allowing to detect the Supply Guarantee status~~
HOLD 35	~~Total power consumption (W)" EMCS assume that the total Active Power absorbed by the Electrolyzer from the grid is not yet implemented (as per the response from the vendor).~~
HOLD 36	~~"Current Power Setpoint" EMCS assumes that the current power set point followed by Electrolyzer, or " Power setpoint(W)" used this information, there is no equivalent to power setpoint which is not yet implemented by vendor.~~
HOLD 37	~~To have the electrolyzer working it is enough to send the start command without the need to sent a setpoint~~
HOLD 38	~~Vendor shall specify, EL_MAX_SET_POINT in the IO list.~~
HOLD 39	~~Vendor shall specify, MIN_RUNNING_TIME (Minimum time to wait before the electrolyzer can be stopped) in the IO list.~~
HOLD 40	~~Exposed by FC interface~~
HOLD 41	~~This control logic does not prevent the ideal scenario where the BESS gets depleted while there is still some reserve of hydrogen. To guarantee to prevent it, an intentional charging of the BESS from the fuel cell should be foreseen when such incipient condition arises.~~
HOLD 42	~~The HV-SCADA will provide a signal to understand if the HNA5 is in fault.~~
HOLD 43	~~Ask Freqcon if the BESS is able to autoregulate and to follow the Loads energy consumption,~~
HOLD 44	~~In Grid-Forming mode, if the BESS is not fully charged, it is always able to absorb up to 1 MW (charging) only during the time needed for packages to curtail at set point send by EMCS, with the respect of the BESS MAXIMUM OPERATING RESERVE.~~

1. Scope of Document

This document describes the functional requirement specification of the Energy Management and Control System (EMCS) of the CROSSWIND BLPH project. This document is intended to produce a synthesis and unique interpretation of the requirements deriving from all the precedent project documents. The present functional requirement specifications are intended to be the input for the engineering design of the EMCS.

2. Context – Crosswind BLPH

The Base Load Power Hub (BLPH) is an innovation project which includes the piloting of an offshore water electrolysis-fuel cell round trip system and a lithium-ion battery installed on an offshore monopile. The BLPH is designed to integrate with one of the wind turbine generators in the Hollandse Kust Noord (HKN) wind farm thereby delivering a baseload of at least 20% of the average electricity production of a Wind Turbine Generator (WTG) (i.e., 1 MW) 99% of the time independent of wind conditions, demonstrating time-shifting flexibility on hours-to-days resulting in reduction of the intermittent power output.

BLPH will provide 'Innovation and Time Shifting Flexibility' where the power output of a single wind turbine will be shown to remain above 20% of average (1MW) regardless of the prevailing weather conditions for 98.5% of turbine up-time.

2.1 Project Overview

CrossWind, a Shell and Eneco joint venture, was recently awarded the tender to develop the offshore HKN wind farm, located 18.5km off the coast of The Netherlands near the town of Egmond aan Zee. The consortium plans to have HKN operational in 2023 with an installed capacity of 759MW, generating at least 3.3TWh per year. This is enough renewable power to supply more than 1 million Dutch households with green electricity. Offshore wind projects produce intermittent electricity. Balancing these dips and peaks and integrating this electricity into the national energy system requires new technologies. That is why the offshore wind farm will include several new technology demonstrations that could be implemented at full-scale in the future. Among others, the new technologies being explored include a floating solar farm, a short-term battery storage as well as long-term storage via green hydrogen produced by water electrolysis and subsequently consumed in a Fuel Cell (FC). The combination of these individual measures, herein referred to as the BLPH, will ensure a continuous power supply regardless of the wind situation. All components included in the BLPH will be installed in an offshore location within the boundaries of the HKN wind farm. At its simplest, the BLPH will store energy during periods of high electricity generation from renewable sources (a wind turbine generator and the floating solar farm) and release it during periods of low generation. In practice, it is expected that the energy stored will supplement generation from renewable sources to ensure that at least 1.0MW of power is exported to the electrical grid regardless of wind/solar availability. Electricity in the BLPH will be stored in the form of electrons in a Battery Energy Storage System (BESS) as well as converted into green hydrogen via water electrolysis. In addition of the charge held by the BESS, pressurized H2 gas will be converted back into electricity using a FC cell to extend the discharge duration. Note that transporting H2 out of the BLPH is not an option, energy must leave the BLPH in the form of electricity through an inter-array cable leading to a substation provided by the Transmission System Operator (TSO) TenneT.

2.2 Project Location

The Hollandse Kust Noord (HKN) wind farm is located 18.5km off the coast of the Netherlands near the town of Egmond aan Zee.

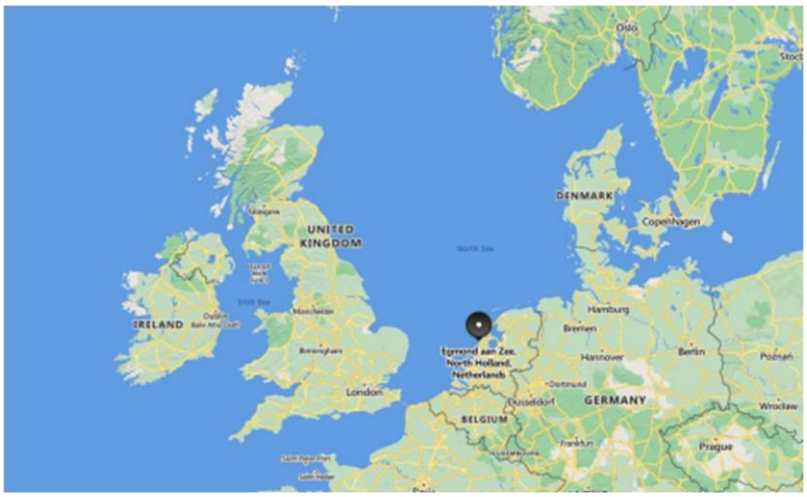


Figure 1 HOLLANDSE KUST NOORD WIND PART Location Map



Figure 2 Wind Park Details

The wind farm will consist of No. 69 x 11.5MW wind turbine generators each to be installed on a dedicated monopile structure. A 70th monopile located on coordinates E 590719.1, N 5841602.3 is reserved for installing the platform accommodating the BLPH. The monopile structure was designed and installed by Van Oord Offshore Wind (VooW) and therefore not part of the BLPH scope.

2.3 Electrical Distribution

All components included in the BLPH will be integrated onshore on a topsides and installed in an offshore location within the boundaries of the HKN wind farm. At its simplest, the BLPH will store energy during periods of high electricity generation from renewable sources (a wind turbine generator and the floating Solar farm) and release it during periods of low generation.

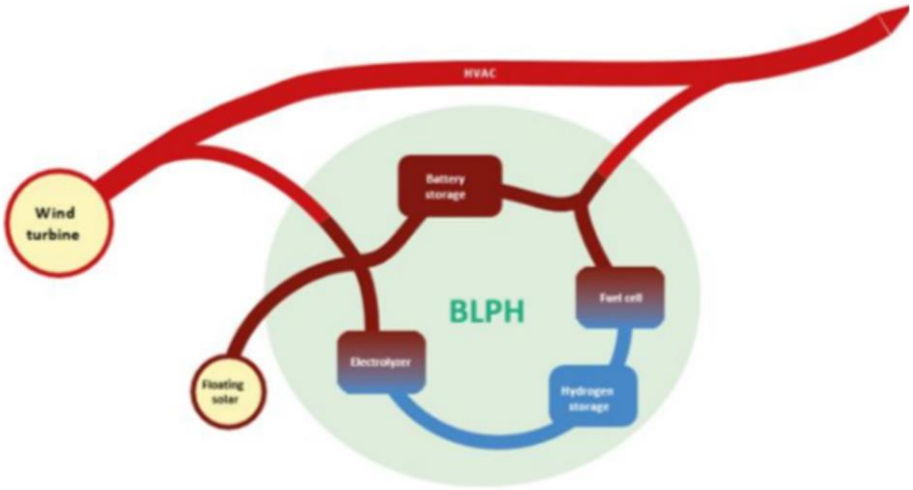


Figure 3 BLPH Concept

In practice. It is expected that the energy stored will supplement generation from renewable sources to ensure that at least 1.0MW of power is exported to the electrical grid regardless of wind/solar availability.

2.4 Production Units and Loads

Electricity in the BLPH will be stored in the form of electrons in a battery energy storage system (BESS) as well as converted into green hydrogen via water electrolysis. When the power output from the connecting wind turbine drops to below 1 MW, the BLPH will return its stored energy to supplement the remaining power output. This will be by discharging the BESS, while stored hydrogen will be converted back into electricity using a fuel cell to extend the discharge duration. The purpose of the BLPHs to function as a testbed for the integration of energy storage technologies with renewable generation. It is expected that equipment installed on the BLPH will operate as Normally Unmanned Installation for at least two (2) years with no or minimal maintenance and it will have its own independent control room with the ability to communicate with Crosswind's control room.

2.5 Operational Constraints

The Central Control System (CCS) is responsible for the normal operations of BLPH, with an independent system to the elements of the Safety System. The components that CCS is required to control all process (power generation) systems, utilities systems, and electrical equipment on the platform following Document 123A90-DDL-IN-DD-40019 Data Network Architecture. As agreed with operations, a single operator shall be required for both electrical and process systems on BLPH. CCS reacts to changes from the HNA5 Wind Turbine, power output only. Only output/status of HNA5 Wind Turbine affects operating modes. The CCS shall act independently of the safety system and shall not interfere with any of its functions. The objective of the BLPH is to demonstrate time shifting flexibility and capability of providing 1MW Power output using the full capacity of the inventory stored on the platform. BLPH does not plan its output on weather forecast – BLPH output is planned depending on the actual power output of the HNA5 Wind Turbine. The facility can be operated remotely from on-shore Control room, and has the ability to shut down, start-up, to adjust and/or tune, to connect and disconnect to the grid and to monitor BLPH. The measured response of BLPH will be tied to the power generation profile of an individual wind turbine HNA5.

The technologies being demonstrated at BLPH are:

1. Floating Solar farm.
2. Short-term Battery Energy Storage.
3. Long-term Hydrogen Energy Storage (Electrolyzer to create green hydrogen).
4. Fuel-Cell.

Energy harvested from both wind and sun will be stored either directly in a Battery Energy Storage System (BESS) or indirectly using water electrolysis to create hydrogen. Stored hydrogen will be consumed onboard by a fuel-cell to produce electrical power. Monitoring and control of BLPH will be remote (shore based control room) and the solar farm, battery and fuel-cell shall act cooperatively so that power from all sources will be combined to export power regardless of the prevailing weather.

NOTE: Energy stored as hydrogen will leave only in the form of electricity through the Inter-Array Cable (IAC) connecting BLPH indirectly to a grid sub- station provided by Transmission System Operator (TSO) TenneT.

The fuel-cell is slow-acting whilst the BESS is fast acting. Therefore, the BESS (whenever available) will be used as ‘lead supply’ / ‘load follower’ and operate in its most efficient / effective manner with the fuel cell operating in parallel or series to optimize both the efficiency and availability of the entire system. The CCS will be programmed to act upon multiple inputs / factors e.g. BESS Available Energy, HNA5 (EMCS will receive the data from HNA5 and based on these values will react), stored hydrogen availability, CCS operation mode, equipment operating status, equipment operating mode, circuit breaker status, etc. Whenever possible the fuel-cell will consume the platform’s stored hydrogen prior to discharging the BESS.

3. Reference Documents

This is a selection of the key documents of the project relevant for the EMCS. It is not an exhaustive list of the available documentation and not even of the relevant documentation for the EMCS. This set of documents should be enough to identify and have a first level refinement of all the requirements, operational constraints and interoperation aspects of the EMCS.

Document No.	Description
123A90-DDL-IN-RE-40095	Process Control Logics Description
123A90-DDL-EL-SP-20141	Electrical System Description & Design Philosophy
123A90-DDL-IN-SP-40098	Control System (PCS) Specification
123A90-DDL-EL-RE-20176	Electrical System Study Report - Transient In-Rush
123A90-DDL-EL-RE-20171	Electrical System Study Report - Short Circuit
K559-2254-PM-PLN-003	Basic Design Engineering Package BLPH FEED
123A90-PML-PM-TQ-00050	Reactive power control requirement for BLPH
123A90-DDL-EL-DG-20158	Overall/Key Single Line Diagram
1724000594-IN-DD-00015	System Architecture
SRN – 04270	Operations Modes Review – Base Load Power Hub
123A90-DDL-IN-SP-40097	System Specification for Main Automation Contractor
123A90-DDL-IN-SP-40100	Safety System (ESD, Fire and Gas) Specification)
123A90-MOM-RM-STAT-CW-003	Minute of Meeting - Freqcon & Statron-Control Workshop with Rosetti's MAC
123A90-MOM-RM-STAT-CW-003	123A90 - Interface control workshop with Rosetti MAC-BESS-Point 9 and 10-Synchronization Procedure-Via Mail
123A90-PML-PM-TQ-00053	Technical Query – Interface with BESS
123A90-MOM-ELO-ROS-CW-003	Minute of Meeting- Electrolyzer- CPI Interface Meeting
123A90-PML-PM-TQ-00052	Technical Query – Interface with Electrolyzer
123A90-PML-PM-TQ-00051	Technical Query – Interface with Fuel Cell
123A90-MOM-RM-BAL-CW-004	Minute of Meeting – Control Workshop with Rosetti's MAC.
123A90-PML-PM-TQ-00055	Technical Query – Interface with Solar Farm
123A90-PML-PM-TQ-00054	Technical Query – Interface with Windfarm and HNA5
123A90-MOM-ELE-ROS-CW-023	Minute of Meeting - Control Workshop with Rosetti's MAC
K559-2254-CWIWP4202201-C08-001	BESS - Control Philosophy & Block Logic Diagrams
C63-AUT-002	Electrolyzer – Communication Table
K559-2254-CWIWP4202202-C08-001	BALLARD- Control Philosophy & Block Logic Diagrams
CWHKN-INN-INP-SPC-00005	SCADA Functional Design Specification

123A90-DDL-EL-LIS-20016	Electrical Load List & Balance (CCS MODE 1 'IMPORT')
123A90-DDL-EL-LIS-20143	Electrical Load List & Balance (CCS MODE 2 'HOT STANDBY')
123A90-DDL-EL-LIS-20144	Electrical Load List & Balance (CCS MODE 3 'EXPORT')
123A90-DDL-EL-LIS-20145	Electrical Load List & Balance (CCS MODE 4 'COLD STANDBY')
123A90-DDL-EL-LIS-20146	Electrical Load List & Balance (CCS MODE 4A 'EMERGENCY MODE')
23A2007_240628_PROFINET_Register BESS_V1_0_0_3	BESS_PROFINET_SIGNAL LIST
K559-2254-CWIWP4202201-J10-001	FREQCON MSC - Product Description
MAN002 Integration Manual FCwave 2.2.0	FC Wave Marine Fuel Cell Integration Manual
CW-BALL-TQ-0008 - Fuel Cell - Rev B - BAL RESPONSE	Minute of Meeting Response
Crosswind Modbus Table - Main PLC - External Cut	Fuel Cell MODBUS Map
HKN1-02-REG-341	Manual for controlling the solar farm via the client connector REV A

3.1 Definition & Abbreviations

ALARP	As Low as Reasonably Possible
AVR/OLTC	Automatic Voltage Regulator/On Load Tap Changer
BESS	Battery Energy Storage System
BLPH	Base Load Power Hub
BPCS	Basic Process Control System
COMPANY or Client (CPY)	Crosswind
CCS	Central Control System (PCS + EMCS)
CPI	Company Provided Item
DCS	Distributed Control System
ESD	Emergency Shut down
EWS	Engineering Workstation
EMCS	Electrical Management Control System
FEED	Front-end Engineering Design
FGS	Fire & Gas System
FO	Fiber Optics
GUI	Graphical User Interface
HMI	Human Machine Interface
HKN	Hollandse Kust Noord
HV-SCADA	The given name for the COMPANY's control system for the HKN wind farm infrastructure. BLPH's control system shall operate autonomously but will interface with HV-SCADA
HSE	Health, Safety & Environment
HV	High Voltage
HVAC	Heating, Ventilation and Air Conditioning
IACS	Industrial Automation & Control System
ITER	Instrument & Telecoms Equipment Room (located Offshore)
LV	Low Voltage
MV	Medium Voltage
OER	Onshore Equipment Room
PAS	Process Automation System
PFD	Process Flow Diagram
P&ID	Piping & Instrumentation Diagram
PSD	Process Shut Down
PV	Photo Voltaic
SCADA	Supervisory Control and Data Acquisition
SoC	State of Charge
SF	Solar Farm
SS	Safety System (SIS+FGS)
TQ	Technical Query
UCP	Unit Control Panel
UFD	Utility Flow Diagram

UPS	Uninterrupted Power Supply
WTG	Wind Turbine Generator

4. Functionalities of the EMCS

The EMCS has the following primary functionalities:

1. Enable Supervision and Control by CCS and Higher-Level SCADA
2. Power Control & Energy Management
3. Load Shedding
4. Manage the Electrical Distribution Equipment
5. Wind Farm Grid Connection Procedure

Each functionality is defined in the following sections.

4.1 Enable Supervision and Control by CCS SCADA HMI

We refer to the "CCS SCADA" as the CI Servers, which are supposed to implement the CCS HMI. The user interaction with the EMCS within the CCS will be made through such HMI.

NOTE: The communication interface between the Electrical Monitoring & Control System (EMCS) and the Process Control System (PCS) will be separated from the one between the EMCS and the CCS SCADA (CI Server).

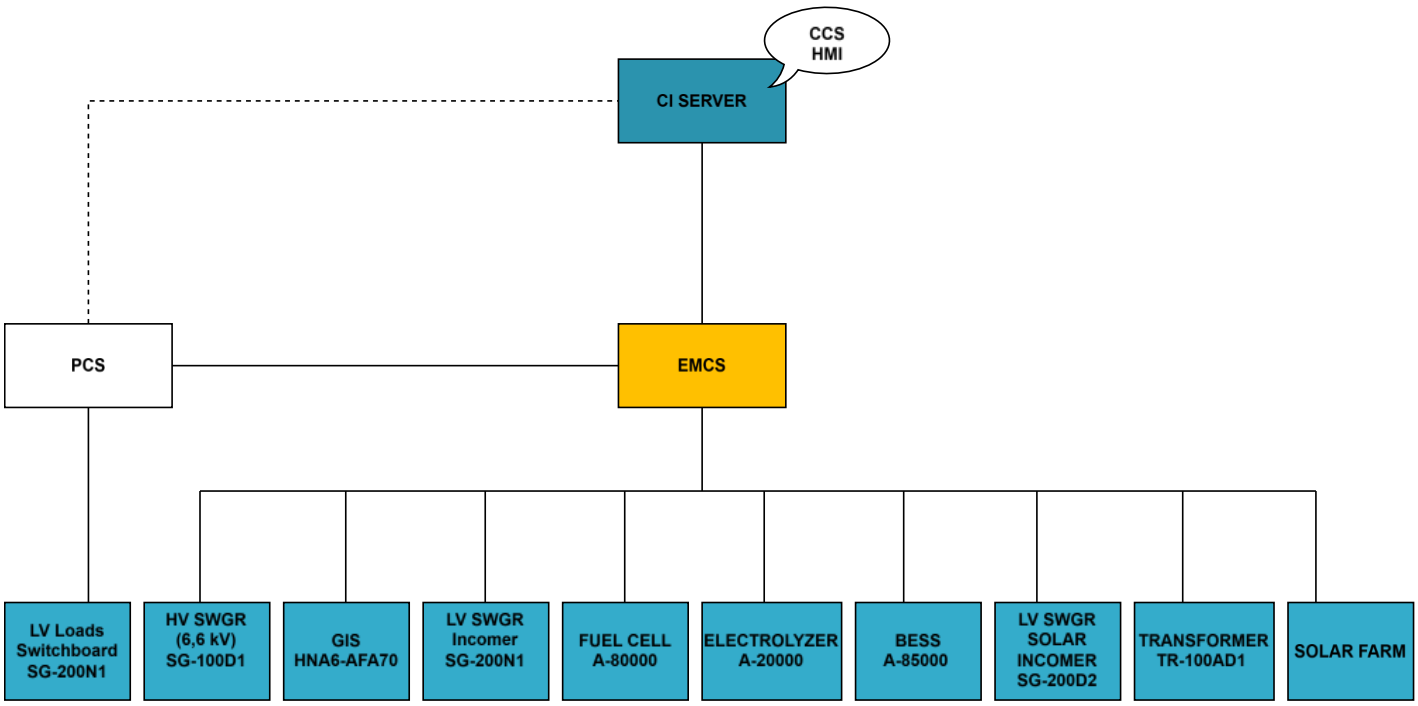


Figure 4 System Architecture Data Flow

4.1.1 Supervision

The EMCS shall gather the real-time power and status signals exposed by the peripheric elements (packages, OLTC, WF HV-SCADA…) and it shall provide these signals to the CCS SCADA, so to feed its supervision and, through the CCS SCADA, enable any higher-level supervision. Among the others, the signals exposed to the CCS SCADA shall include all the permissive signals which enable or prevent the execution of commands, so to allow the SCADA HMI to report to the operator the correct availability of the commands.

The EMCS shall provide to the CCS SCADA all the samples received from the peripheric elements, within the technical limits of the data interface selected.

The EMCS shall expose the original timestamp samples, if available in the communication protocol of the package, in its interface to the CCS SCADA.

For each signal, the EMCS shall expose the data to the CCS SCADA preserving the sequence of events of every sample reported.

In its interface to the CCS SCADA, for these signals the EMCS receives over a protocol without external timestamping, this including hardwired signals, the EMCS shall expose the reception time as the original timestamp of the data.

The EMCS shall expose to the CCS SCADA the real-time value of status and variables defining the state machine of the control policy of the EMCS. The EMCS shall expose to the CCS SCADA its real-time diagnostic signals, so to allow the CCS SCADA to detect the presence of anomalies in the EMCS.

4.1.2 Command

The EMCS shall receive real-time commands, concerning EMCS control functions, from the CCS SCADA.

The EMCS interface for real-time commands with the CCS SCADA, shall be “fire and forget”; i.e.: the reception of a single command message shall be sufficient to produce the execution of the command, without requiring, putting on hold or expecting further interaction with the CCS SCADA.

The EMCS shall not implement intentional delays of the commands received from the CCS SCADA, unless specifically required.

4.1.3 EMCS Flow Chart

In Figure 5 EMCS Flow Chart shows the transition between each mode with respect to the pre-condition.

The 1-minute transition time condition can be considered that the modes transition can take 1-minute. On the other hand, it can be configured in the software algorithm to keep the previous mode until the 1-minute transition time is completed.

These are extreme conditions, but the system knows where to be according to the Status Machine. Additionally, added the "set first execution," which is independent of the time variable. So, if the system is in EMCS automatic mode, grid-tied, and supply guarantee on, the first start/execution will be **1-minute time independent** and moves immediately to the designated mode as per the preconditions. Once the EMCS is in one mode (Export, Cold Stand-by, Hot Stand-by, Import 1A, or Import 1B), it will follow the 1-minute transition time to move from the current mode to another.

If the PCS removes the HotStandby permission, during the HotStandby MODE, the EMCS move to ColdStandby according to BLPH mode Transition.

If the PCS removes the Export permission, during the Export MODE, the EMCS move to ColdStandby according to BLPH mode Transition

If the EMCS is waiting for permission (according to BLPH mode transition) from PCS to enter in Export MODE and PCS don't give the permission within a timeout (PCS.PermissiveModeTimeout), the EMCS move to ColdStandby.

Furthermore, another possible scenario is If the system resets and switches to off-grid mode or EMCS manual mode, the timer will restart. After the reset, the system will focus on meeting the required conditions without considering the timer at first. Once the conditions are met, it will switch between modes every minute (1-minute) based on the timer.

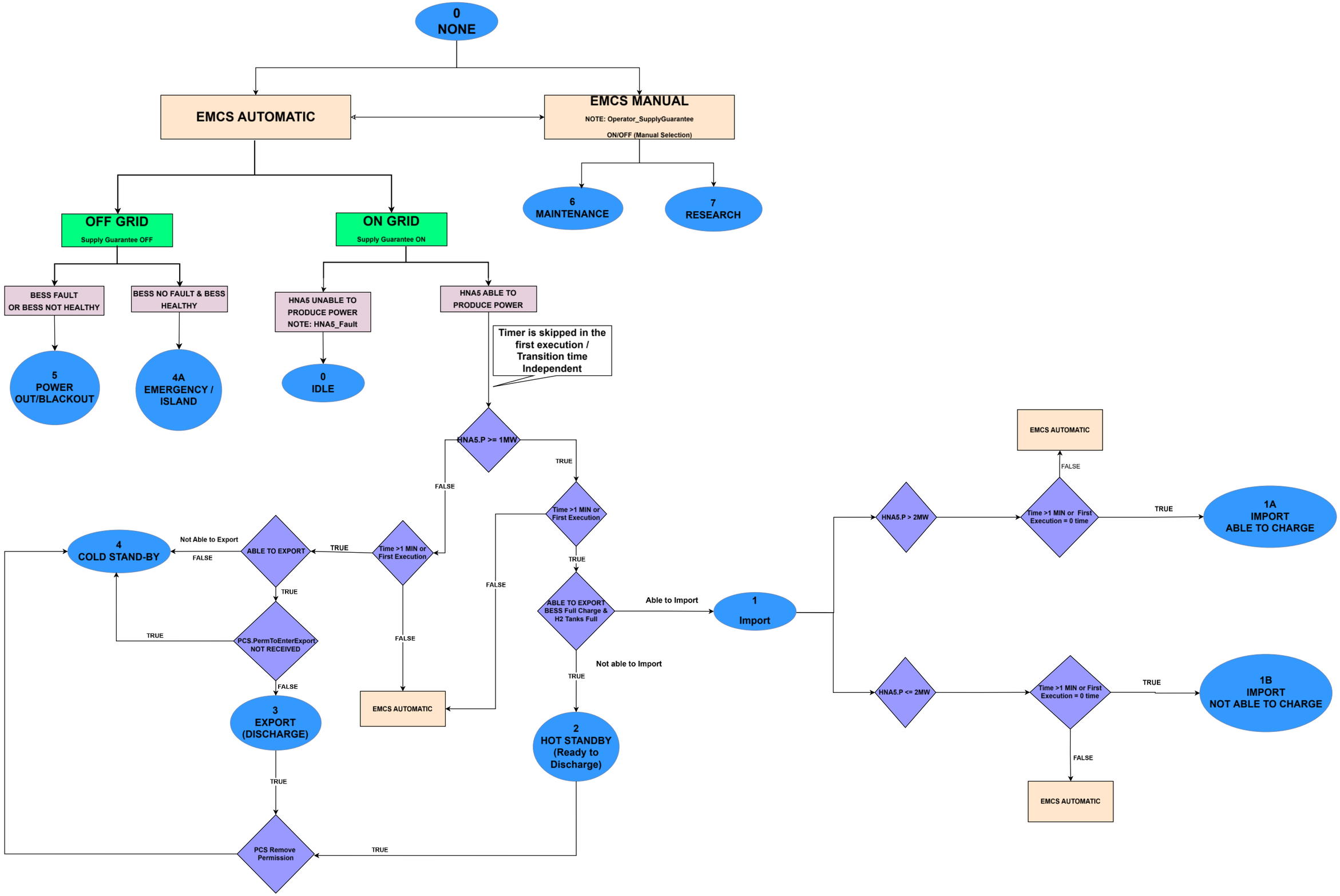


Figure 5 EMCS Flow Chart

4.1.1 EMCS Status Machine



Figure 6 EMCS Status Machine

4.2 Power Control & Energy Management

4.2.1 Energy Management

4.2.1.1 Introduction

When HNA5 is connected / operating and providing at least 1MW to the wind farm 'surplus' power will potentially be available for import to BLPH. This renewable energy will be used to run the plant whilst simultaneously charging the BESS and/or running the electrolyzer to create & store hydrogen.Conversely, when HNA5 provides less than 1MW BLPH will export solar power (if available) and/or the energy stored in the BESS or produced by Fuel Cell to ensure the wind farm continues to receive at least 1MW. NOTE: Power provided by the solar farm shall always (as per preference e.g. Solar production can be curtailed when in Emergency Mode) be used to the fullest extent possible.

The energy management design philosophy described in the project documents is founded on a BLPH logic variable, dubbed MODE, identified by the real time conditions of the BLPH and of the HNA5. The MODE is intended to univocally define the steady-state (i.e. tendential) operational mode of each subsystem of the BLPH, and in particular its power units (Solar Farm, BESS, Fuel Cell, Electrolyzer). In such a design philosophy, the MODE is function of: the ability to operate ("healthiness") of the machines (HNA5, BESS, Fuel Cell, Electrolyzer), the production of the HNA5, the status of electrical interconnection of the BLPH to the grid. The control policy was supposed to do not affect any of these conditions with its activity, with the exception of the state of the energy reserves (BESS and hydrogen), which indirectly affects the ability to operate of BESS and Fuel Cell. Such design philosophy, and particularly the provided descriptions of the MODES, introduces some constraints and deviations from the goal defined in the Functional Statement. Due to this, the latter is not supposed to be the direct basis of the functional requirement of the control.

In the following, we preserved such base structure of the design philosophy, updating it considering the additional available information, merging different statements, and finally translating it into functional requirements. In merging conflicting inputs, we have been driven primarily by the mentioned Functional Statement and secondarily by an interpretation of the aim of the constraints introduced in the definition of the MODES.

There are some main elements introduced in the present definition of the BLPH state-machine that shall be noted:

- **State-machine transitions are driven by trigger conditions**: Instead of having predefined status conditions for each mode, the state machine transitions are defined by specific trigger conditions that occur within each mode.
- **Decoupling of BLPH and subsystem state-machines**: The effect of a MODE on subsystem transitions (mainly for the packages) is clearly defined, rather than relying on a strict, one-to-one mapping between the statuses of the mode and the statuses of the subsystems' state-machines.

4.2.1.2 Assumptions & Definitions

The BLPH is always in a single MODE at a time.

The BLPH MODE state-machine is fully determined by the real-time conditions reported to the EMCS, except for stabilization control features as hysteresis and inertia implemented in the EMCS.

The BLPH MODE state-machine has the following pseudo steady-state statuses, dubbed MODES:

- MODE 0 = IDLE (Power Import Only)
- MODE 1A = IMPORT MODE (Able to Charge)
- MODE 1B = IMPORT MODE (Not Able to Charge)
- MODE 2 = HOT STANDBY (Ready to Discharge)
- MODE 3 = EXPORT MODE (Discharge)
- MODE 4 = COLD STANDBY (Power Import: Not able to Export)
- MODE 4A = EMERGENCY MODE (Island)
- MODE 5 = POWER OUT (Black-Out)
- MODE 6 = MAINTENANCE
- MODE 7 = RESEARCH
- MODE 8 = NONE MODE

The additional NONE MODE is intended for specific conditions, such as during EMCS initialization except after the BLACK START scenario because after black start scenario the initialization will start from RESEARCH MODE.

The EMCS should try to use the solar farm to the maximum extent possible.

The charging of the BESS while the Fuel Cell is producing shall be considered energy inefficient in steady-state condition.

There is no requirement to prevent in hard-lock (as with an interlock) the charging of the BESS while the Fuel Cell is producing; it is allowed to happen in transients (and it must be allowed in off-grid scenario, for system balance).

The EMCS shall be designed such that rapid cycling / quick switching of the BESS, Fuel Cell and Electrolyzer is prevented.

The fuel cell internal production balancing logic implemented by the fuel cell controller foresees committing fuel cell modules in sequence, according to the power set-point. Due to this, the raise of the set-point over specific levels produces the start of the warmup of part of the still unused modules; conversely, the decrease of the fuel cell power set-point may produce the stop of some modules in production.

The HNA5 Active Power value will be delivered to the EMCS through the interface link with the Wind Farm (HV-SCADA)

The Active Power of BLPH is calculated as the sum of BESS, Fuel Cell & HNA5 Power in EXPORT MODE.

The Supply Guarantee is defined on the based of three key signals:

- **Operator_SupplyGuarantee**: A selector configured by the operator via the SCADA HMI, which can take one of three values: AUTOMATIC, ACTIVE, or INACTIVE.
- **HNA5_SupplyGuarantee**: A signal provided by the HV SCADA, indicating whether the BLPH platform is connected to grid (TRUE) or not (FALSE).
- **HV_SCADA_Connected**: A signal confirming whether the EMCS is connected to the HV SCADA communication server.

The Supply Guarantee formula is:

SupplyGurantee (OperatorSupplyGuarantee = AUTOMATIC AND HNA5_SupplyGurantee AND HV_SCADA_Connected) OR

Operator_SupplyGuarantee = ACTIVE

“Power Surplus” definition: It refers to the HNA5 Wind Turbine producing Active Power > 1MW.

The EMCS will drive the electrolyzer as a load (ON/OFF), no partialization will be implemented.

The energy management policy implemented by the EMCS shall foresee to stop the electrolyzer only if the hydrogen storages are full.

For the Energy Management goals, in case HNA5-AFA70 power will go under zero, it shall be considered as zero production.

The EMCS has no control over the HNA5 or the wind farm, this including the related electrical equipment.

The BLPH activity has no direct or indirect effect on the ability to operate or the production of the HNA5 or the wind farm, this includes the status of the related electrical equipment. This includes the absence of any control logic of the HNA5 or wind farm that takes in input any status or level from the BLPH, so to avoid the creation of any feedback loop. The EMCS is not in charge of implementing any electrical protection function. Among the others, this holds true with specific reference to overcurrent, underfrequency, undervoltage, synchronization check functions and safety interlocks.

EMCS will open the CB of a package on SG-100D1 if the package does not apply control requests.

For example, if the EMCS will send the stop command to the Fuel Cell, and it does not stop within a timeout (parametric), the EMCS will open the related CB on the SG-100D1.

POWER GUARANTEE is defined on the basis of the signals:

- SUPPLY GUARANTEE;
- HNA5_FAULT not active

In this way BLPH will be able to compensate the production of HNA5 and ensure, to the grid, at least 1 MW of active energy exported; regardless of the availability of wind/solar energy.

The “BESS charge level” and the related BESS-MINIMUM-OPERATING-RESERVE (and the others parameters about “BESS charge levels”) are based on absolute values of energy, expressed in MWh: As per confirmation from the BESS vendor, the BESS exposes over the data interface the absolute value of energy available to discharge, and this value is representative of the BESS ability to produce power and hence to sustain the isolated grid.

4.2.1.3 Description of Requirements Priority & Evaluation Rule

Conditions						MODE	Specific exit contition
EMCS in automatic identification of the MODE	Grid-tied AND Supply Gurantee ACTIVE	HNA5 NO Fault	HNA5.P < 1 MW for a min time (1 minute)	Able to export		**EXPORT** (Discharge)	PCS.Remove Export Permission
				Not able to export		**COLD STANDBY** (Not Able to Discharge)	
			HNA5.P >= 1 MW for a min time (1 minute)	Not able to import	Able to export (BESS full charge & H2 Tanks full)	**HOT STANDBY** (Ready to Discharge)	When PCS.Remove Hot Standby Permission
				Able to import	HNA5.P > 2 MW for a min time (1 minute)	**IMPORT 1A** (Able to Charge)	
					HNA5.P <= 2 MW for a min time (1 minute)	**IMPORT 1B** (Not Able to Charge)	
		HNA5 Fault				**IDLE** (Power Import Only)	
	Off-grid (i.e. not grid-tied) OR Supply Guarantee INACTIVE	BESS → NO FAULT				**EMERGENCY** (ISLAND)	
		BESS → FAULT (ie. BESS problems, BESS SoC in low range, etc.)				**POWER OUT** (Black Out)	
Command to enter in RESEARCH MODE						**RESEARCH**	Command to return in automatic identificatio the mode
Command to enter in MAINTENANCE MODE						**MAINTENANCE**	Command to return in automatic identificatio the mode
Default / fallback						**NONE**	

Figure 7 BLPH Mode Transition Table

Figure 7 BLPH Mode Transition Table demonstrates the conditions under which the EMCS transitions between different modes take place. It categorizes these conditions based on the system being grid-tied or off-grid (i.e.: not grid-tied), with further distinctions depending on whether the HNA5 Fault or HNA5 No Fault, and specific power thresholds (HNA5.P < 1 MW and HNA5.P >= 1 MW) that determine the system's ability to export or import power. For instance, when grid-tied with the Supply Guarantee on and HNA5.P < 1 MW for a minimum time (1-minute), the system enters either in EXPORT or COLD STANDBY mode based on its export capability. Conversely, with HNA5.P >= 1 MW for a minimum time (1 minute), the system can enter HOT STANDBY (Ready to Discharge) if it can't import (able to export, when BESS is fully charged & H2 storage are full). On the other hand in the similar condition if the system is being grid-tied, Supply Guarantee ON and HNA5.P >= 1 MW but able to Import in two conditions, first condition is if HNA5.P > 2 MW for (1-minute) the system will enter in IMPORT MODE 1A (Able to Charge), second condition is if HNA5.P <= 2 MW for (1-minute) the system will enter in IMPORT MODE 1B (Not able to Charge). If the HNA5 is in Fault, the system remains in IDLE mode. Off-grid scenarios are distinguished by the status of BESS (NO FAULT) & MV 6.6kV bars, with energized bars triggering EMERGENCY mode and non-energized bars triggering POWER OUT mode BESS (FAULT). Special modes like RESEARCH and MAINTENANCE can be manually entered (protected by password), with specific commands to revert to automatic mode identification.

To ensure optimal operation and accurate mode transitions, the system prioritizes safety, placing the highest importance on modes like EMERGENCY and POWER OUT. Operational efficiency follows, prioritizing modes such as EXPORT and IMPORT. Reliability ensures the system transitions seamlessly into HOT STANDBY and COLD STANDBY when needed, while flexibility allows entry into RESEARCH and MAINTENANCE modes without disrupting performance. The system continuously monitors conditions, verifying them against mode criteria and applying transition logic to shift to the appropriate mode. It resolves conflicts using predefined priority rules and checks exit conditions for special modes, reverting to automatic identification when necessary.

If the EMCS is in Export mode and the PCS permission to stay in Export mode is removed, the BLPH will transition to Cold standby.

If the EMCS is in Hot standby mode and the PCS permission to stay in Hot standby mode is removed, or if the BESS is at fault, the BLPH will transition to Cold standby.

If the EMCS is waiting the permission (according to BLPH mode transition) from PCS to enter in Export MODE and PCS don't give the permission within a timeout (PCS.PermissiveModeTimeout), the EMCS move to ColdStandby.

NOTE: The EMCS shall always choose an operating mode. If the conditions to enter or remain in an operating mode fail or are not met, the EMCS will move the BLPH into another operational mode. While waiting for signals from other systems, the BLPH will remain in the previous mode and the HMI will blink.

In healthy status the BESS is able to operate. For the definition of HEALTHY status see paragraph 4.2.1.6.3.

Definition of HNA5_Fault: The HNA5 Fault is determined based on the Wind Turbine Status codes, which reflect the turbine's current state. The status codes are as follows:

Code	Turbine State
0	Operating - On Grid
1	Operating - Waiting for converter cut-in
2	Operating - Waiting for release
3	Operating - Waiting for wind/acceleration
4	Stopped - Pitch exercising/lubrication
5	Stopped - Untwisting cables
6	Stopped - Wind speed too high
7	Stopped - Grid error
8	Stopped - Error with auto-reset (only applicable for WTC3)
9	Stopped - Manual alarm reset required
10	Safety Stop (only applicable for WTC3)
11	Remote Stop

Fault Condition

The wind turbine is considered in a fault state if the status code matches any of the following values:

HNA5_Fault:

- Status = 7
- Status = 8
- Status = 9
- Status = 10
- Status = 11

OR if the HNA5_QA1 CB is OPEN

4.2.1.4 Layered Structure Among State-machine

The state-machine composing the system: Design includes one State Machine for the BLPH and one State Machine for each package, which is as follows:

- BLPH
- Electrolyzer
- BESS
- Fuel Cell
- Solar Farm

In Figure 8 BLPH State Machine Transition, state-machine of each package interacts with the state-machine of BLPH MODE, as the status of one can enable or trigger the transitions in another. The logic works in layer, each layer can perform the actions allowed by the lower layer.

The power control policy is implemented through the BLPH MODE state-machine, which translates these policies into specific operational modes. Subsystem state-machines then execute actions allowed by the BLPH MODE, ensuring that interlocks and permissions managed by the PCS are respected.

4.2.1.5 BLPH State-Machine

The BLPH MODE state-machine governs the overall operational mode of the system. It interacts with the state-machines of various subsystems to coordinate transitions and ensure cohesive operation. This interaction ensures that changes in one subsystem can trigger necessary transitions in others, maintaining an integrated control approach.

The hierarchy of logics is as follows:

- BLPH Power Control Policy
- BLPH MODE state-machine
- Sub-system state-machine
- Interlocks / Permissions (e.g. PCS coordination)
- Physical capability & communication limits.

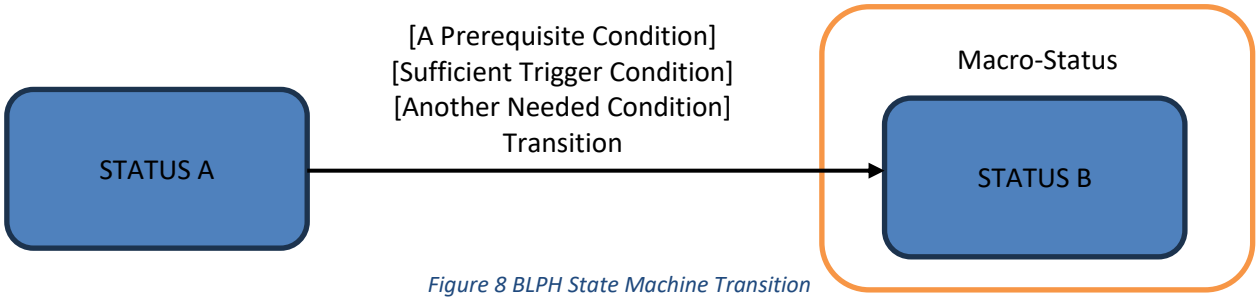


Figure 8 BLPH State Machine Transition

4.2.1.6 Electrolyzer State Machine

In Figure 9 Electrolyzer State Machine manages the electrolyzer's operation through states such as Running, Stoppable, Started, and stop. It transitions between these states based on conditions like running duration and PCS permission.(For Example: the system will transition to Stop state if PCS permission is revoked (i.e., H2 storages are full).

The BLPH State Machine will correspond with Electrolyzer State Machine, to do the following:

- EMCS requires permissive signal from PCS to start the Electrolyzer. (i.e. PCS.PermToStartEL).
- EMCS shall not partialize the Electrolyzer, requiring it either to not produce or to produce at full power (EL_MAX_SET_POINT).
- If the PCS.PermToStartEL is not fulfilled or if the signal shall be remove during the working, the Electrolyzer will be stopped by EMCS.
- If the PCS.PermToStartEL is not reached, EMCS will not give the start command to the Electrolyzer.

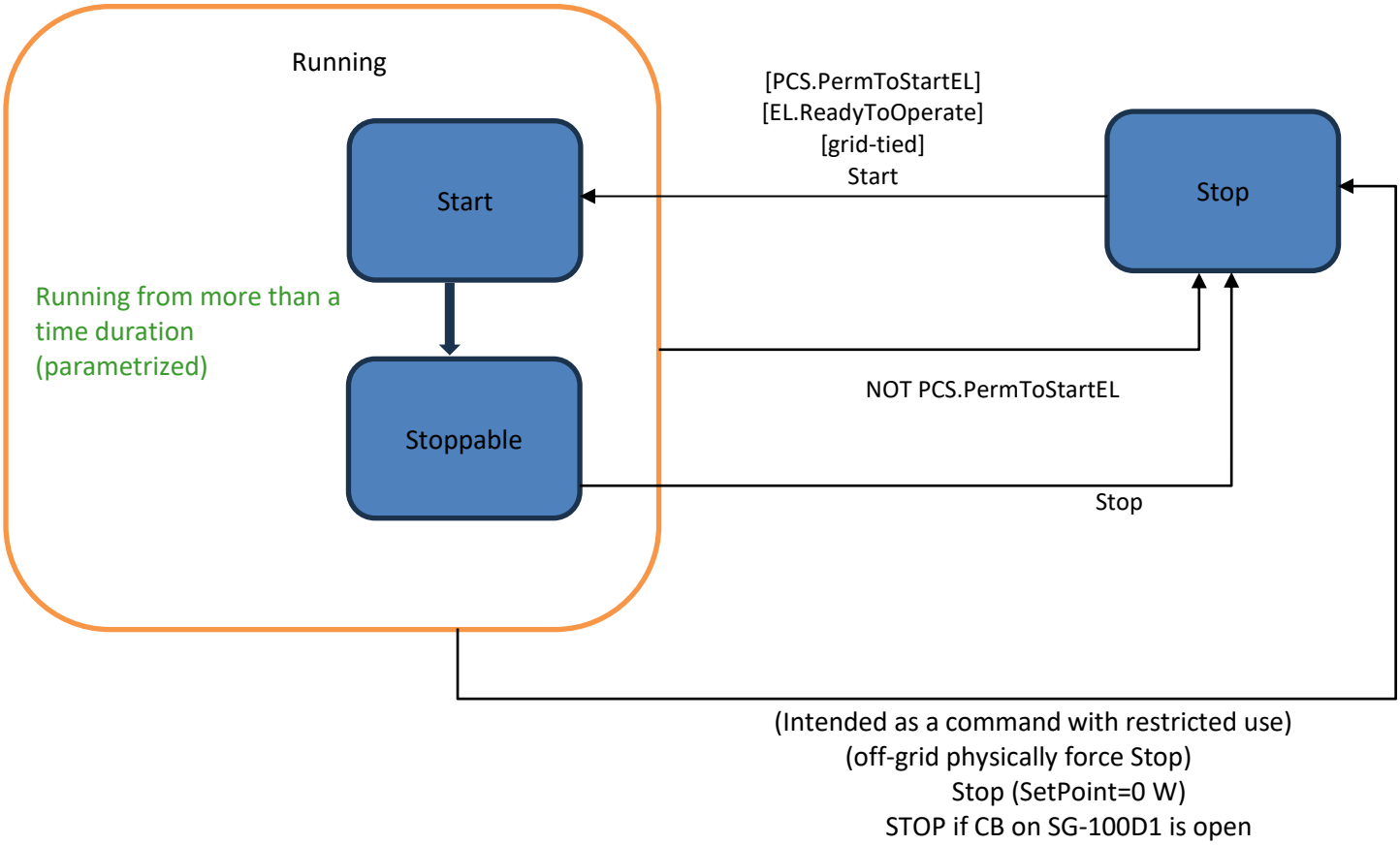


Figure 9 Electrolyzer State Machine

4.2.1.7 Fuel Cell State Machine

EMCS manages the Fuel Cell according to Figure 11 Fuel Cell Container State Machine and transitions between these states are based on conditions like running duration and PCS permission (for example: the system will transition to Stop state if PCS permission is revoked (i.e., H2 storages are empty)).

The BLPH State Machine will correspond with Figure 10 Fuel Cell State Machine , to do the following:

- EMCS requires permissive signal from PCS to start the Fuel Cell. (i.e., PCS.PermToStartFC).
- EMCS send the set point according to the Fuel Cell Setpoint.
- If the PCS.PermToStartFC is not fulfilled the Fuel Cell will be stopped by EMCS.
- If the PCS.PermToStartFC is not reached, EMCS will not give the Start command to the Fuel Cell.

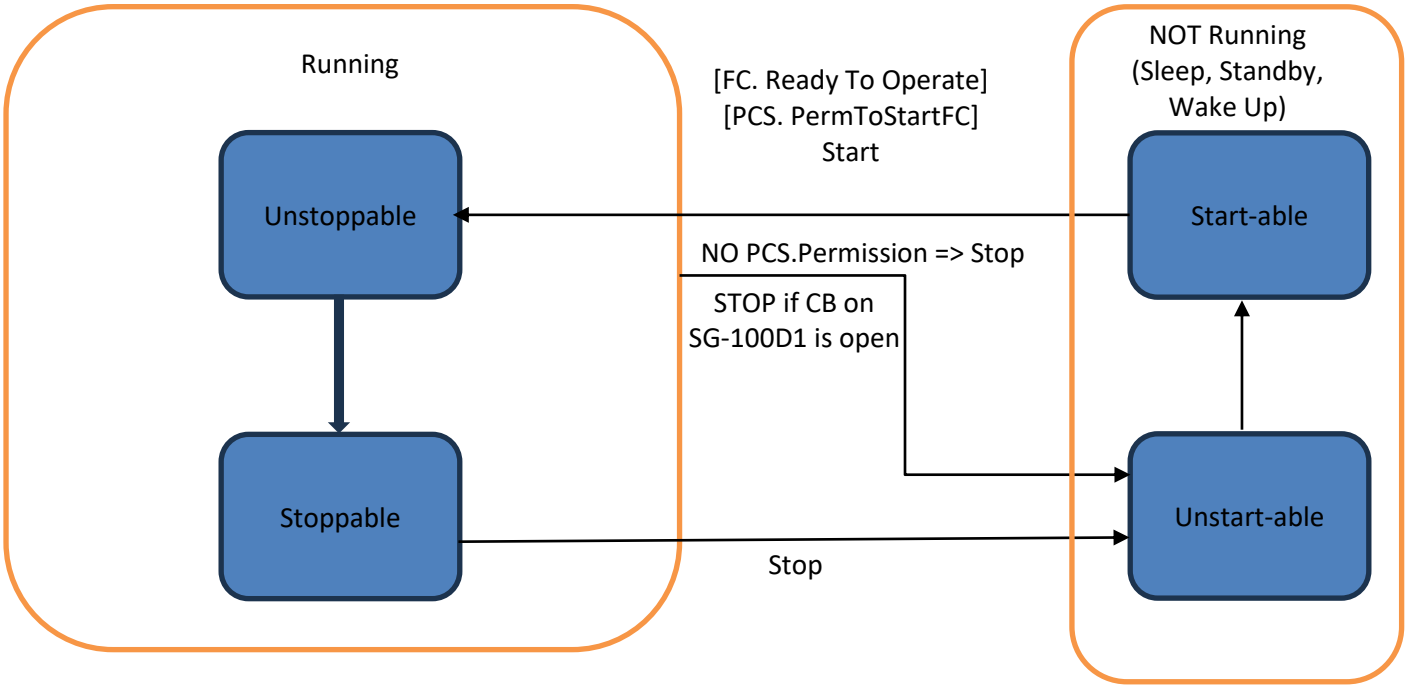


Figure 10 Fuel Cell State Machine

The commands to the Fuel Cell must be issued according to Figure 11 Fuel Cell Container State Machine, the process must follow the steps without skipping any, as detailed below:

1. FC is in SLEEP
   1. EMCS command WAKEUP
   2. FC moves to STANDBY
   3. After receiving the STANDBY feedback from FC → EMCS command START

2. FC moves to RUNNING
   4. FC is in RUNNING
   5. EMCS command STOP
   6. FC moves to STANDBY
   7. After receiving the STANDBY feedback from FC → EMCS command SLEEP (if necessary)

3. The EMCS set-point will be in kilowatts (kW) not in percentage (%), with a minimum set-point of 50 kW. It is possible to send a new set-point value every second, but repetitive toggling (e.g., set-point value → 0 → set-point value → 0 → …) is not allowed.

4. To keep the Fuel Cell in the RUNNING state, a minimum set-point of 50 kW must be provided. The Fuel Cell will then continue to produce 50 kW of energy, otherwise the STOP command is issued, and the Fuel Cell will transition to STANDBY after 5 minutes. In STANDBY state, it can remain indefinitely as needed.

5. After the STOP command from EMCS, the Fuel Cell transitions to the RAMPDOWN state, during this phase, the Fuel Cell continues to produce energy (even if the set-point is 0). In this state, energy production decreases by 100 kW every second. The starting point depends on the previous set-point set by the EMCS during RUNNING state.

6. If the Fuel Cell (CB) on the SG-100D1 panel (6.6kV) opens, there are no issues from the CPI's perspective. The Fuel Cell package will self-adapts.

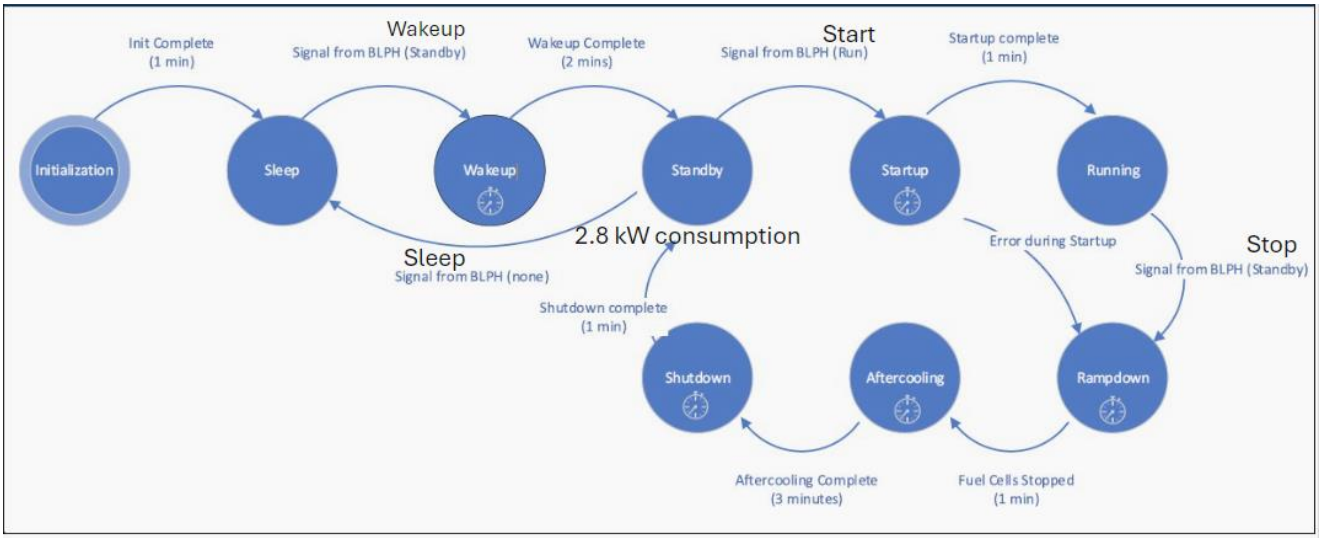


Figure 11 Fuel Cell Container State Machine

4.2.1.8 BESS State Machine

In Figure 12 BESS State Machine Figure 12 BESS State Machinemanages the charging and discharging processes of the Battery Energy Storage System. States include Charging, Discharging, and Idle, influenced by the Available Energy and PCS permissions via EMCS. The system will charge if the Available Energy is below the maximum threshold and PCS permission is granted via EMCS, and it will discharge if the Available Energy is above the minimum threshold and PCS permission is granted via EMCS. The system transitions to Idle if PCS permission is revoked via EMCS.

To start BESS, via EMCS, as per the IO list "23A2007_240628_PROFINET_Register BESS_V1_0_0_3 " (Profile_converter_control 1.13) which: IF set to 1 = BESS start, IF set to 0 = BESS Stop.

Available Energy for charging, Profile_converter_status_3, charge_energy, defines the remaining capacity that can be charged into the BESS which (i.e., 200(Kwh), then 200(Kwh) can be stored in the BESS).

Available Energy for Discharging, Profile_converter_status_3, discharge_energy, defines the available energy for discharge from the BESS (i.e., 200(Kwh), then 200(Kwh) can be discharged from the BESS)

The Sum of Charge and Discharge Available Energy is equal to the maximum BESS capacity

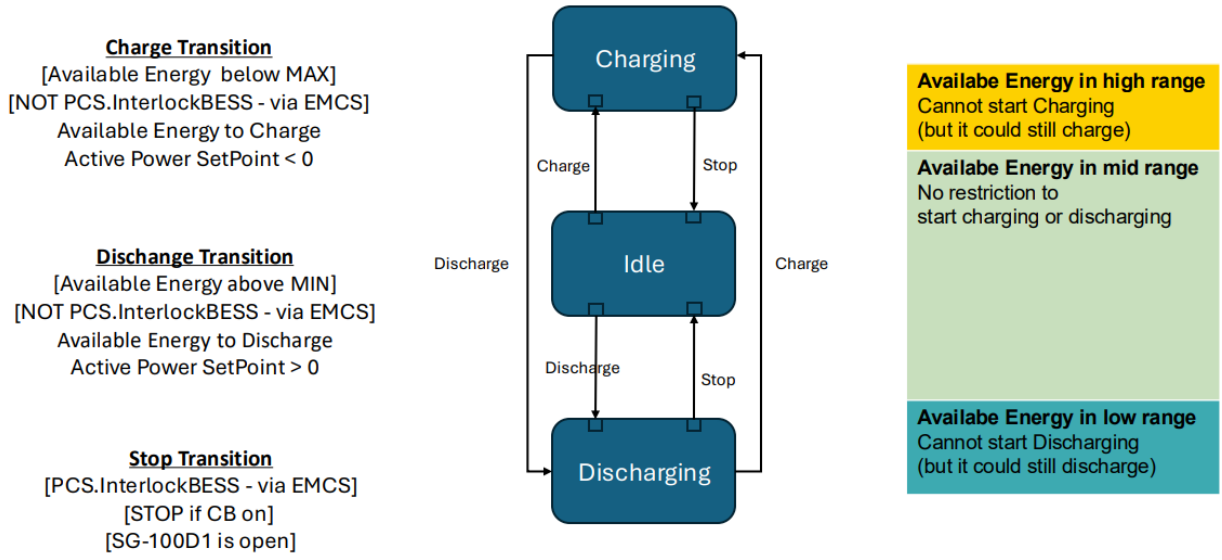


Figure 12 BESS State Machine

4.2.1.9 Solar Farm State Machine

In Figure 13 Solar Farm State Machine Figure 13 Solar Farm State Machineillustrates transitions between "Started" and "Stopped" states within the broader context of "Operating." The "Started" state indicates that the system is actively managing or generating energy, whereas the "Stopped" state signifies that the system is not operating and has been shut down. Conversely, the transition from "Started" to "Stopped," labeled as "Shutdown," can occur due to critical conditions such as emergency mode activation or the system not being grid-tied, ensuring the system is safely deactivated when necessary. Within the "Started" state, there is a loop indicating the "Curtail" action (EMERGENCY MODE only), which allows the system to reduce or adjust its output without shutting down completely, in response to conditions like excess energy production. This ability to curtail helps maintain efficient energy production while staying operational.

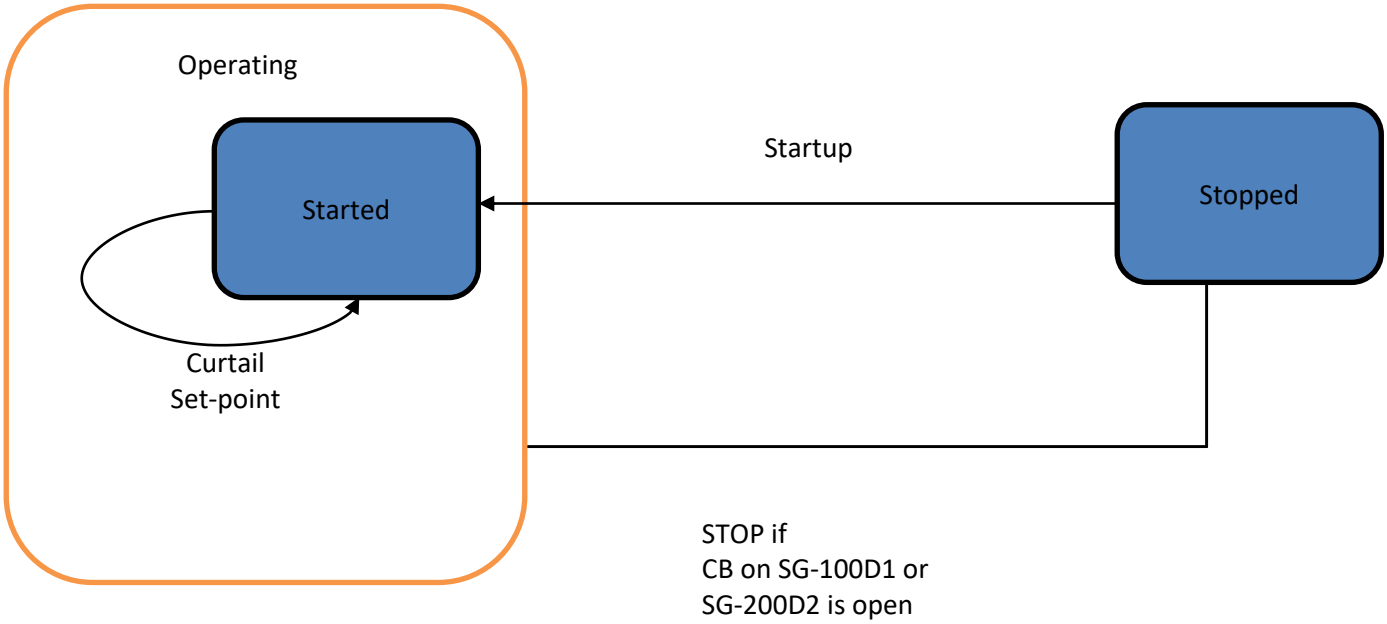


Figure 13 Solar Farm State Machine

4.2.1.10 General requirements on the Energy Management Policy

The EMCS shall drive the production and consumption of the power units in the BLPH and the Solar Farm according to a pre-defined, deterministic state-machine of the BLPH; such state-machine being defined in the present functional requirement specifications, specifically about the MODE.

The EMCS shall identify the real-time value of the BLPH MODE, reporting it over the data interface to the CCS SCADA.

The EMCS shall report the supply Guarantee request status over the data interface to the CCS SCADA.

The EMCS shall expose a command to the CCS SCADA under password protection that allows the operator to set the Operator_SupplyGuarantee to INACTIVE only in manual mode (i.e. Maintenance or Research)

The EMCS shall expose to the CCS SCADA, under password protection, the following parameters:

- WINDFARM_SURPLUS_MIN_POWER (set to +1MW)
- WINDFARM_SURPLUS_MIN_POWER_ABLE_TO_CHARGE (+2MW by HNA5)
- WINDFARM_SURPLUS_MIN_TIME_ENTRANCE_INERTIA (60sec by HNA5)

The EMCS shall expose a command to the CCS SCADA that forces the MODE into any of the listed values. NOTE: This means that the EMCS may act according to the control policy defined by a MODE, independently from the actual conditions of the system under password protection, the wind farm and the environment.

As outlined in the paragraph 4.2 Power Control & Energy Management , these parameters are used to determine the BLPH power in each mode.

The WINDFARM_SURPLUS_MIN_POWER_ABLE_TO_CHARGE parameter must be greater or equal to WINDFARM_SURPLUS_MIN_POWER , the modification of the parameters must be validated at the OPC-UA EMCS interface level. Any change that violate the above rule shall be denied and the current value of the parameter is kept.

4.2.1.11 General requirements on the Power Distribution Management

By default (i.e. unless required to open or keep open), the EMCS shall ask to close and keep closed all the MV (6.6kV) outgoing feeders of the BLPH distribution under the busbar SG-100D1, this including the Solar Farm. This requirement explicitly does not apply to the incoming MV switchgear and upstream equipment.

By default (i.e. unless required to open or keep open), the EMCS interacts with PCS to close and keep closed all the contactors of the BLPH LV loads (switchgear SG-200N1). Solar Farm interacts with EMCS interface to drive the switchgear SG-200D2 (managed by the Solar Farm via EMCS).

If an operator should manually open a circuit breaker locally (BLPH), the EMCS system must not close it automatically, even if it is in automatic logic. Instead, it should send an alarm signal to the HMI and HV-SCADA indicating the authorized opening of a circuit breaker. This is because the command to open the circuit breaker also functions as a STOP protection.

EMCS shall implement out-of-command timeout of the stop packages commands, EMCS shall implement the related open command on each 6.6kV CB on SG-100D1 (even if this is due to the package being in local).

4.2.1.12 Grid forming service

The EMCS shall provide the BESS a HW permissive signal that enables the grid-forming mode. By default, the signal shall be True. If the BESS charge level is below the BESS-MINIMUM-OPERATING-RESERVE threshold, or BESS is not HEALTHY. The EMCS shall set to False the permissive signal that enables the grid-forming mode to the BESS.

BESS will operate in Grid forming only when HW signals (1 from EMCS and 1 from SG-100D1 [parallel of open states of CB]) are active.

BESS will operate in Grid forming, following the loads without any necessity to receive the set-point from the EMCS, the maximum load allowed in Grid forming is 1MVA.

4.2.1.13 General policies on the machines transitions

4.2.1.6.2 ELECTROLYZER

The EMCS shall not partialize the Electrolyzer, requiring it either to not produce or to produce at full power (EL_MAX_SET_POINT).

All the package control signals (Status & Commands) will be exchanged with BLPH State-machine through PROFINET Communication.

The EMCS shall not stop the Electrolyzer on the sole basis of the production needs required by the energy management policy (given by the MODES).

The EMCS shall stop the hydrogen production by the Electrolyzer when the storages are full (i.e. 100% value).

The EMCS request to the PCS the permissive to start the Electrolyzer and, after receiving "PCS.PermToStartEL" (true), it commands the start.

When "PCS.PermToStartEL" (permissive signal allowing the Electrolyzer to run) is set to false, the EMCS sends a command to stop the Electrolyzer. The PCS send also the "Process Fully Charged Status" to EMCS informing that storages are full.

The PCS shall allow to start the Electrolyzer via EMCS only if the stored hydrogen level is below a threshold. When the Electrolyzer starting to produce Hydrogen, as per the EMCS requirement, PCS starts the "Process Charging Mode". The "Process Charging mode" is a normal operating mode when the hydrogen storages are not full after a process discharging mode and the storage that previously contained hydrogen shall be refilled.

"WATCHDOG" EMCS shall write a value in variable periodically, sending different values every second.

EMCS shall set the value of "Setpoint_Choice" to zero and will manage the Electrolyzer only using the PowerSetpoint (FlowSetPoint is not used).

"Status_Electrolyzer", EMCS assumes that the Electrolyzer will ignore all commands when the status is one of the "LOCAL MODE" group. On the other side, the EMCS assumes that the Electrolyzer can receive set points command when the status is one of the "DISTANT MODE/REMOTE MODE" group.

The EMCS will consider the active power of Electrolyzer measured at SG-100D1.

The EMCS shall allow the start of the Electrolyzer only if the Electrolyzer is ready to operate, status_electrolyzer (14: MODE Stand-by)

4.2.1.6.3 BESS

The EMCS shall allow the request of BESS discharge (i.e. start and keep going) only if the BESS charge level is above the BESS-MINIMUM-OPERATING-RESERVE. The EMCS shall allow to set such parameter over the data interface with the CCS SCADA.

The EMCS shall allow the request to start BESS discharge only if the BESS charge level is above the BESS_HIGH_OPERATING_RESERVE. The EMCS shall allow to set such parameter over the data interface with the CCS SCADA, and it shall be not lower than the BESS-MINIMUM-OPERATING-RESERVE value. Signal "Available Energy for Discharging" (profile_converter_status_3.Discharge_Energy in IO List) indicates the available energy for discharge.

The EMCS shall allow the request of BESS charge (i.e. start and keep going) only if the BESS charge level is below the BESS-MAXIMUM-OPERATING-RESERVE. The EMCS shall allow to set such parameter over the data interface with the CCS SCADA. Signal "Available Energy for Charging" (profile_converter_status_3. Charge_Energy in IO List) indicates the remaining capacity that can be charged into the BESS.

The EMCS shall allow the request to start BESS charge only if the BESS charge level is below the BESS_LOW_OPERATING_RESERVE. The EMCS shall allow to set such parameter over the data interface with the CCS SCADA, and it shall be not higher than the BESS-MAXIMUM-OPERATING-RESERVE value.

The figure below shows the BESS operating parameters:

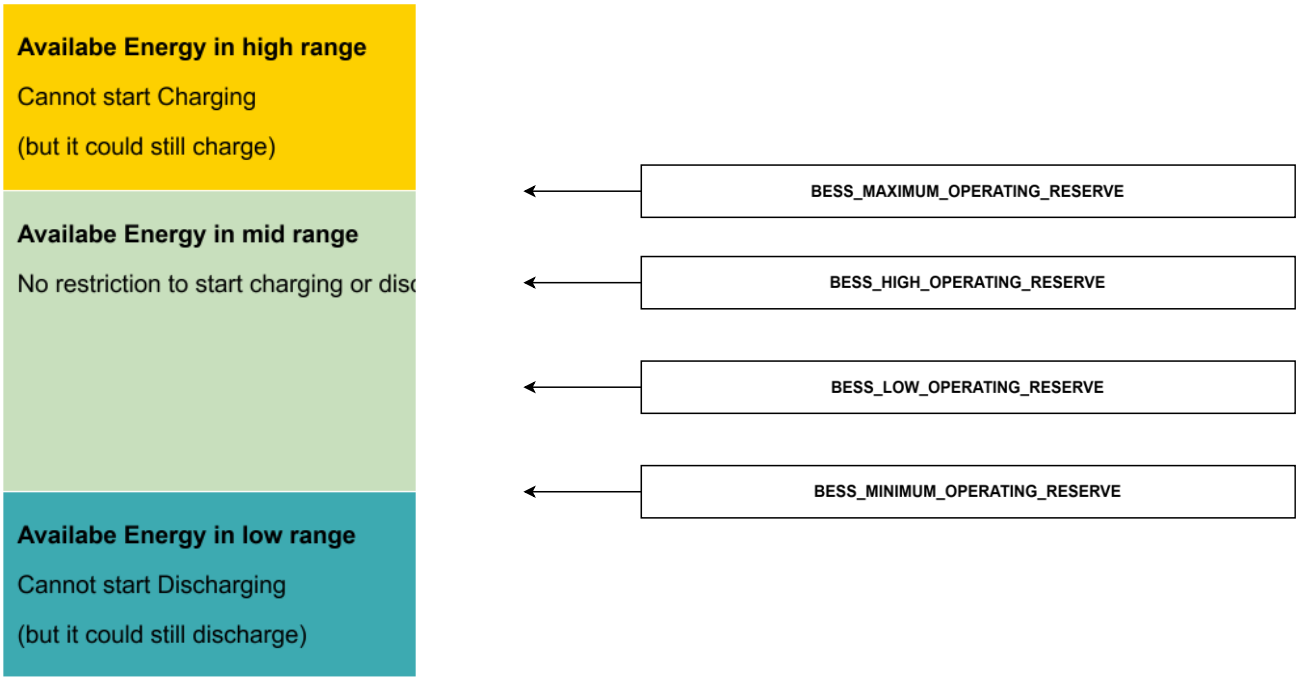


Figure 14 – BESS Operating Parameters

The EMCS shall allow to START & STOP the BESS with control variables (profile_converter_control 1.13):

IF set to 1 = BESS START

IF set to 0 = BESS STOP

The following values must be kept every time the profile_converter_control 1.13 signals are sent to BESS.

In HEALTHY status the BESS can operate in grid-forming mode, ensuring that the BLPH can operate as defined in the EMERGENCY mode (disconnected from the wind farm) providing energy for equipment and most important loads.

If the BESS is not HEALTHY, the BLPH disconnection from the grid will lead the EMCS to operate in POWER OUT mode, causing the opening of the relevant switchgears to prevent damage of the equipment.

On the basis of the BESS I/O list, a healthy status can determined by the satisfaction of the following conditions:

Healthy = Profile_converter_status_3.available == true **AND**
Profile_converter_status_3.BESS_CPI_STATUS = true **AND**
Profile_converter_status_3.SOC > [CONFIGURABLE_SOC_THRESHOLD] **AND**
Profile_converter_status_1.Statusword.BIT_1 == 0 **AND** "Error"
(Profile_converter_status_1.Statusword.BIT_3 == 1 **OR** "Standby State"
Profile_converter_status_1.Statusword.BIT_5 == 1 **OR** "Ready State"
Profile_converter_status_1.Statusword.BIT_6 == 1 **OR**) "Active State"

Give the following StatusWord definition

Bit	**Name**
0	Warning
1	Error
2	Preheat State
3	Standby State
4	Precharge State
5	Ready State
6	Active State "In Operation"
7	Safety relais triggered

When EMCS receives the "BESS in fault" signal from the PCS, the EMCS stops immediately the BESS (regardless of the BLPH operating MODE).

4.2.1.6.4 FUEL CELL

The EMCS shall allow the start of the fuel cell only if it receives the PCS.PermToStartFC permissive signal (i.e., the stored hydrogen level is above a FUEL_CELL_MIN_H2_THRESHOLD: default 0 kg). All the package control signals (Status & Commands) will be exchanged with BLPH State-machine through MODBUS TCP Communication.

The EMCS shall change the fuel cell set-point applying a deviation-vs-time filter on the requested value (the tendential set-point), unless the update is forced. Such deviation-vs-time filter shall produce an update of the signal according to the following conditions (evaluated in this given order), compared to the value and time of the last update:

1. Do not update before a FC-SETPOINT-MIN-UPDATE-TIME (default value 10 seconds);
   - This limitation is used to limit the rate of set point sent;
2. Update after FC-SETPOINT-MAX-UPDATE-TIME (default value 60 seconds);
   - The sent point will be sent after this parametric period (60 seconds) even if the setpoint is not changed;
3. Update if the upward deviation is more than FC-SETPOINT-HIGH-DEVIATION (default value 50 kW) and update if the downward deviation is more than FC-SETPOINT-LOW-DEVIATION (default value 50kW).
   - This parametric range is used as a dead-band: if the set point changes within this range, no sent point is sent to the Fuel Cell (at least before the FC-SETPOINT-MAX-UPDATE-TIME time is elapsed)

The EMCS shall allow to set the parameters of the fuel cell set-point deviation-vs-time filter over the data interface with the CCS SCADA.

The EMCS shall set a power set-point of zero on the fuel cell for any value that would otherwise be less than the FC-MIN-NONZERO-SETPOINT parameter (defined non-negative, default value 0.05 MW), so to prevent the request of set-points lower than the threshold and different from zero. The EMCS shall allow to set such parameter over the data interface with the CCS SCADA.

4.2.1.6.5 SOLAR FARM

The EMCS shall allow the start of the solar farm only if the solar farm is ready to operate.

The EMCS assumes that the Solar Farm Controller will follow a given setpoint (available for control) when the following logic is met:

Status= 0x0001 **AND**	**//**(Operating)
Remote Control Available= 0x0001 **AND**	**//**(Available)
Solar Farm Main CB Closed status = 0x0001 **AND**	**//**(Closed)
Solar Farm Main CB Open status = 0x0000 **AND**	**//**(Not Open)
External CB Closed status = 0x0001 (Closed) **AND**	**//**(Closed)
External CB Open status = 0x0000	//(Not Open)

The signals reported in the previous logical expression are taken from the IO List of the communication interface of the package.

These conditions ensure that the Solar Farm Controller is ready and able to respond to the setpoint provided by the EMCS.

NOTE: in the case the imposed set point is not followed by the solar plant controller, the EMCS will open the related SG-100D1 6.6kV CB., because the SG-200D2 is under control of Solar Farm and is not managed by EMCS. EMCS, however, is in direct communication with SG-200D2 and acts as a proxy for the control of the SG-200D2 by the Solar Farm.

4.2.1.14 Functional requirement related to the BLPH MODE

4.2.1.7.1 MODE 0 = IDLE (POWER IMPORT ONLY)

The BLPH shall enter IDLE MODE if:

- It is grid tied
- Supply Guarantee is ACTIVE.
- HNA5_Fault = True.

The EMCS shall allow to consider an inertia on the above entrance condition to IDLE MODE. Such time duration shall be parametric, positive, with default value zero seconds.

For the HNA5_Fault definition see the paragraph 4.2.1.3.

In IDLE MODE the EMCS shall charge BESS and run the electrolyzer, according to their availability and machine transition policy, as much as the machines allows and follows logic:

- EMCS requires PCS to enter in “IDLE Mode“with “PCS.EnterMode(IDLE)”
- Fuel Cell package is not in production.

NOTE: In IDLE MODE there are no constraints on the power import of BLPH related to any target power exchange level with the wind farm.

NOTE: When the EMCS is in IDLE MODE and the Electrolyzer is running and producing H2, even if the Wind Power goes below the Power Guarantee the EMCS must stay in IDLE MODE, knowing that when the Electrolyzer is started it cannot be stopped until the H2 storages are full (PCS.ProcessFullyCharged).

4.2.1.7.1 MODE 1 = IMPORT

The BLPH shall enter in IMPORT MODE 1, under following conditions:

- It is Grid Tied.
- Supply Guarantee ACTIVE.
- The HNA5 produces more than 1 MW for one minute.
- Check the BESS is NOT fully charged or NOT PCS.ProcessFullyCharge (H2 storages not full)

If the above condition is satisfied, the EMCS requests the PCS to enter in IMPORT MODE. After receiving the permissive “PCS.PermToEnterImport”, the BLPH enter in IMPORT MODE.

The EMCS shall allow to consider an inertia on the above entrance condition to IMPORT MODE. Such time duration shall be parametric, positive, with default value zero seconds. The EMCS shall allow to set such time duration parameter over the data interface with the CCS SCADA.

The BLPH is considered “able to operate in import” if it can charge the BESS or produce H2 with the electrolyzer (at least one of the two) and neither the BESS nor the Fuel Cell are committed to continue producing power (according to their transition policy and any prevailing control logic).

The BLPH shall stay in this mode until the condition to move in MODE 1A or 1B are satisfied.

4.2.1.7.2 MODE 1A = IMPORT (CHARGING)

The BLPH shall enter in IMPORT MODE 1A (Able to Charge), under the following condition:

- HNA5.P > 2 MW for one minute (Power surplus).

EMCS shall constrain the range among negative set-points only (charge), so to prevent power flow inversion (with the aim to avoid consequent possible stress on the BESS).

In IMPORT MODE 1A, the EMCS shall charge the energy storages (charge the BESS and run the electrolyzer to produce hydrogen), using the power surplus available in real-time (HNA5.P > 2MW), so to respect the Power Guarantee (1 MW of active power to the wind farm for 1 minute, at point Q0(QA1) of HNA6-AFA70 66kV), the system will enter in IMPORT 1A (Able to Charge). In this mode, the system is able to import energy, which means it can charge the BESS or store energy in the hydrogen storages. This state indicates surplus energy production that can be utilized for charging.

NOTE: To load the energy storages, the BLPH can utilize only the power surplus, so to respect the Power Guarantee; however, this constraint is subordinated to the electrolyzer and BESS status, and any other machine transition policies. Due to this, the Power Guarantee may be not respected in power reduction conditions, as the EMCS may be not allowed to stop consumption immediately (only for the electrolyzer).

In IMPORT MODE 1A, the EMCS shall allow the start of the electrolyzer only if the power surplus stays above a minimum value (i.e. a threshold relay with inertia) as per power management policy. The default values of these parameters shall be zero (i.e. no effect of the relay).NOTE: This is to avoid untimely the start of the electrolyzer. When the Electrolyzer is started it cannot be stopped until the H2 storages are full (PCS.ProcessFullyCharged).

NOTE: If the EMCS is in IMPORT or IDLE MODE and the Electrolyzer is running and producing H2, even if the Wind Power goes below the Power Guarantee the EMCS must stay in IMPORT or IDLE MODE.

In IMPORT MODE 1A, the EMCS shall give priority to the charging of the BESS over the electrolyzer in the use of the power surplus. NOTE: This means that the EMCS shall start the electrolyzer only when there is sufficient power surplus to run it after considering the BESS power draw. This is an energy requirement, and it does not impose that the BESS will start importing power after the electrolyzer.

NOTE: Electrolyzer policies may foresee to prevent the stop.

The formula for calculating the BESS set point is defined in paragraph 4.2.3.3.

4.2.1.7.3 MODE 1B = IMPORT (NOT ABLE TO CHARGE)

The BLPH shall enter in IMPORT MODE 1B (Not Able to Charge), under following condition:

- HNA5.P <= 2 MW for one minute (Power Deficit).

In IMPORT MODE 1B, the EMCS shall not be able to charge the energy utilizing the power available in real-time (WTG.P <= 2MW), so to respect the Power Guarantee (1 MW of active power to the wind farm for 1 minute, at point Q0(QA1) of HNA6-AFA70 66kV).

The Wind Farm will sustain the platform LOADs only.

4.2.1.7.4 MODE 2 = HOT STANDBY (READY TO EXPORT)

The BLPH shall enter in HOT STAND-BY MODE under following conditions:

- It is Grid Tied
- Supply Guarantee ACTIVE.
- The HNA5 produces more than 1 MW for one minute.
- Check the BESS is full charge AND PCS.ProcessFullyCharge (H2 storages full)

EMCS requires PCS to enter in Hot Standby by “PCS.EnterMode(HOT STAND-BY)”. Once the permissive signal PCS.PermToEnterStartHOTStandby is received, the EMCS moves to the HOT STAND-BY mode.

The EMCS shall allow to consider an inertia on the above entrance condition to HOT STAND-BY MODE. Such time duration shall be parametric, positive, with default value zero seconds. The EMCS shall allow to set such time duration parameter over the data interface with the CCS SCADA.

In HOT STAND-BY, the EMCS shall keep the Fuel Cell in Hot Stand-by (e.g. in the following mode neither Electrolyzer nor the Fuel Cell is required to run).

The Electrolyzer is stopped.

4.2.1.7.5 MODE 3 = EXPORT MODE (DISCHARGING)

The BLPH shall enter in EXPORT MODE under following conditions

- If it is grid tied.
- Supply Guarantee is ACTIVE.
- The HNA5 produces less than 1 MW.
- BESS is Healthy

EMCS requires PCS to enter EXPORT MODE by “PCS.EnterMode(EXPORT)”. Once the permissive signal PCS. PermToStartEXPORT arrives, the EMCS moves to the EXPORT MODE.

The EMCS shall allow to consider an inertia on the above entrance condition to EXPORT MODE. Such time duration shall be parametric, positive, with default value zero seconds. The EMCS shall allow to set such time duration parameter over the data interface with the CCS SCADA.

The BLPH is considered “able to operate in export” if it can produce power from BESS. Electrolyzer will be stopped.
EMCS requires PCS the permission to start the Fuel Cell. Once the permissive signal arrives the EMCS starts the Fuel Cell. If the permission doesn’t arrive, the EMCS stay in EXPORT MODE and continues using the BESS energy until the minimum energy threshold is reached.

EMCS shall constrain the range among positive set-points only (discharge), so to prevent power flow inversion (with the aim to avoid consequent possible stress on the BESS) which is only valid for BESS.

In EXPORT MODE, the EMCS shall not start the Electrolyzer. BLPH exports power from the Solar Farm, BESS and/or fuel Cell to support HNA5, because BLPH will use available power from Solar(day), BESS and/or Fuel Cell to export NOT more than what’s necessary to guarantee the 1 MW energy in wind farm according to the production of HNA5 (to maximize the period of assistance that will be provided) as stated in Electrical System Description & Design Philosophy.

In EXPORT MODE the EMCS shall use the BESS, Fuel Cell and HNA5 Power (if permission is received), according to their availability and machine transition policy, to generate enough power to meet the Power Guarantee of 1 MW, or at least to reduce as much as possible the related power shortfall.

$$\text{Target Power Export} = \text{BESS} + \text{FUEL CELL} + \text{HNA5 Power} \geq 1\ \text{MW}$$

In EXPORT MODE, the EMCS shall give priority to the use of the fuel cell over the BESS in the generation of power to meet the Power Guarantee. This is an energy requirement, and it does not impose that the BESS will start producing power after the fuel cell.

4.2.1.7.6 MODE 4 = COLD STANDBY (NOT ABLE TO EXPORT)

The BLPH shall enter in COLD STANDBY MODE under following conditions:

- If it is in Grid-tied
- Supply Guarantee ACTIVE.
- HNA5 produces less than 1 MW
- BESS is not able to operate in export (BESS Fault)

EMCS requires PCS to enter in COLD STAND-BY MODE by “PCS.EnterMode(COLD STANDBY)”
PCS sends to EMCS the “Permissive to start” for COLD STAND-BY MODE with “PermToStartCOLD STAND-BY”

The EMCS shall allow to consider an inertia on the above entrance condition to COLD STANDBY MODE. Such time duration shall be parametric, positive, with default value zero seconds. The EMCS shall allow to set such time duration parameter over the data interface with the CCS SCADA. In COLD STANDBY MODE the EMCS shall stop the Electrolyzer and the Fuel Cell according to their machine transition policy.

In COLD STAND-BY MODE BLPH is unable to respect the Power Guarantee.

In COLD STAND-BY MODE, all relevant auxiliaries will be operational at reduced capacity due to the equipment being out of operation. **Only those auxiliaries needed for the platform to remain safe will operate in this operation mode.**

The BLPH auxiliaries’ loads will be supported by the wind farm and solar farm.

4.2.1.7.7 MODE 4A = EMERGENCY (ISLAND)

The BLPH shall enter in EMERGENCY MODE if:

- It is islanded (off-grid) OR Supply Guarantee = INACTIVE
- BESS is healthy (NO FAULT)
- BESS charge level is above the BESS-MINIMUM-OPERATING-RESERVE threshold.

The EMCS shall allow to set the value of the BESS-MINIMUM-OPERATING-RESERVE parameter from the data interface with the CCS SCADA. The value shall be strictly positive. In EMERGENCY MODE, the EMCS shall curtail or stop the solar farm production, to prevent the overload of the system in a situation where the BESS cannot compensate the production exceedance.

Solar Farm is able to guarantee the strict respect of the active power limit provided by the EMCS, or the respect of the limit with a maximum upward tolerance (supposed within 10%, parametrized) in normal operating conditions.

In EMERGENCY MODE, if the Solar Farm is not able to guarantee the respect of the received set-point, the EMCS shall open the 6.6 kV CB on SG-100D1 and command Solar Farm to stop.

In EMERGENCY MODE, the EMCS shall curtail or stop the fuel cell production, to prevent the overload of the system in a situation where the BESS cannot compensate for the production exceedance. This also accounts for possible sudden drops in the loads.

In EMERGENCY MODE, The EMCS shall give priority to the use of the fuel cell over the BESS discharge, according to machines reaction times and capabilities.

In EMERGENCY MODE, The EMCS shall give priority to the reduction of fuel cell use over the BESS charge, according to machines reaction times and capabilities.

In EMERGENCY MODE, BLPH operates as an ‘Island’ and if Solar Farm is not in production, BESS and/or Fuel Cell will use their stored energy to support BLPH for the maximum time possible, CCS will be programmed to minimize the balance of plant and vendor package auxiliary demand to prepare for the potential recovery from a ‘black start’ condition.

NOTE: There is no requirement to charge the BESS in EMERGENCY MODE; however, the BESS is allowed to charge and may be expected to charge in temporary periods. According to that, the EMCS may act so to track a BESS charge level to a target value or within a range. Charge and discharge periods may alternate in such tracking. Due to the fluctuation of loads (a sudden reduction) and solar production (a sudden increase), there may be transient periods where BESS is charging while the fuel cell is producing.

NOTE: The “BESS charge level” will be based on the “discharge_energy” signal provided by the BESS communication interface. The value is normalized between 0% and 100% (0 to 5MWh) to be used in the calculation of the threshold.

NOTE: In Grid Forming Mode, the BESS production is determined by the energy balance of the BLPH.

EMCS – PCS coordination shall remain in place for package permissions.

For the power management of each single package see the paragraph 4.2.3.4**.**

In this mode the Load Shadding procedure will be applied according to the paragraph Load Shedding.

In EMERGENCY MODE, Formula/algorithm that will be used to estimate the remaining time before moving to POWER OUT MODE, is dependent on the following variables:

- T_{REM} = Remaining Time before Power Out mode
- E_{H2} = Energy available from Hydrogen storages (based on current H2 level)
- E_{BESS} = Remaining Energy in the BESS (based on Available Energy for Discharging)
- P_{SF} = Current Power production from Solar Farm
- P_{Aux} = Power consumption of the auxiliary loads (measured at the incoming breaker SG-200N1)
- P_{Net} = Net power required after accounting for Solar & Auxiliary loads

The net power demand on the BESS and the fuel cell is the difference of total load and the contribution from the solar farm:

$$P_{Net} = P_{Aux} - P_{SF}$$

The total available energy from the BESS and the fuel cell:

$$E_{Total} = E_{H2} + E_{BESS}$$

Where:

- $E_{H2} = H_{2Quanity}$ x Conversion Efficiency x $FC_{Efficiency}$
- E_{BESS} = Available Energy for Discharging

Variable	Description	Notes
$H_{2Quantity}$	Quantity of the H_2 for **all** storages expressed in kg	Exposed by PCS
Conversion Efficiency	kWh produced per 1 kg of H_2	Exposed by FC interface (33.33 kWh/kg)
$FC_{Efficiency}$	Fuel Cell efficiency (> 0 and < 1)	Exposed by FC interface (Input Register 1202)

The remaining time before the energy reserves are depleted:

$$T_{REM} = \frac{E_{Total}}{P_{Net}}$$

The formula to estimate the remaining time T_{REM} before moving to POWER OUT mode is:

$$T_{REM} = \frac{E_{H2} + E_{BESS}}{P_{Aux} - P_{SF}}$$

4.2.1.7.8 MODE 5 = POWER OUT (BLACK-OUT)

The BLPH shall enter in POWER OUT MODE if:

- It is islanded (Off-Grid) **OR** Supply Guarantee = INACTIVE **OR** EMCS is informed of ESD-1D activation (reference doc. “Process Safety Cause & Effect Matrix”)
- BESS NOT Healthy **OR** BESS charge level is below the BESS-MINIMUM-OPERATING-RESERVE threshold (BESS FAULT) **OR** the SG-100D1 voltage measure on the BLPH 6.6kV distribution bus is absent.

In POWER OUT MODE, the EMCS shall open all the CBs under the busbar SG-100D1, immediately.

NOTE: it shall not ensure that the CBs are held open, allowing manual closing.

Once in POWER OUT MODE, EMCS shall send a command to PCS (PCS.PowerOutMode) to trip all the valves, stop command for process items and according to their energy transition policy.

NOTE: When the ESD-1D signal (exposed by the PCS) is active, the EMCS goes in Power Out MODE from any mode except Research Mode.

4.2.1.7.9 MODE 6 = MAINTENANCE

The BLPH shall enter and remain in MAINTENANCE MODE if the EMCS receives the request to enter in this MODE from the data interface of the CCS SCADA (protected under password).

The BLPH shall exit from the MAINTENANCE MODE if, and only if, the EMCS receives the request to return in automatic identification of the MODE from the data interface of the CCS SCADA through a software exit button.

In MAINTENANCE MODE, the EMCS implements the commands arriving from the data interface of the CCS SCADA, respecting permissions.

In MAINTENANCE MODE the EMCS shall not dispatch any command required by any automatic logic in the EMCS, including any open/close command, load shedding command, change in power setpoint.

NOTE: This is to assure total manual control to the operators.

NOTE: In Maintenance Mode the Fuel Cell and the Electrolyzer must remain stopped (start-up is not permitted), also if requested by the operator via CSS SCADA.

Transition Conditions: Entrance on a command to get in the MANTENANCE MODE, Exit on a command to return in automation identification of the MODE.

EMCS performs pass-through of manual commands.

At entrance in the MODE a procedure shall be followed:

- EMCS shall stop and hold stop (prevent start command) the Electrolyzer.
- EMCS shall stop and hold stop (prevent start command) the Fuel Cell.
- EMCS shall stop the BESS.
- EMCS – PCS coordination shall remain in place for package permissions.
- EMCS sent to the PCS the command PCS.EnterMode(MANUAL).

4.2.1.7.10 MODE 7 = RESEARCH

The BLPH shall enter and remain in RESEARCH MODE if the EMCS receives the request to enter in this MODE from the data interface of the CCS SCADA (protected under password). BLPH will ignore the power output of the HNA5 wind turbine.

WARNING for the operator: while in the RESEARCH MODE one the following conditions could lead to BLPH black out:

- Intentionally opening of the QA1 of HNA6-AFA70.
- Intentionally opening the INCOMER CB of SG-100D1.
- Intentionally open the CB of SG-100D1 for supply the SG-200N1.

EMCS requires PCS to enter RESEARCH MODE by “PCS.EnterMode(RESEARCH)”.

The BLPH shall exit from the RESEARCH MODE if, and only if, the EMCS receives the request to return in automatic identification of the MODE from the data interface of the CCS SCADA through an exit button.

RESEARCH MODE shall be used for First Energization and re-energization during Black Start.

In RESEARCH MODE, the EMCS implements the commands arriving from the data interface of the CCS SCADA, respecting permissions of packages state machines.

When the EMCS transitions to Research Mode from any other mode, all machines must be stopped. However, this logic does not prevent the operator from manually performing machine operations.

In RESEARCH MODE the EMCS shall not dispatch any command required by default behavior requirements, including any open/close command, load shedding command, change in power setpoint. NOTE: This does not prevent the EMCS to automatically dispatch commands that are due to specific functional requirements which are not indicated as generic defaults behavior (e.g. it does not prevent the EMCS to automatically stop the electrolyzer when the hydrogen storages are full).

Transition Conditions: BLPH execute control commands arriving from the CCS SCADA. Entrance on a command to get in the RESEARCH MODE, exit on a command to return in automation definition of the MODE.

4.2.1.7.11 MODE 8 = NONE MODE

The EMCS shall identify NONE MODE as default BLPH MODE and during EMCS initialization.

In NONE MODE the EMCS shall not dispatch any command required by default behavior requirements, including any open/close command, load shedding command, change in power setpoint.

NOTE: This does not prevent the EMCS to dispatch commands that are due to specific functional requirements which are not indicated as generic defaults behavior (e.g. it does not prevent the EMCS to automatically stop the electrolyzer when the hydrogen storages are full).

At start-up the EMCS shall enter into an initialization status. During initialization, EMCS shall not dispatch any command, manual or automatic, including any open/close command, load shedding command, change in power setpoint. The EMCS shall exit from initialization status if the conditions to enter in a BLPH MODE (different from None) are met.

4.2.2 Management Under BLPH Internal Communication Failures

Electrolyzer, Fuel Cell, Solar Farm vendor provide heartbeat/watchdog allowing the package and the BESS to verify the presence of communication between the two systems.

In case of loss of communication, after OUT-OF-COM-TIMEOUT of that package, the EMCS shall consider that the package will auto shutdown. After MAX-GRACEFULL-SHUTDOWN- TIME (a parameter with default value zero seconds), if the package still exchange power, the EMCS shall open the related CB on SG-100D1 and EMCS will move BLPH in other MODE accordingly to CPI FAULT.

When the communication with the package is retrieve, the EMCS ensures that the package is stopped, and after the check, the EMCS commands the closing of the related CB.

4.2.3 Power Control

It is described the strategy of dynamic control of the active power tracking. The power control is intended to cope with the state machines, logic and physical constraints and limitations imposed by the system. The scope of the power control is to reach the best performance in chasing the target output, always considering the trade-off with the complexity of the design and implementation.

The EMCS shall implement power control in the following scenarios:

- When in EXPORT MODE, to guarantee the target power export, which is ideally defined as 1 MW export to the wind farm QZ93, by operating on the BESS and Fuel Cell.
- When in IMPORT MODE, to utilize the most, and only, the power surplus to charge the energy reserves of the BLPH, using BESS and electrolyzer for serial or parallel charging.
- In EMERGENCY MODE, to maintain the BESS within the Operating Parameters, by operating the Solar Farm and the Fuel Cell. NOTE: In this scenario, there might be also possible additional requirements, here not considered, to prevent frequent power inversions of the BESS, taking into account the oscillation of the power request, expected to be due to both the oscillation of the solar farm output and the loads.

NOTE: The power control is limited to active powers. No reactive power or power factor shall be controlled or accounted for by the EMCS; this holds in every BLPH operational scenario, independently from the fact that the BLPH is grid tied or islanded. At least for the EMCS purposes, there are no grid code requirements to comply with, except EMERGENCY MODE in which the BESS **is in charge of mitigation** of active power as well as reactive power.

4.2.3.2 Power Control in EXPORT MODE

The ideal goal of the BLPH in EXPORT MODE is, as stated in the Functional Statement, to guarantee 1 MW in export to the Wind Farm at QZ93. However, the measure of such quantity is not available. The goal of the BLPH is hence identified in guaranteeing the export of a quantity of power calculated and sum of BESS, FUEL CELL & HNA5 ≥ 1MW. Such value can be considered independent from the BLPH power production itself (no feedback effect).

Considering the dynamics of the machines, the following control architecture has been identified:

- Pure feedforward (open loop)

The goal of the power control in EXPORT MODE: Guarantee the minimum power export target, ideally defined as 1 MW export to the Wind Farm. The practical goal, the target for the sum of BESS exported power and Fuel Cell exported power is:

BESS.ExportedPower + FuelCell.ExportedPower = 1MW – HNA5.Power

System Target = 1 MW – HNA5.Power

Whereas:

- Fuel Cell Setpoint = System Target
- BESS Setpoint = System Target - Fuel Cell Power (Formula floored to zero, i.e., negative values will be considered zero)

During the EXPORT MODE, the Loads consumption is not considered in the power provided to the Wind Farm and the Solar Farm production, because we are assuming that the production will compensate the Loads consumption. This could not guarantee the export of the required power during the night or adverse weather. Supply is guaranteed using BESS and FUEL CELL.

The Fuel Cell set point formula will actually have two parameters (C1 Default = 1; C2 Default = 0): Fuel Cell Setpoint = System Target * C1 - C2 (Formula floored to zero).

4.2.3.1 Pure Feedforward

Track the BLPH target in feedforward (open loop), defining the set-point of BESS and fuel cell as a repartition of the power target form storages according to a theoretical formula of the power need from the energy storages.

Both solar farm and loads are measured and shall not be controlled in this scenario, hence are usable as independent variables.

The repartition of the total power request between the BESS and the Fuel Cell can take into account desired energy priority, desired margins and also the different reaction time of the machines. A proposed repartition of the power request is the following:

1. Calculate the power set-point of the fuel cell (the slower machine) as a percentage of the total power request, or/and considering an absolute margin (to be always left to the BESS); apply a low pass filter in output to better respect fuel cell dynamics (i.e. average the result slowly, so to smooth any rapid movement).
2. Calculate the power set-point of the BESS as the difference between the total power request and the measured power output of the BESS (so to compensate its dynamics).

This architecture has no feedback loops at all, and it is intrinsically stable (in the limits of the internal stability of the machines in following a set-point); the resulting error is the one given by:

- The physical model approximation (i.e. the fact that the sum of the productions is not equal to the output)
- The disturbance due to the dynamics during the settling time of the machines, which is particularly relevant for the fuel cell and may be just partially limited by the BESS.
- The tracking error of the machines.

4.2.3.3 Power Control in IMPORT MODE

The goal of the BLPH in IMPORT MODE is to charge the energy reserves using the power surplus, which is the power available in excess of the Power Guarantee level of 1 MW to the Wind Farm. As already explained in the paragraph 4.2.1.7.1 the BESS will be charged and the Electrolyzer will be started when the power produced by the HNA5 is above 2 MW.

It is particularly relevant that the Electrolyzer cannot be partialized and its power is much more than that the one of the BESS.

Moreover, once the Electrolyzer starts it cannot be stopped according to power needs. It may hence happen that the Electrolyzer is still running even when there is no sufficient power surplus (or even any at all). This consideration, it is assumed that a simple control architecture based on feedforward control is the best trade-off, as there is no point in selecting a more complex architecture given the intrinsic limitations of the possible performances.

NOTE: If the EMCS is in Import Mode and the Electrolyzer is running and producing H2, even if the Wind Power goes below the Power Guarantee the EMCS must stay in Import Mode.

The proposed architecture is to identify the charging set-point of the BESS from the theoretic calculation of the powersurplus available for the BESS charge, considering and based on the power measures of HNA5, solar farm, Electrolyzer and loads consumption, plus an estimation of the internal losses. The set-point shall be limited to the maximum charge power of the BESS.

The Electrolyzer will be started when the theoretic calculation of the power surplus available for the Electrolyzer is higher than its nominal power; the power surplus available for the Electrolyzer shall be calculated considering and based on the power measures of HNA5, solar farm, BESS and loads consumption, plus an estimation of the internal losses.

In this architecture, during a progressive rise of the power from the HNA5 and solar farm, the first to operate will be the BESS, rising from zero to its maximum power. Note that the maximum possible consumption of the BESS can be zero, if it is full. After the BESS has reached it maximum power, the power surplus available to the Electrolyzer will start to rise starting from zero. When it reaches a level higher than the nominal power of the Electrolyzer, the latter will start. Then, if the power from HNA5 and solar farm will decrease, the BESS will progressively reduce its charge power according to the available power surplus, eventually stopping.

NOTE: When the Electrolyzer is not required to produce, the setpoint will be set to zero, and its operating status shall be changed to STOP.

This architecture may produce stable behavior due to the all-or-nothing dynamics of the electrolyzer. However, these behaviors are prevented by the latching policy that prevents to stop the electrolyzer independently from the power needs, in the limit of the latching period.

During a progressive rise in power from the HNA5 and Solar Farm:

- The first to operate will be the BESS, rising from zero to its maximum consumption power. NOTE: The maximum possible consumption of the BESS can be zero, if it is full.
- After the BESS has reached its maximum power, the power surplus available to the Electrolyzer will start to rise starting from zero. When it reaches a level higher than the nominal power of the Electrolyzer, the latter will start.

Afterwards, if the power from HNA5 and Solar Farm progressively decreases:

- The BESS will progressively reduce its power according to the available power surplus, eventually stopping.

- The Electrolyzer will be stopped only when its State-machine allows/impose such transition (which includes pre-conditions on the H_2 level); in case the Electrolyzer status allows the stop transition (but now impose it), the EMCS will stop the Electrolyzer if its start condition is not met (adding a hysteresis margin).

Power Surplus formula is HNA5.Power - 1 MW

The formula for calculating the BESS set point is the following:

BESS Set Point = HNA5.P – 1 MW – BLPH.AuxLoad – EL.Consumption + Solar.P

The formula for calculating the Electrolyzer set point is the following:

IF (ElectrolyzerCanRun()) THEN

Electrolyzer Set Point = ELECTROLYZER_MAX_SET_POINT

ELSE

Electrolyzer Set Point = 0

Where ELECTROLYZER_MAX_SET_POINT is a parameter preset to 2500 kW by default and ElectrolyzerCanRun() is a function taking care of the power surplus available, the permissive to start the Electrolyzer and its electrical connectivity to the 6.6 kV BUS.

4.2.3.4 Power Control In EMERGENCY MODE (Islanded Mode, BESS in Grid Forming)

The goal of the BLPH in EMERGENCY MODE is to sustain the off-grid operativity as much as possible, which means to preserve the energy reserves, especially the one of the BESS. In case of need, the energy priority shall be to utilize the fuel cell before the BESS reserves.

The charging of the BESS while the fuel cell is producing energy is considered inefficient, so it will not be implemented in the control logic.

The control shall avoid the depletion of the BESS and its overload, which would lead to a power outage.

This considering, the goal of the power control can be reduced to maintaining a good level of charge of the BESS, respecting the mentioned constraints. It is assumed that, to prevent the (potential) power overload of the BESS, the sum of the Fuel Cell set-point and the Solar Farm set-point shall be less than the BESS charge power at any moment in time, which is assumed to be always more than 0.6 MW.

The control dispatchment policy shall be to implement such constraints in a hard manner, lowering one set-point increasing the other. The proposed architecture is based on the identification of a control range AA in the BESS charge levels (e.g. SoC 60%-80%), that should be parametrized (BESS-MINIMUM-OPRATING-RESERVE, BESS-MAXIMUM-OPERATING-RESERVE, see the paragraph 4.2.1.6.3).

The term "charge level of BESS AA" refers to the Available Energy of a specific Battery Energy Storage System (BESS) identified as "AA."

If the BESS charge level is below the control range AA (low range):

- The fuel cell set-point will be calculated as the difference between the load consumption and the solar farm production, if positive, averaged over a time window: FC SetPoint = AuxLoad – SolarFarm.
- The solar farm will be NOT curtailed: SolarFarm SetPoint = 100%
- BESS absorbs the power coming from the Solar farm during the settle time of the Fuel Cell setpoint.

If the BESS charge level is within the control range AA (middle range):

- The fuel cell set-point will be calculated as the difference between the load consumption and the solar farm production, if positive, averaged over a time window and progressively limited, from 100% to 0%, linearly decreasing in the control range AA: FC SetPoint = (AuxLoad - SolarFarm) * X.
- The solar farm will be limited to the AuxLoad active power measure; no progressive limitation is applied: SolarFarm SetPoint = AuxLoad.
- BESS is in Load following.

If the BESS charge level is above the control range AA (high range):

- The solar farm will be curtailed to zero power: FC SetPoint = 0%
- The fuel cell set-point will be set to zero: SolarFarm SetPoint = 0%
- BESS is in load following.

If the Available Energy reaches the MAXIMUM_OPERATING_RESERVE, the CB on SG100D1 of Fuel Cell and Solar Farm must be open. When the Available Energy goes below the MAX_DISCHARGE_RESERVE(HIGH) the CB on SG100D1 of Fuel Cell and Solar Farm must be closed back. If the Available Energy goes below the MIN_CHARGE_RESERVE (LOW) the EMCS commands 100% set point to Solar Farm.

The progressive curtailment level of the solar farm within the control range AA is a means to avoid astable behavior.

NOTE: this control logic does not prevent the ideal scenario where the BESS gets depleted while there is still some reserve of hydrogen. To guarantee to prevent it, an intentional charging of the BESS from the Fuel Cell is foreseen when such incipient condition arises (by the operator in Research Mode).The goal of the power control in EMERGENCY MODE: Sustain the BLPH off-grid operativity as much as possible, which means to preserve the energy reserves, especially the one of the BESS, the energy priority shall be to utilize the Fuel Cell before the BESS reserves.

To avoid outages, EMCS shall guarantee that, with the given setpoints:

Fuel Cell Power + Solar Farm Power < BESS Power Charge Capability [PowerLimit]

Available Energy in low range (below the SoC limitation range):

- $FC_{SetPoint}$ = Aux.Power – SolarFarm.Power
- Solar Farm is curtailed to respect the BESS Charge Capability

Available Energy in middle range (Range is intended LOW, HIGH thresholds):

- Fuel Cell set-point defined so to ideally compensate the residual load consumption considering Solar Farm production but capped to a progressively decreasing value.
- Solar Farm is curtailed to respect BESS Charge Capability but capped to a progressively decreasing value.

Available Energy in high range (above the SoC limitation range):

  - $FC_{SetPoint}$ = 0
  - $SF_{SetPoint}$ = 0

4.2.4 Forecasts-based Control

There are no requirements at the EMCS about using or receiving any forecast of data or values.

4.2.5 Coordination with the Process Control System

The EMCS shall not run (i.e. not starting and stop if running) the BESS without a positive permissive signal from the PCS.

PCS communicates with EMCS through internal communication (Modbus TCP) and the following signals (commands, statuses and permissive) will be exchanged between the two systems:

Signal	Description
PCS.EMCS.PermToStartFC	Permissive to start Fuel Cell sent by PCS
PCS.EMCS.PermToStartEL	Permissive to start Electrolyzer sent by PCS
PCS.EMCS.ProcessFullyCharged	PCS indicates if the Fuel Tanks are full
PCS.EMCS.BESSFault	Sent by PCS. 1: fault; 0: OK. When 1 the BESS must be immediately stopped
PCS.CmdToLoadShedStage1	Request sent from EMCS to PCS to activate the Load Shedding of EMERGENCY MODE
PCS.CmdToLoadShedStage2	Request sent from EMCS to PCS to activate the Load Shedding of LOW BESS LEVEL
PCS.EntertMode	Request sent by the EMCS to the PCS to enter in a specific mode. The PCS monitors the value change to capture the mode request. POWER OUT mode is a special condition. The EMCS move to the POWER OUT mode without waiting for the PCS permission.
PCS.CurrentMode	EMCS communicates through this register which is its current MODE. The PCS listens for the mode change. If the POWER OUT MODE is reached, the PCS takes the predefined actions (trip everything).
FuelCellOperatingStatus	Signal exposed by the EMCS to communicate the operating status of the Fuel Cell.
ElectrolyzerOperatingStatus	Signal exposed by the EMCS to communicate the operating status of the Electrolyzer.
PCS.EMCS.PermToEnterMode	Permissive to enter in the mode indicated by the register value.
PCS.EMCS.HydrogenLevel	Hydrogen level in Kg. PCS communicates the level periodically to the EMCS.
PCS.EMCS.ESD-1D	PCS inform the EMCS to go in Power Out mode
PCS.PermissiveModeTimeout	Parameter set by the PCS (default 3 sec). This parameter is used by the EMCS as waiting time for the permissive signal to enter in a MODE.

If the Permissive to stay in **Export** or in **Hot Standby** MODE is removed or if the permission request to enter in these modes is not received within the timeout, the EMCS moves automatically in Cold Standby.

The EMCS before entering the **Emergency**, **Power Out**, **Idle**, **Cold Standby**, **Maintenance** or **Research** MODEs sends the request to enter in the MODE but does not wait until the permission is received. The purpose of the request is to inform the PCS what is the next MODE where the EMCS will transit.

If the EMCS wants to move to the **Import** MODE and the PCS permission is not received, the EMCS stays in the

current MODE until the permission is received or the preconditions to move to some other MODE are satisfied.

The EMCS monitors continuously the permissive signals communicated by the PCS. If the permissive signal to run a package is removed, the EMCS sends the stop command to the related package and, if required by the EMCS MODE transition logic, the EMCS moves to the MODE which preconditions are satisfied.
In some cases, even if the permission to run a package is removed and the package is stopped, the EMCS stays in the current MODE.
For example, if the EMCS is in EXPORT MODE and the permission to run the Fuel Cell is removed, the EMCS continues to operate in EXPORT MODE until it is supported by the BESS.
Another example is, when the EMCS is in IMPORT MODE and the permission to run the Electrolyzer is removed, the EMCS continues to operate in IMPORT until the BESS can be charged.

4.3 Load Shedding

In EMERGENCY MODE, the EMCS shall shed the loads in the list LOAD-TO-SHED-IN-EMERGENCY-MODE, by requesting the PCS “Cmd.To.LoadShed” to open the related LV contactors on the switchboard SG-200N1.

The EMCS shall allow to mark each load, singularly, as included or excluded in the LOAD-TO-SHED-IN-EMERGENCY-MODE from the data interface of the CCS SCADA.

The default list LOAD-TO-SHED-IN-EMERGENCY-MODE(Island) “Cmd.To.LoadShed_1” immediately upon entry is the following:

- PCS Stop Electrolyzer auxiliaries
- PCS Stop Water package
- PCS Stop Sea Water Pumps

The EMCS shall allow to reset the default value of LOAD-TO-SHED-IN-EMERGENCY-MODE from the data interface of the CCS SCADA.

In EMERGENCY MODE, if the Available Energy is below BESS-LIMIT-FOR-ADV-LOAD-SHEDDING parameter value, the EMCS shall shed the loads in the list LOAD-TO-SHED-IN-LOW-BESS-LEVEL, by requesting to the PCS to open the related LV contactors on the switchboard SG-200N1.

The EMCS shall allow to set the value of the parameter BESS-LIMIT-FOR-ADV-LOAD-SHEDDING over the data interface with the CCS SCADA. The default value of the parameter being 25% Available Energy .

The EMCS shall allow to mark each load, singularly, as included or excluded in the LOAD-TO-SHED-IN-LOW-BESS-LEVEL from the data interface of the CCS SCADA.

The list LOAD-TO-SHED-IN-LOW-BESS-LEVEL “Cmd.To.LoadShed_2” is the following:

- HVAC
- Welding Sockets
- BOP Distribution Panel
- Crane

During the electrical mode these systems are DISABLE to START according to Load Shedding:

- Electrolyzer
- Sea Water Pumps
- Water Treatment System
- HVAC
- Welding Sockets
- BOP Distribution Panel
- Crane

The EMCS shall allow to reset the default value of LOAD-TO-SHED-IN-LOW-BESS-LEVEL from the datainterface of the CCS SCADA.

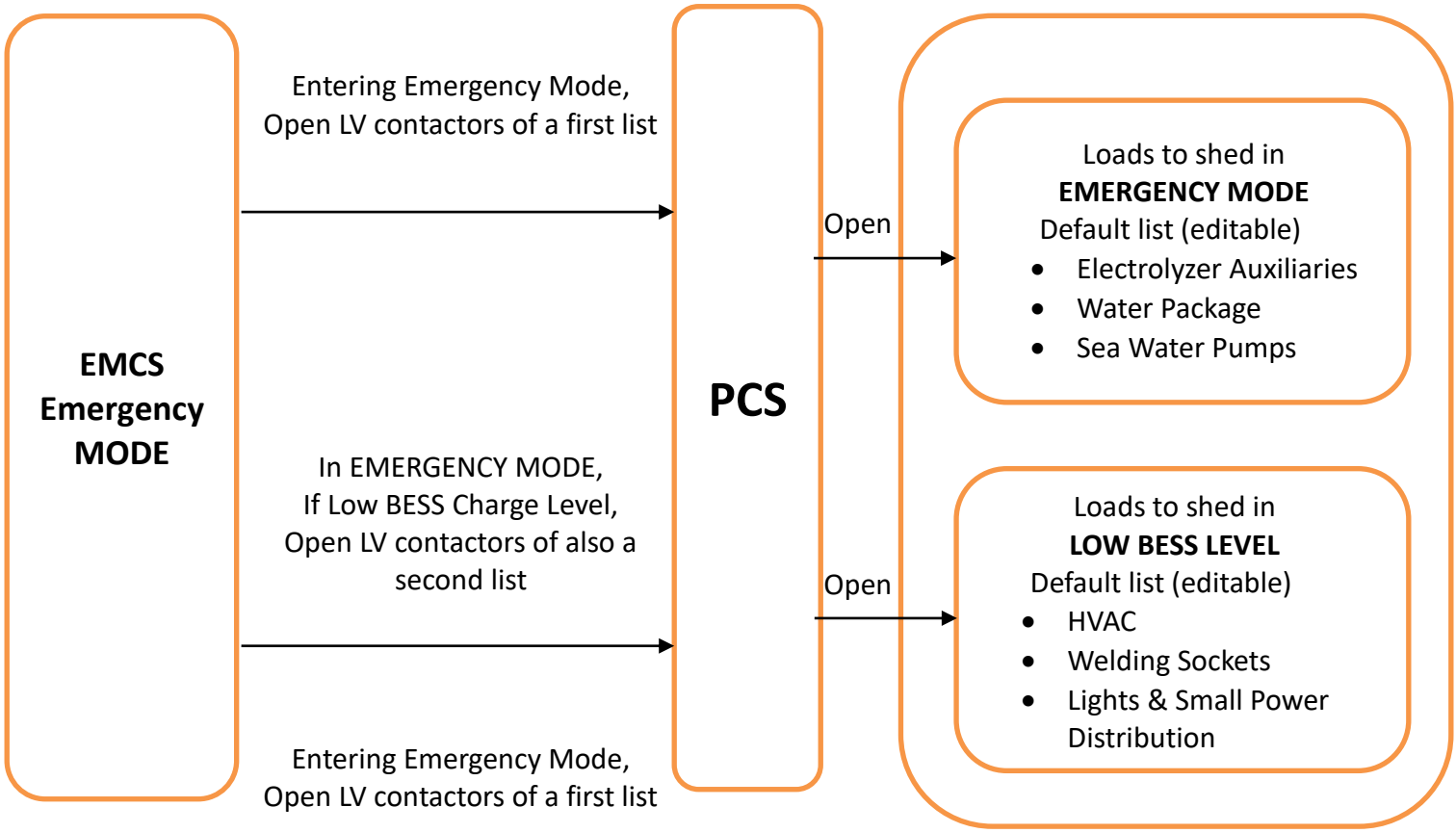


Figure 15 Load Shedding Procedure

The EMCS removes the commands to PCS for CmdToLoadShedStage1 and CmdToLoadShedStage2 when it exit from Emergency mode. PCS manages the contactor on the LV Switchboard SG-200N1 according to the control logic.
EMCS manages the CBs on the 6.6kV Switchgear SG-100D1 and HNA6-AFA70 according to the control logic.

4.4 Management of Electrical Distribution Equipment

If IEC 61850 communication between the HV-SCADA & 66kV HNA6-AFA70 is lost, the HNA6-AFA70 will not take any automatic action.

If OPC-UA communication between the HV-SCADA and EMCS is lost, the EMCS does not take any automatic action on 66kV HNA6-AFA70. In conjunction with this communication loss, the EMCS will immediately command the platform in IDLE MODE “PCS.EnterMode(IDLE)”.

The EMCS shall allow the operator to open the HNA6-AFA70 Q0(QA1) from the data interface of the CCS SCADA.

The EMCS shall allow the operator to close the HNA6-AFA70 Q0(QA1) from the CCS SCADA data interface only in presence of a permissive signal from the wind farm SCADA (and there is communication with the wind farm SCADA).

The HV-SCADA can open any time the HNA6-AFA70 Q0(QA1) through the direct link (IEC-61850), while simultaneously removing the permissive signal to close.

The control of OLTC through AVR command has signals from the EMCS that allow to put the AVR/OLTC in MANUAL mode or AUTO mode, only software manual command by operator will be available (password protected). See the paragraph for the control logic 5.7. The set point of the AVR shall be in the range of 6.6 kV ± 5%

The exiting from any island mode (RESEARCH or EMERGENCY), once the voltage is back on the Wind Farm up to the BLPH 66 kV HNA6-AFA70, it is possible to reconnect the system to the grid by means of manual procedure.

The operator first of all has to close the line switches and the circuit breaker of the 66 kV HNA6-AFA70 in order to energize the step-up transformer, to be ready to take the load from the 6.6 kV system.

Once the transformer is energized, the operator will request from the CCS SCADA to close the incoming breaker on the 6.6 kV switchgear (only after black start scenario or first energization). The closure of the breaker will be managed by the BESS system (only in EMERGENCY mode), which has the capabilities necessary to synchronize the isolated 6.6 kV system with the grid.

With the closure of the 6.6 kV incoming breaker, the 6.6 kV system will be connected back to the grid and the BLPH platform will return in the operating mode requested in that moment.

4.5 Wind Farm Grid Connection and BLPH Synchronization After Emergency Mode

In Figure 16 Status of Signals & Electrical Sequence defines the status of signals and electrical sequence to manage the closing of the HNA6-AFA70 on BLPH. Windfarm will have a direct connection to the BLPH 66kV HNA6-AFA70 CB for control and monitoring, the electrical sequence is as follows:

- Q0(QA1) "CB Open" command, directly to the BLPH HNA6-AFA70 from HV-SCADA
- Q0(QA1) "Ready to close" permissive to EMCS from HV-SCADA
- Full control of QZ92 line and earthing switches from HV-SCADA (not controlled by EMCS)

BLPH Q0(QA1) "CB Close" command and "CB Open" commands will also be available to BLPH HNA6-AFA70 by the EMCS.

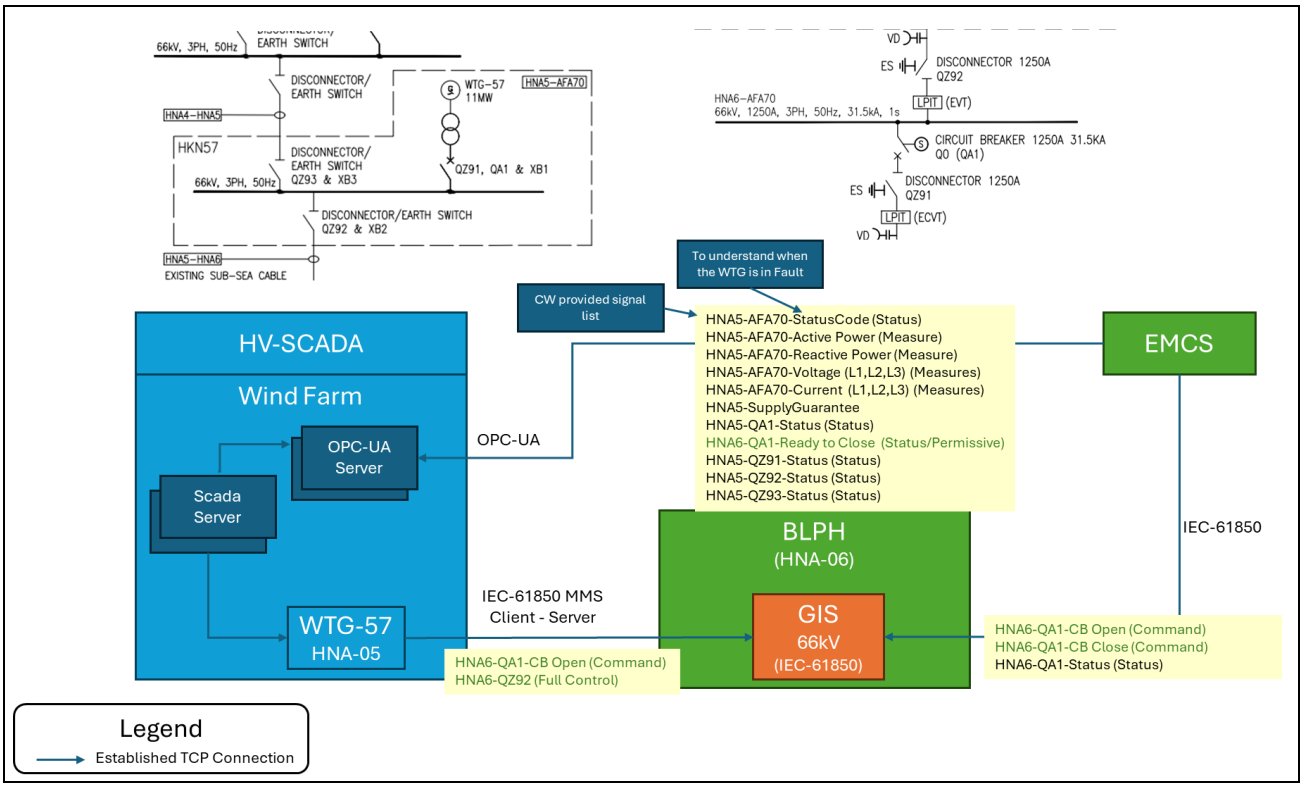


Figure 16 Status of Signals & Electrical Sequence

- The synchronization with the grid is performed by the BESS, by means of hardwired voltagemeasures connected directly to the BESS (from the SG-100D1).
- The BESS will provide the (hardwired) closing command directly to the 6.6kV incoming CB to perform the parallel with the grid.
- A hardwired signal will identify off-grid condition (an OR between Open status of Q0(QA1) HNA6-AFA70 and open status of 6.6kV SG INCOMMER CB).
- The EMCS will provide a hardwired permissive signal as described in Figure 17 BESS-Hardwired Interface_rev5_FREQ to the BESS allowing the Grid-Forming mode (enter and stay in such mode = 1)

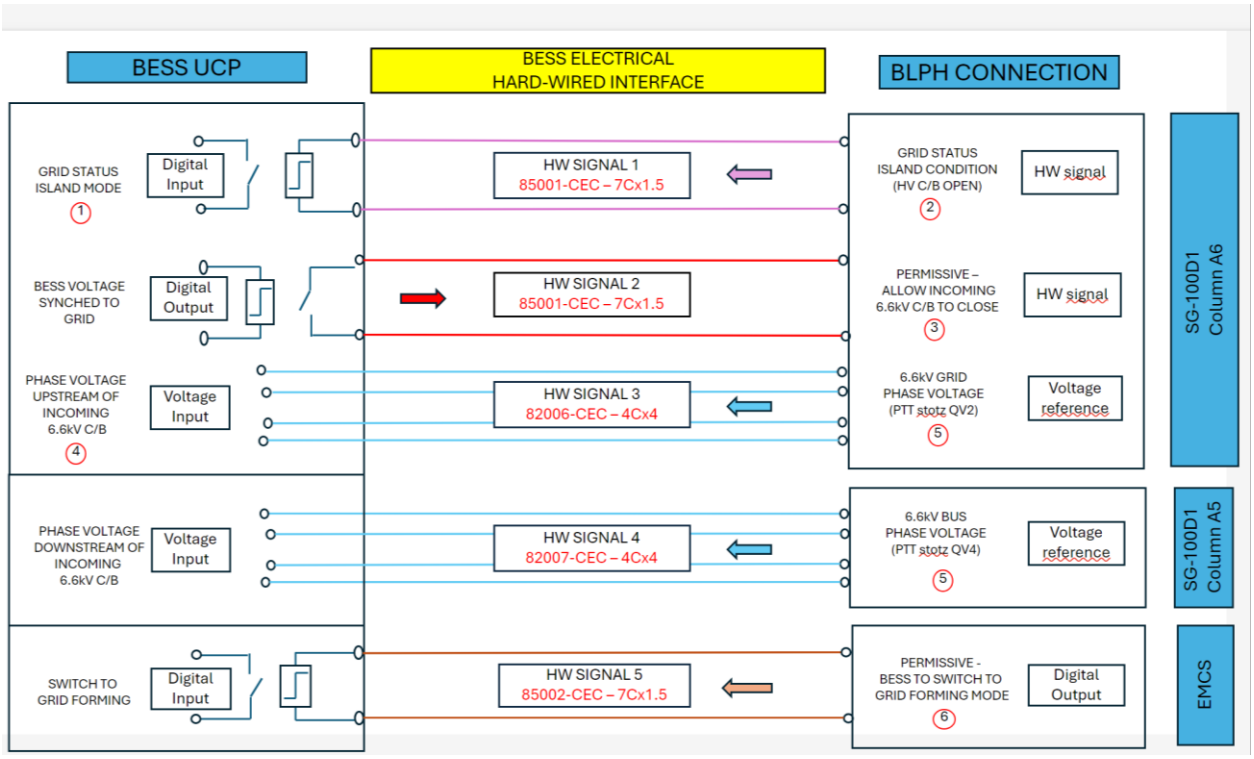
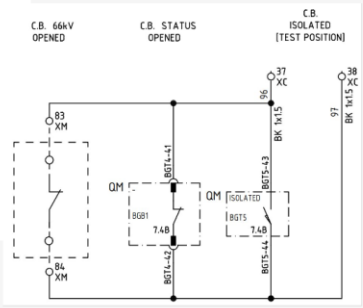


Figure 17 BESS-Hardwired Interface_rev5_FREQ

Signals as described in Figure 18:

1 GRID STATUS ISLAND MODE: 0 = 6.6 kV System is synchronized with the grid and BESS has to operate in grid following
1 = 6.6 kV System is islanded from the grid and BESS has to operate in grid forming IF the permissive is received

2 GRID STATUS ISLAND MODE: the signal is generated as OR of the 66 kV CB open status and the 6.6 kV incoming CB open status as per following scheme



3 PERMISSIVE – ALLOW INCOMING 6.6kV C/B TO CLOSE: This signal is connected as input to the REX 640 protection relay on the 6.6 kV incoming CB in order to close the breaker, provided that the synchrocheck function gives the permissive. The input BI6 on card D will be used.

4 PHASE VOLTAGE UPSTREAM OF INCOMING 6.6 kV CB: Once BESS read a voltage 110 V on this signal it has automatically to start the synchronization to the grid in order to reach the synchronization and send the permissive to close signal to the incoming CB.

5 VOLTAGES FROM 6.6 kV SWITCHGEAR: These signals are voltage references from secondary side of voltage transformers, so they are at 110 V 50 Hz, with 4 wires.

6 PERMISSIVE - BESS TO SWITCH TO GRID FORMING MODE: This signal will be maintained at 1 until the operator will not reset it manually, in order to prevent the islanding or the automatic return from the island (as per note 4)

Figure 18

The BESS performs the parallel closing request to the INCOMMER CB SG-100D1 automatically after the synchronization, without waiting for any input from the EMCS.

5. Data Interoperation

5.1 BESS Data Interface

The EMCS commands and supervises the BESS. The data interface between the EMCS and the BESS will be based on MODBUS TCP/IP.

The signal list of the data interface with the BESS will be as reported in the document "23A2007_240628_PROFINET_Register BESS_V1_0_0_3".

5.2 Electrolyzer Data Interface

EMCS commands and supervises the Electrolyzer. The data interface between the EMCS and the electrolyzer will be based on PROFINET. No hardwired signals are shared between the EMCS and the electrolyzer.

The electrolyzer PLC requires a custom time synchronization interface, based on dedicated signals (specifically: year, month, day, hour, minute, second) to be updated by the EMCS; it is assumed that the precision required is equal to the resolution.

The signal list of the data interface with the Electrolyzer will be as reported in the document "C63-AUT-002_04_ PLC Communication Table".

5.3 Fuel Cell Data Interface

EMCS commands and supervises the fuel cell.

The data interface between the EMCS and the fuel cell will be based on Modbus TCP.

The interface will allow to read the power set-point received by the EMCS. It will also provide information on the capability of the fuel cell to respect the power limitation imposed by such set-point within the given design tolerance (as opposite to the presence of an internal fault that prevents it).

No hardwired signals are shared between the EMCS and the fuel cell.

The signal list of the data interface with the Fuel Cell will be as reported in the document "Crosswind Modbus Table - Main PLC - External Cut v3".

5.4 Solar farm Data Interface

EMCS commands and supervises the solar farm.

The data interface between the EMCS and the solar farm will be based on ModbusTCP.

The interface will allow to read the power set-point received by the EMCS.

It will also provide information on the capability of the solar farm to respect the power limitation imposed by such set-point within the given design tolerance (as opposite to the presence of an internal fault that prevents it) and the signals that allows to communicate the commands to the EMCS regarding the solar farm CB SG-200D2.

No hardwired signals are shared between the EMCS and the solar farm.

The signal list of the data interface with the Electrolyzer will be as reported in the document "HKN1-02-REG-341 Manual for controlling the solar farm via the client connector REV A".

5.5 Wind Farm Data Interface

The EMCS receives information from the data interface of the Wind Farm SCADA (HV-SCADA).

The data interface between the EMCS and the Wind Farm SCADA (HV-SCADA) will be based on OPC-UA.

The presence of communication between the EMCS and the HV-SCADA is checked intrinsically by the OPC-UA client running in the EMCS.

The IEC-61850 network connection from HNA5 and HNA6-AFA70 on BLPH will not be redundant and it shall be directly connected to HNA6-AFA70, since the EMCS is not allowed to share the same IEC-61850 connection.

The details of the signals exposed by the SCADA refers to Figure 16 Status of Signals & Electrical Sequence.

NOTE: The HNA5 power signal has a sampling rate of 5 seconds and resolution 0.1 MW.

5.6 Electrical Distribution Equipment

The EMCS will supervise and command the equipment of the electrical distribution of the BLPH, including switchgears on the 6.6kV and 66kV sides incoming CB SG-200N1 and 800V SG-200D2 directly. However, the other outgoing feeders of SG-200N1 or main items (UPSs) are supervised and directly controlled by PCS.

The data interface of the EMCS with the electrical distribution equipment of the BLPH will be based on IEC-61850 and Modbus TCP/IP.

5.7 OLTC/AVR Data Interface

The EMCS supervises and controls the AVR/OLTC of the TR-100AD1 6.6kV/66kV transformer.

The HMI can set the AVR/OLTC in AUTO or MANUAL mode, the latter mode intended to enable the possibility to directly control the OLTC position.

EMCS can provide the command to RAISE and the command to LOWER the position of the OLTC directly to the AVR, allowing the OLTC remote control by operator.

The data interface between the EMCS and the AVR will be based on Modbus TCP.

In MANUAL mode the operator pushes the buttons on the HMI which will allow EMCS to INCREASE and DECREASE movements of the OLTC position (one request, one step). In more details, the HMI will write the value 1 in the TapLower or TapRaise signal (of the EMCS OPC UA interface) to perform the related operation. Once the EMCS sends the commands to the AVR interface, it auto resets to zero the TapLower and TapRaise signals.

The EMCS shall provide to the AVR of the OLTC the set-point voltage target on the secondary winding (the 6.6 kV side). Such value being a parameter with default value 6.6 kV. The EMCS shall allow to set this value from the data interface of the CCS SCADA.

Only in RESEARCH MODE, the EMCS shall allow to set the AVR/OLTC in MANUAL mode or AUTO mode, from the data interface of the CCS SCADA.

In AUTO mode the operator writes a SET-POINTs, EMCS checks the error between BLPH voltage and the set-point and EMCS sends the command to AVR to move the OLTC cursors INCREASE or DECREASE (one request, one step) at each step EMCS re-check the error, reiterating the control and commands if necessary.

5.8 PCS and LV Loads

The EMCS exchange real-time signals with the Process Control System (PCS) in order to:

- Coordinate the operation of the packages with PCS (by requests and permissive signals);
- Request the opening/closing of the LV contactors (which are controlled by means of the PCS), in order to manage the load shedding.
- Obtain the hydrogen storage level;
- Obtain time reference for its time synchronization of server's clocks.

The data interface between the EMCS and the PCS will be based on the protocol Modbus TCP.