Appendix G

Meshed Ready Technical Requirements

This appendix defines the technical parameters that Proposers must follow to ensure that all Projects are able to communicate and transmit power between one another safely and effectively. Defining these requirements ensures that Offshore Wind Generation Facilities selected for award under this RFP will be built "Meshed Ready" and capable of successful future interconnection with other Offshore Wind Generation Facilities in New York in the event that the Public Service Commission directs the implementation of a Meshed Network.

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Acronyms and Definitions

AC – Alternating current

C&P – Control and production

CIP – Critical Infrastructure Protection

DC – Direct current

FAT – Factory acceptance test

GIS – Gas Insulated Switchgear

HIL – Hardware-In-the-Loop

HVDC – High voltage direct current

Meshed Network – Offshore transmission configuration in which individual Offshore Wind Generation Facility substations are linked by connecting the AC side of several offshore converter platforms as shown in Figure G.2. The interconnection allows more than one power-flow path between the AC grid and the offshore Meshed Network.

Meshed Ready – An Offshore Wind Generation Facility and its associated radial link to the onshore point of interconnection which have been designed to have the performance, interface, controls, functional and physical requirements identified in the following sections of this document. These requirements enable the Offshore Wind Generation Facility to distribute power to other Meshed Ready projects which are categorised into control, interface, performance, functional and physical requirements.

Meshed Transfer Capacity – The amount of power that each mesh grid shall be able to transmit, which is defined as at least 300MW of AC power over the distance between the neighboring offshore substations using a summer rating. The power is to be transmitted via two separate 230 kV cables

MGCC – Meshed Grid Coordinated Controller

NERC – North American Electric Reliability Corporation

OEM – Original equipment manufacturer

OGC – Offshore Grid Controller

Operator- The future Operator of the Meshed Network. The exact entity assuming operation of the Meshed Network will be determined at a future stage in offshore wind grid development and will necessitate additional Orders issued by the New York State Public Service Commission, delineation of the control area of the Meshed Network, and any access or operational parameters determination by FERC. This entity could include the NYISO or another future unknown entity. The Operator of a Meshed Network maintains authority over operational controls and scheduling controls.

Owner – The owner of the offshore wind transmission assets including the Meshed Ready offshore substation or future AC links in the Meshed Network. The Owner at the time of the Meshed Ready phase may be synonymous with the Owner of the Offshore Wind Generation Facility. The Owner may differ at a future time when the Meshed Network is implemented. The Owner maintains physical operational control of the assets as part of a Meshed Network and would operate at the direction of the Operator.

SCADA – Supervisory Control and Data Acquisition

VSC – Voltage Source Converter

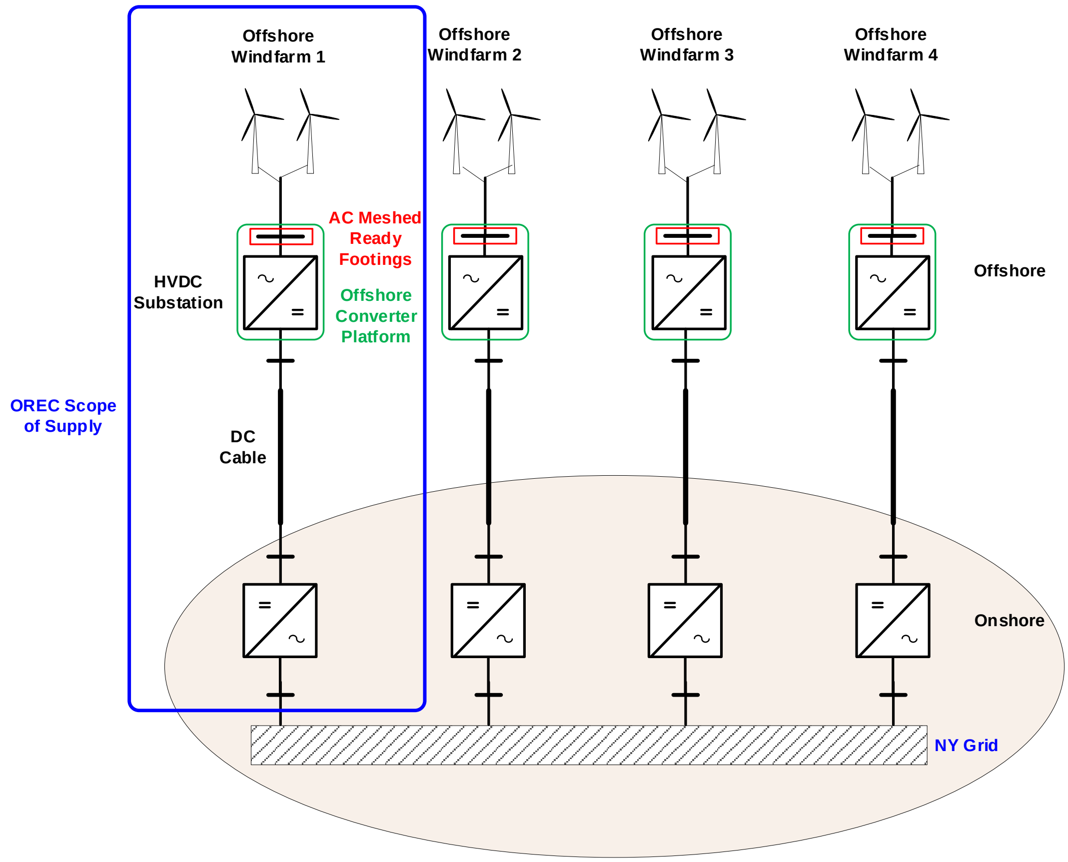
WTG – Wind turbine generator

WTG String – Several wind turbine generators are connected together to act as a one sub-feeder to the wind collector system

G.1 Meshed Ready Phase

The Meshed Network will not be constructed unless and until its implementation is directed by the Public Service Commission. To preserve this optionality for the future and continue OREC procurements, the Public Service Commission has authorized NYSERDA to procure offshore wind projects on a Meshed Ready basis. . The Meshed Ready phase will be constructed at the same time as the Offshore Wind Generation Facility and the development of the offshore substation. The goal of the Meshed Ready phase is to develop the necessary links to ensure that the offshore substation platform has the necessary equipment and control systems to allow for the Meshed Network to be able to be implemented in the future. The Meshed Ready system design is shown in Figure G.1.

Figure G.1: Meshed Ready Phase



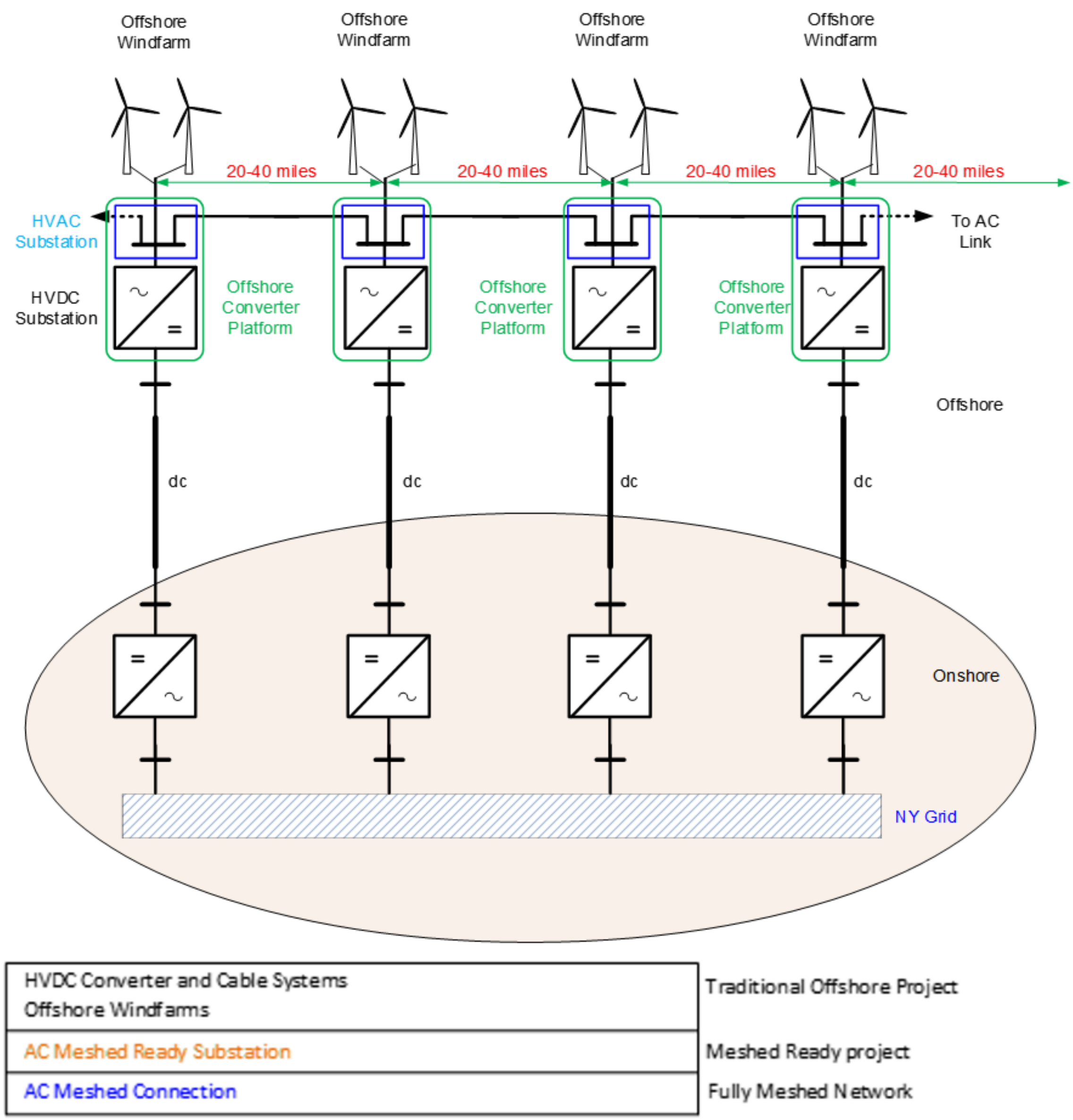
The purpose of the Mesh Ready phase is to reduce upfront costs and allow for an optimized meshed system to be implemented at an appropriate time. By ensuring that all offshore systems are Meshed Ready, the implementation of an offshore Meshed Network can occur with reduced costs compared to attempting to integrate offshore systems that do not have the necessary equipment or controls (not Mesh Ready) to integrate with other offshore systems.

G.2 Meshed Network

G.2.1 System Configuration

In the Meshed Network implementation phase, a meshed grid would be implemented by connecting the AC side of the several offshore converter platforms as shown in Figure G.2. The offshore Meshed Network would be expected to have Offshore Wind Generation Facilities directly connected in a mesh configuration using AC cable systems. The Meshed Network would be expected to consist of several of wind farms connected to the shore using point-to-point VSC HVDC transmission links.

Figure G.2: Meshed Network Configuration



G.2.2 Meshed Network Development

A coordinated process with the HVDC cable developers, Offshore Wind Generation Facility developers, and AC switchyard and platform developers would be required to implement the offshore Meshed Network.

The radial connection would serve as the starting point. The approach would be to first identify the Project that would be integrated to the offshore Meshed Network. Based on the high-level assumptions outlined in Section G.2.3, the distance between the offshore platform of the new Project and the platform of the meshed connection point assumes the offshore platforms are located within adjacent Offshore Wind Generation Facilities and are within a 20 to 40 mile range.

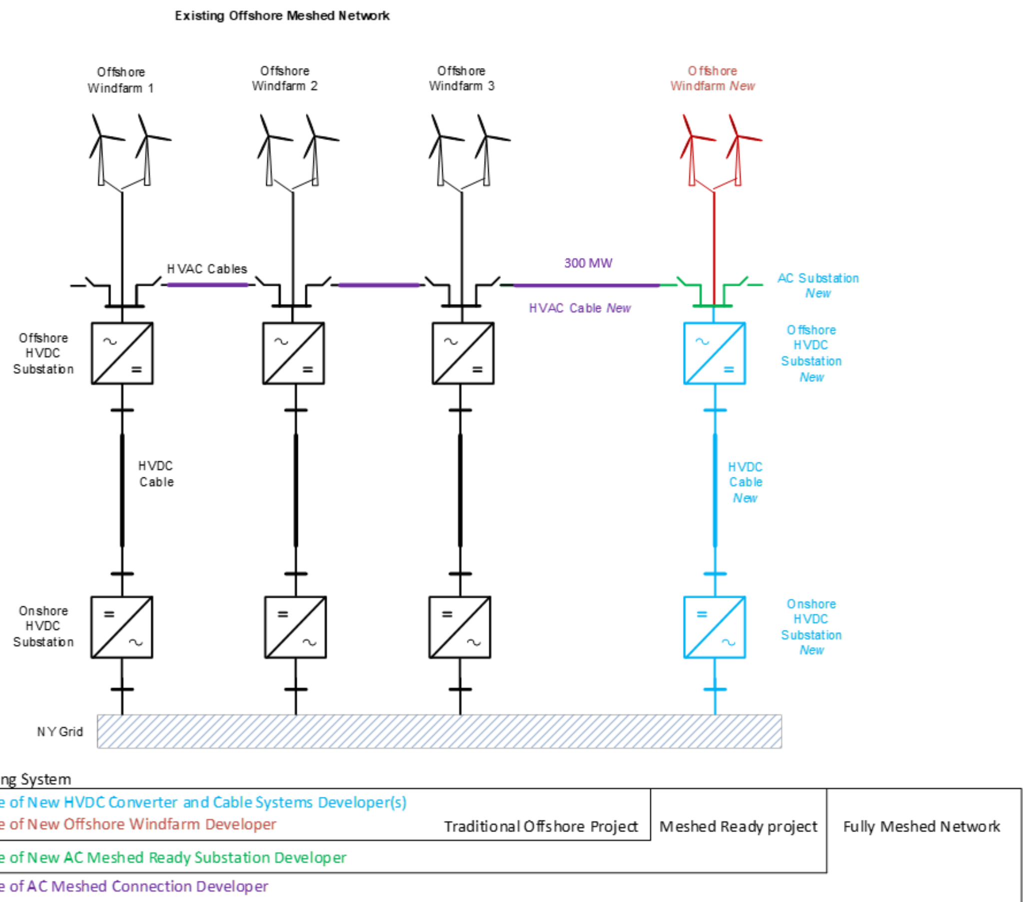
In the second stage, the new Project would be added to the offshore Meshed Network as shown in Figure G.3. The meshed connection would be able to transmit a minimum of 300 MW of active power within the distance between two neighboring Meshed Ready platforms using 230 kV AC cable technology. As discussed in Section G.2.3, a single 230 kV AC cable circuit would be utilized to meet the 300 MW active power transfer capability and the power carrying capacity of the meshed AC cables shall be confirmed.

The associated AC cable to the meshed grid connection point and/or AC switching station would consider the number of cables being connected for the new Project as well as another connection to a future project. This approach reflects that the exact design of the future connection will not introduce any restrictions to connect to the Meshed Network.

During this coordinated implementation process, the functional requirements for the Meshed Network connection would be provided by Offshore Wind Generation Facility design, AC switchgear design, and the HVDC converter design as identified in Section G.6.

Suitable design measures would be considered for the new Project to minimize the modifications to the existing system when connecting the new Project to the Meshed Network. The design would ensure that connecting the new Project to the Meshed Network will not cause any risk of damage either to the HVDC system or to the Offshore Wind Generation Facility of the new Project while the Meshed Network operates satisfactorily under all conditions.

Figure G.3: Meshed Network Development



G.2.3 Key Assumptions

The following assumptions were made to define the parameters that allow a system to be considered Meshed Ready:

- The offshore grid design requirements shall be developed by NYSERDA or another entity considering overall New York future offshore wind development plan.
- The radial connections from the off-shore wind to the on-shore points of interconnection will be based on the VSC HVDC technology as it is required by the PSC Order on Power Grid Study Recommendations issued on January 20, 2022
- The Meshed Network will be constructed after the completion of the individual projects. Each individual Project will have its own radial HVDC link that will transmit power to shore.
- The HVDC link is assumed to be capable of transferring the rated capacity of the wind power generated by the corresponding Offshore Wind Generation Facility regardless of its connection to the Meshed Network.

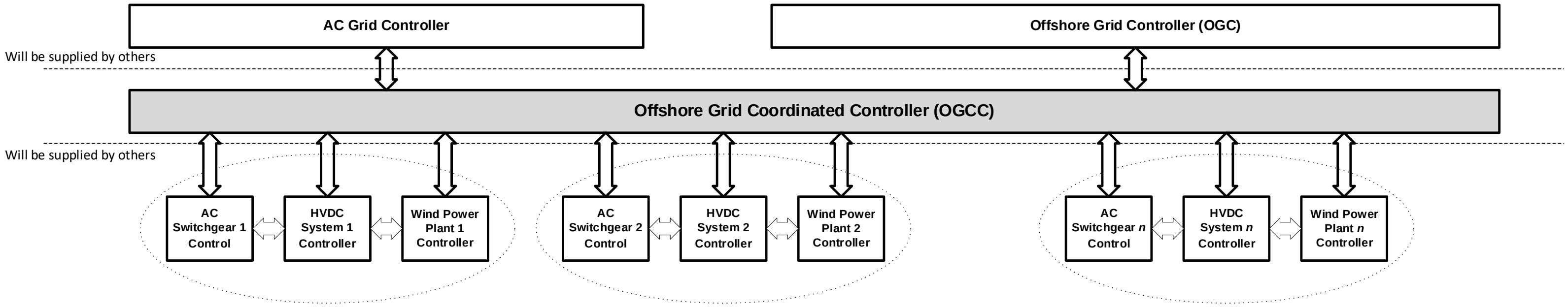
- The implementation of a Meshed Network will not increase the total capacity of the offshore grid. Designing and building the offshore Meshed Network provides grid benefits by improving reliability and reducing curtailments in case of transmission outages.
- The Offshore Wind Generation Facilities must design their offshore substations with the capability to be Meshed Ready.
- Each substation shall be able to connect to two neighboring offshore substations (hosting 2 mesh connections).
- Each meshed connection will be an AC connection and will be able to transmit at least 300MW of power throughout the Meshed Network between two the offshore stations as defined by Meshed Transfer Capacity. Proposers may determine the distance requirement of Meshed Transfer Capacity based on the Project's proximity to other Offshore Wind Generation Facilities.
- The Meshed Network is to transmit the energy at a voltage level of 230 kV.
- Each platform will connect only to two other nearby platform in the Meshed Network.
- The internal layouts of Offshore Wind Generation Facilities are in radial or radial-ring configuration, so that active power flows only from wind turbines to the offshore Meshed Network.
- The Meshed Network will not include Projects with hybrid AC/DC radial interconnection. AC interconnection between the offshore Meshed Network and the onshore converter station may introduce additional challenges and design requirements for all Offshore Generation Facilities in the Meshed Network such as higher fault currents, wider transient over voltage, and different control requirements.

G.3 Control Requirements

G.3.1 Control Concept

A centralized control system, hereafter the "Meshed Grid Coordinated Controller" (MGCC) necessary for the Meshed Network operability shall be considered in the Meshed Ready phase. The MGCC system shall be fully redundant and shall be designed to permit control and monitoring of the Meshed Network, HVDC links, and Offshore Wind Generator Facilities in a coordinated manner. The high-level, conceptual design of the MGCC is shown in Figure G.4.

Figure G.4: Meshed Grid Coordinated Controller



The MGCC shall be available to access from a local control room within each offshore HVDC converter station and from the Owner's remote dispatch center (or at any remote location specified by the Owner).

The general concepts of the centralized Meshed Grid Coordinated Controller shall be based on the following:

- It shall be possible to select MGCC system located in any offshore platform or the remote-control center as the active MGCC system.
- It shall act as a master control facility for the Meshed Network to properly coordinate active power flow within the Meshed Network at the discretion of the future Operator .
- It shall monitor the power flow of the Meshed Network and shall ensure that the power flow within its limits and cables are not overloaded.
- It shall properly coordinate the power flow within the Meshed Network when the AC grid controller requests a power transfer change for any of the radial HVDC connections to the onshore grid.
- The startup and shutdown of an HVDC system shall be supervised and coordinated.
- The MGCC shall interface the AC grid controller and the offshore grid controller with the offshore HVDC controllers, and the Offshore Wind Generation Facility controllers as shown in Figure G.4.
- The control design and its implementation shall be such that high reliability and availability of the entire Meshed Network is achieved.

G.3.2 MGCC Control Functions

G.3.2.1 Active Power Flow Coordination Within Meshed Network

The MGCC design shall consider coordinating the active power within the Meshed Network. The active power coordination shall consider the following parameters:

- Active power transfer limits of the meshed connected cable system
- Active power transfer limits of the radial HVDC connections
- Minimal transmission losses
- Higher active power transmission utilization
- Maintain appropriate reliability at a N-1-1 criterion for the radial HVDC connections
- Maximum stability margins for the offshore Meshed Network

For the active power coordination within the offshore Meshed Network, the following approach is proposed:

- The VSC HVDC transmission systems will act as the primary control source for controlling the voltage and frequency of the offshore Meshed Network and they will behave as slack sources in the network. The distribution of the total power in the network among VSC HVDC transmission systems will be controlled by applying frequency droop schemes for the VSC controls. The droop scheme will allow power sharing between VSC HVDC transmission systems in the failure and/or limitation of any transmission system or during loss of communication.

- The MGCC shall determine the frequency droop settings that can be applied to determine the optimum steady-state stable operating point for any operating scenarios considered in the design. E.g., in the event of loss of a HVDC link, the controls shall reallocate any lost power to the other HVDC links within their capability and the maximum possible power transfer to the NYCA shall be achieved uninterruptedly.
- The active power coordination shall determine and assign set points, droop settings, dead bands as necessary to each HVDC controller connected considering the dynamic and stability aspects during all the network conditions of offshore grid and the VSC HVDC systems.
- The active power coordination design details shall be demonstrated using system studies considering the number of onerous contingencies for the Meshed Network in determining the credible worst-case scenarios.
- In case of loss of a converter, the power will be shared by the remaining converters of the meshed system to a maximum extent possible. The converters or AC cables shall not be overloaded. Emergency remedial actions such as sending orders to reduce wind power generation, trip a section of wind power generation or adding an AC chopper scheme, etc., shall be taken into consideration to ensure the stable operation of the Meshed Network within their rating limits and prevent unnecessary tripping during a sudden loss of a HVDC link.
- Provision shall be provided by the Meshed Network to support auxiliary power to any offshore platform during start up of the Project and when there is no available generation (no wind or excessively high wind).
- The power flow coordination design shall consider the following network events, as a minimum:
    - Normal operation
    - HVDC converter trips
    - AC/DC cable outages
    - Trip of an Offshore Wind Generation Facility
    - Decrease/increase of wind power generation
    - Grid power injection changes in response to the onshore grid

The power coordination controller shall be designed considering requirements in future grid expansion as outlined in Section **Error! Reference source not found.**. The configuration and parameters of the controller shall be flexible to allow for future modifications and system developments.

The power coordination controller design shall be demonstrated to NYSERDA during the Project development before the design is finalized. It shall also be possible to consider an alternative active power flow coordination approach that can meet all Project requirements by clearly demonstrating its capabilities and limitations to NYSERDA during the Project development.

G.3.2.2 Reactive Power Support

The control of the AC voltages on the converter AC buses is expected to be achieved by the HVDC converter control within the converter's reactive power rating. As long as the converter reactive power has not reached the inherent limit, the steady state AC voltages of the Meshed Network will be maintained by the HVDC converter.

The reactive power flow on the Meshed Network is dependent on the active power transfer of the cables. The reactive power support for the Meshed Network shall be provided using switchable and/or fixed reactors that are capable of providing reactive power requirement for the Meshed Network up to the maximum active power transfer within meshed connected cables. The reactive power for the Meshed Network shall be independent of the reactive power capability of the HVDC converters and Offshore Wind Generation Facilities during steady state operation.

When responding to the AC system disturbances, the system may utilize the reactive power capability of nearby converters and Offshore Wind Generation Facilities, as needed.

The reactive power flow between the HVDC converters and the Offshore Wind Generation Facilities shall also be monitored by MGCC.

G.3.2.3 Automatic Switching Sequences

Management of AC switches for the Meshed Network for the following event shall be coordinated by the MGCC:

- Connect and energize any AC cable circuit to the Meshed Network
- Deenergize and isolate any AC any cable circuit from the Meshed Network
- Connect/disconnect reactive power sources

The switching sequences shall be initiated by the MGCC. The switching will automatically be executed at the converter connection platforms by the AC switchyard control.

G.3.3 MGCC Control System Design

G.3.3.1 General

The MGCC design shall ensure that the control is fully automatic, with control settings relevant to the operation of the Meshed Network.

It shall be possible to set the relevant control modes and settings from the active control location (i.e., either from the remote-control center or from the local converter control room). Studies shall be performed to determine appropriate automatic variations of the control settings in response to the variation of transmission, to obtain satisfactory system operation without operator interaction.

The control design shall include the control characteristics and control methodology to achieve efficient and reliable operation during normal operation and during system faults and the dynamics that follows major events in the Meshed Network and/or within the connected AC/DC systems.

The control characteristics shall include actions to achieve coordinated responses to major changes in the Meshed Network, such as tripping of converter stations and faults in the AC cables with a minimum impact to the working system.

The interface requirements shall be implemented as detailed in Section G.4.

The converter performances with the telecommunications disabled shall also be demonstrated during both Dynamic Performance Studies and Factory System Tests.

G.3.3.2 Redundancy and Physical Separation

The control design shall consider redundancy and physical separation to meet the availability requirements.

The control system shall consist of two redundant control systems in an “active” and “standby” configuration. Each system shall include separate input circuits, output circuits, telecommunication circuits and all the other control equipment. The design shall ensure that failure of a single element within the control systems does not result in reduced control capabilities and functionality, and does not cause equipment damage or malfunction of control systems.

Features shall be provided to initiate changeover from an active control system to the standby system either automatically or by manual initiation. If one system has a fault or has been manually switched out for maintenance, then the active control system shall not change over to it. Changeover shall not result in a disturbance or any change in the transmitted power level, outside of the tolerance of the measurement system, and it shall not influence the normal operation of the Meshed Network.

The redundant design shall aim to promote high flexibility of maintenance, commissioning, testing and operation of the Meshed Network, and to ensure the lowest unavailability caused by control system faults. The design shall ensure to provide fail-safe states for any inputs/outputs in case the associated controller fails or loses power.

Two redundant control systems shall be identical in all respects. Maximum electrical and physical separation shall be maintained between redundant control systems such that the proper operation of each system shall not be compromised in any respect by the shutdown of the other system.

G.3.4 Multi-Vendor Design Requirements

Upon request from the Operator, the Owner shall provide study models and control models of the converter stations and the Offshore Wind Generation Facilities from different contracts. Black box models are acceptable to respect the intellectual properties. These models shall be provided in the format requested by the Operator. The Owner may sign formal agreements with the Vendors such as Intellectual Property security requirements or Non-Disclosure Agreements.

The study models and controls shall be suitable to use in the studies and the test state in Section G.5.

Vendors shall comply with the interface requirements as identified in Section G.4 and physical requirements as identified in Section G.8.

G.4 Interface Requirements

G.4.1 Switchgear Requirements

Provisions for 230 kV shunt reactors and accessories must be included in the offshore converter platform if needed. The number of spare shunt reactors shall also be considered and need to be derived from reliability and availability requirements as determined by the Operator. If the design requires separate breakers for shunt reactors, then additional bays shall be provided in the AC GIS to connect each shunt reactor. The AC GIS Bay may include circuit breaker, disconnect and ground switches and measuring devices to allow proper control and protection of the shunt reactor. The Owner shall determine the shunt compensation requirements based on their studies. The cost implication of such requirement should also be described.

Provisions for AC cable terminations shall be allowed in the offshore converter platform. The number of spare AC cables (if required) shall also be considered and need to be derived from reliability and availability requirements as determined by the Operator. Additional bays shall be provided in the AC GIS to connect AC cables. The AC GIS may include circuit breaker, disconnect and ground switches and measuring devices to allow proper control and protection of the AC cable.

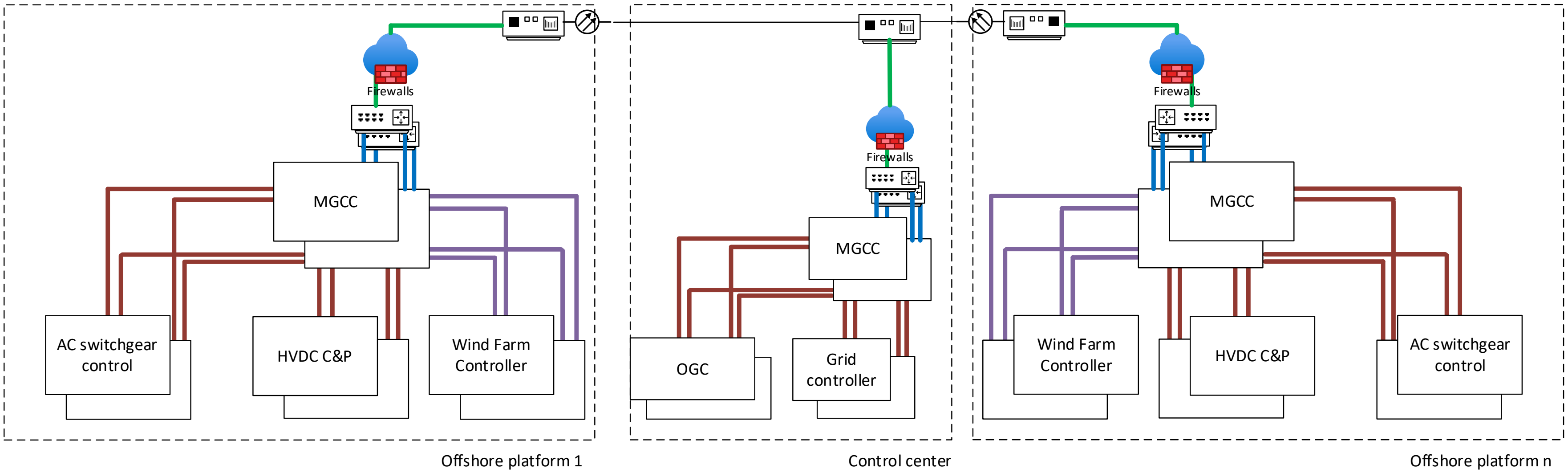
Provisions for AC chopper equipment shall be allowed in the offshore converter platform and AC GIS shall include additional bays, if AC chopper is necessary to meet the performance requirements as mentioned in Section G.5. The cost implication of such requirement must also be carefully evaluated and described. The AC GIS Bay may include circuit breaker, disconnect and ground switches and measuring devices to allow proper control and protection of the AC chopper.

G.4.2 Control and Protection Signal Interfaces

Figure G.5 shows the conceptual overview of MGCC with interfacing systems. Interfacing systems are listed below:

- Grid controller
- Offshore grid control center (OGC)
- HVDC system control and protection systems
- Offshore Wind Generation Facility controllers
- AC switchgear protection and control

Figure G.5: Conceptual Overview of MGCC Interface



The Owner shall prepare a detailed signal list for each interfacing system which includes signal type, and communication protocol to reduce interoperability risk when integrating future links with multiple vendors. A conceptual signal list is provided in Table G.1.

Table G.1: Conceptual Interface Signal List for MGCC

Signal name	Interface point	Input/output	Signal type
Schedule Power	AC grid controller	Input	Control
Available Power	AC grid controller	Output	Control
Transmitted Power	HVDC system controllers	Input	Control
Offshore PCC Frequency	HVDC system controllers	Input	Indication
Converter Status	HVDC system controllers	Input	Indication
Available Power	Offshore Wind Generation Facility controller	Input	Control
Wind farm status	Offshore Wind Generation Facility controller	Input	Indication
Wind farm trip/power reduction	Offshore Wind Generation Facility controller	Output	Indication
Additional status and control signals interface with SCADA systems	OGC, AC grid controller, HVDC controllers	Input/output	Indication/ Control

The MGCC shall be able to communicate with each redundant panel installed in the control room of each offshore converter platform and onshore control center.

During a telecommunication outage, each panel shall be able to operate without any interruption to the power flow.

Communication bandwidth and latency requirements will be identified to meet the performance requirements mentioned in Section G.5.

Protection systems for the offshore mesh grid system must be properly designed and coordinated to reliably detect all possible fault conditions and shall be included in AC switchyard protection panels. At least two independent protection systems must be implemented. Both protection systems operate in first time protection zone and under different protection principles.

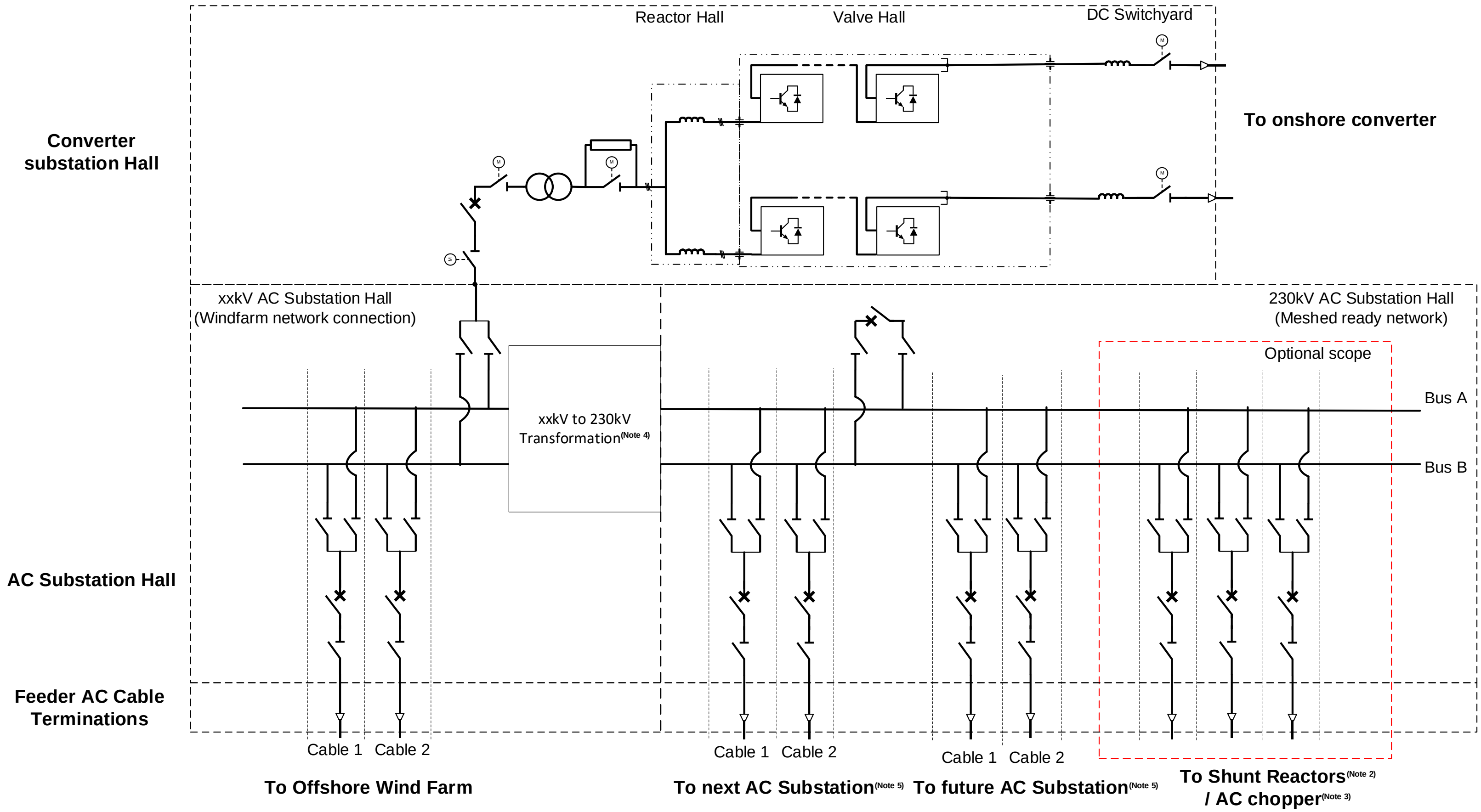
G.4.3 Revenue Metering Requirements

Revenue meters shall be installed at the interface points to the 230 kV AC cables. Interface points will be identified by the Owner in the commercial agreement. Owner shall identify the preferred energy meters for the overall scheme. Revenue metering scheme shall be designed to provide adequate metering points as needed for the commercial agreement between the stake holders.

G.4.4 Equipment Rating Requirements

AC GIS equipment shall be adequately rated for the additional expected maximum current that will be seen during Meshed Network operation. AC GIS equipment in the offshore platform shall have provisions for future upgrades. Conceptual single line diagram for offshore platform is shown in Figure G.6.

Figure G.6: Conceptual Single Line Diagram for Offshore Collector Platform



Notes:

1. Grounding switches, arresters and measuring devices are not shown.
2. These bays are required if the system studies identify switchable shunt reactors.
3. These bays are required if the system studies identify AC chopper.
4. Transform the voltage to 230kV level from the offshore windfarm system voltage level (xxkV).
5. Cable reactive power compensation will be needed at the cable termination.

An AC chopper may be required to achieve fault ride through capability of the wind farms. AC chopper requirement and its sizing will be studied for the system power grid recovery and stability after fault and disturbance in the offshore and onshore power grid.

G.4.5 AC Cable Requirements

The 230 kV AC cables shall be rated to deliver the Meshed Transfer Capacity to match with the peak loading requirements at a summer rating between the offshore platforms. Cable cross sections shall be selected based on studies under the consideration of the thermal rating, short circuit rating and voltage profile. In addition, the optimal cable cross section shall be defined by a cost benefit analysis based on the cable capital costs, installation costs, operation and maintenance, and the cost of losses over the Project lifetime.

G.4.6 230 kV Transformer Requirements

A transformer will be needed to convert the Offshore Generation Facility system voltage to a 230 kV level. The transformer shall be rated to satisfy the performance requirements of the Meshed Network as specified in Section G.5. The transformer shall comply with the most current version of the relevant IEEE standards. The detailed requirement shall be provided by the Owner during Project development to the Operator for consideration.

G.4.7 Interface Management Recommendations

Main technical interfaces and organisational interfaces shall be managed in each Project. The major interface items, and roles shall be defined before the contract finalization. Detail interfaces including detailed interface matrices may develop at a later phase.

The following main technical interfaces have been identified as an example:

- 230 kV cable between the offshore platforms
- 230 kV switchgear at the offshore platform
- Revenue metering points
- Main power equipment and accessories: shunt reactors, and AC chopper
- Telecommunication and fibre optic infrastructure (offshore and onshore)
- MGCC equipment located on offshore platform and control center including:
    - MGCC system
    - HVDC control and production (C&P) interface to the MGCC
    - AC switchyard P&C interface to the MGCC
    - Wind farm control interface to the MGCC
    - AC grid control interface to the MGCC
    - Offshore grid control interface to the MGCC

Involved parties shall be allocated with a functional role for the relevant interface for each phase (design, fabrication, installation, testing and commissioning). Functional roles (RASCI) can be as follows:

- R: The party who is responsible for the interface and is responsible for the execution. The responsible must report to the accountable.

- A: The party who is accountable and qualified for the correct and thorough completion of the interface and must give an approval before an action item or solution can be effective.
- S: The party who supports the responsible party to achieve the result of the work execution.
- C: The party who is consulting the other involved parties regarding the implementation or must be pre consulted.
- I: The party who needs to be informed about the decisions, on the progress, achievements etc.

The Owner will select the party to be responsible for the overall planning of the grid connection.

Interface meetings shall be held on a regular basis between all involved parties

Exchange of documents and formal communication between the parties shall be through a single document management system.

Agreements shall be made between all involved parties on the starting date and (ultimate) date of completion of the works to properly coordinate schedules between the parties.

G.5 Performance Requirements

When connecting a new Project to the Meshed Network, the following performance requirements shall be met. System studies and system tests shall be performed to verify the performance of the Meshed Network. NYSERDA will make arrangement to provide suitable study models and controls from other vendors as specified in Section G.3.4.

G.5.1 Steady State Performance

The steady state and dynamic performance of the Meshed Network shall be demonstrated using system studies to verify the stable operation when connecting a new Project to the Meshed Network. The study model shall include simulation models provided by HVDC and Offshore Wind Generation Facility developers and shall include sufficient details to adequately represent dynamic behavior of the HVDC system and the Offshore Wind Generation Facilities.

G.5.1.1 Power Flow Verification

Power flow studies shall be performed for the Meshed Network to make sure the operating point of each equipment and system connected (e.g., HVDC converters, WTGs, transformers, cables, and busbars, etc.) is within its steady state operating range for all feasible operating conditions, including the following:

Table G.2: Contingency List for Power Flow Verification

Wind Power Generation per Offshore Wind Generation Facility	Number of Offshore Wind Generation Facilities in Operation	Number of HVDC in Operation	Operation of Additional Reactive Power Equipment
100%	N	N	Yes
100%	N	N	No
50%[1]	N	N-1	Yes
50%[2]	N	N-1	No
25%	N	N-1	Yes
25%	N	N-1	No

The following design requirements shall be met for the steady state operation, to a minimum:

- The Meshed Network frequency range
- Steady state active and reactive power range and ratings of the WTGs and HVDC
- Offshore substation busbar voltage and current ratings
- AC cable voltage and current ratings
- Steady state reactive power management of the Meshed Network

G.5.2 Dynamic Performance

The dynamic performance of the Meshed Network shall be studied including detailed PSCAD model of the HVDC converter equipment and controls and Offshore Wind Generation Facility and controls.

G.5.2.1 Dynamic Stability of the Meshed Grid using Active Power Coordination

The active power coordination control shall be capable of stable operation of the Meshed Network while meeting all the requirements, for various changes in the events or combination of events as specified herein, as a minimum:

- Single or three phase faults on AC cable
- Complete Offshore Wind Generation Facility trip
- A WTG string trip
- HVDC system trip events
- Intermittent power output from Offshore Wind Generation Facility
- Single phase and three faults on the on-shore AC system including:
    - Breaker fail
    - Single pole auto-reclose

[1] If three more projects are available.
[2] If three more projects are available.

The performance requirements shall be met for the maximum and minimum continuous levels of AC voltages and frequencies specified for the offshore grid.

G.5.2.2 Dynamic Reactive Power Support

A complete reactive power coordination control study shall be performed in order to design a reactive power control within the Meshed Network. The study shall demonstrate that the reactive power support requirements within the Meshed Network can be achieved using reactive power elements provided and regardless of the operation of any HVDC converters and any Offshore Wind Generation Facilities. The study shall demonstrate reactive power element switching/control strategies needs to be followed for all system operating scenarios.

The studies shall demonstrate the performance of the reactive power support to step changes in AC voltage order and sudden changes in AC bus voltages caused by active power changes or AC system events. A typical study list is provided below (Study scenarios shall be identified once design requirements are defined):

- Step increase in AC bus voltage order of the offshore HVDC converter
- Step decrease in AC bus voltage order of the offshore HVDC converter
- Step increase in reactive power order of the Offshore Wind Generation Facility
- Step decrease in reactive power order of the Offshore Wind Generation Facility
- Single or three phase faults on AC cable
- Complete Offshore Wind Generation Facility trip
- A WTG string trip
- HVDC system trip events

The above studies shall consider different levels of Offshore Wind Generation Facility output.

The Meshed Network shall remain connected and shall continuously provide power transfer capability to the NYCA.

G.5.3 Factory Performance Acceptance Tests

Factory acceptance test (FAT) of the MGCC can be done using replica control systems obtained for the Offshore Wind Generation Facility and HVDC controls. Hardware-In-the-Loop (HIL) type tests shall be performed using replica control systems received for the Offshore Wind Generation Facility and HVDC systems including the other interfacing systems such as other Offshore Wind Generation Facilities and their HVDC connections and onshore and offshore power systems.

The FAT shall be performed for the system events and contingencies listed in Section G.5.2 with and without communication between platforms.

These tests shall identify any interoperability issues of the interfacing control systems.

Replica control system can also be used to validate and test the future C&P upgrades.

G.6 Functional Requirements for HVDC and Offshore Wind Generation Facility and AC Switchyard

G.6.1 HVDC System Design Requirements

When the number of HVDC links are connected to an offshore Meshed Network, each system will be tightly coupled to one another. When a new converter terminal is added to the system, the impact to the existing system will be minimized. Therefore, the new system shall consider design measures to minimize the impact to the existing system design performances. It is assumed that the HVDC Converter System specification will define these requirements in detail.

In addition, the HVDC controls shall be able to interface with all the signals from the redundant MGCC systems to achieve the performance requirements listed in Section G.5. This interface will be verified in the factory acceptance testing for the HVDC control and protection system.

HVDC design shall also consider space and auxiliary power provisions for MGCC system and communication equipment at the offshore converter control room.

G.6.1.1 Design Studies

As a minimum, the following HVDC design studies and verifications will be performed by the HVDC vendor considering operation in the Meshed Network:

- Fault ride-through capability for fault in the meshed grid
- AC/DC Insulation coordination
- AC and DC resonance studies
- Dynamic performance study
- Reactive power control
- AC harmonics study
- Multi-infeed HVDC interaction study
- Transient current analysis
- Short-circuit analysis
- Sub-synchronous interactions studies

The detailed requirements will be specified in the HVDC Converter Station Specification. NYSERDA will coordinate these studies and will be provided necessary inputs and models from the Offshore Wind Generation Facility developer and Meshed Network developer to the HVDC vendor.

The HVDC cable supplier is responsible for providing mitigation methods to meet the HVDC system performance as specified.

G.6.2 Offshore Wind Generation Facility Design Requirements

The Offshore Wind Generation Facility controls shall be able to interface with all the signals from the redundant MGCC systems to achieve the performance requirements listed in Section G.5.

G.6.3 AC Switchyard Design Requirements

The Meshed Network will be connected to the AC GIS. The following equipment and provisions shall be provided for Meshed Network connection, as a minimum:

- Provision for connecting cables and reactive power sources
- GIS bays including circuit breaker bays including disconnectors and measuring equipment
- Suitable interlocks

AC switchyard protection and control system shall be able to interface with all the signals from the redundant MGCC systems to achieve the performance requirements listed in Section G.5. This interface will be verified with the factory acceptance testing for the HVDC control and protection system.

The AC switchyard control system shall provide all the interlocking, monitoring and control for the shut reactors, AC chopper and AC cable switchgears.

The AC switchyard protection system shall provide all the necessary protection functions to the shut reactors, AC chopper and AC cables.

G.7 Recommendations for Spare Parts, Warranty, Control Upgrades and Cyber Security

G.7.1 Spare Parts Strategy

Mandatory spare part requirements for Meshed Ready system will include the following equipment:

- 230 kV AC cables and accessories
- Shunt reactors
- AC chopper (if deemed necessary)
- GIS switchgear equipment and accessories
- GIS measuring devices
- Protection and control equipment
- Communication and SCADA equipment

The Owner may also invest in additional spare parts considering the impact of weather, access, lifting constraints and manpower limitations. The equipment specific spare part requirements are based on the failure rates of systems and components and these data available only to OEMs. Therefore, additional spare parts requirements can be identified during contract negotiation stage of the Project.

The Owner requires the OEMs to identify the spare part inventory at different life cycle stages such as commissioning spares, two-year spares, and ten-year spares (long term spares). Commissioning spares will be used in 'early-life' failure during the warranty periods. Long term spares make provision for obsolescence of equipment and unavailability of suppliers.

The Owner shall manufacture spare 230 kV AC cables and accessories manufacture the spares along with the main cable materials and to put them into storage in a secure location that is convenient for loading them onto a cable repair vessel. Care must be taken that accessory components with limited shelf-life materials are kept up to date. The length of cable required to make a repair can be readily calculated for each Project. It is also prudent to test cables that have been in long term storage before installation at sea.

It is recommended to store spare control and protection equipment at the local station. It is normal practice to install redundant control and protection systems to increase reliability and availability. Therefore, failed control and protection equipment can be replaced on-line, by switching to the other controller. Typically, spare control cards are kept at least one of each type.

G.7.2 Warranty

The warranty philosophy employed in offshore platform contracts shall be applied for the additional primary equipment required for the Meshed Ready system.

The Owner may request ongoing licensing/support services that will be applicable to the MGCC hardware/software being supplied with the contract after in-service/hand-over of the system to the Owner.

The Owner may need support from the HVDC stations and Offshore Wind Generation Facilities, for the future upgrades to accommodate modifications to the control & protection, SCADA system, communication system and HMIs as necessary. Long term maintenance and service contracts with the HVDC stations and Offshore Wind Generation Facilities are recommended for each link.

G.7.3 Future Control Upgrades

Control and Protection system upgrades can be expected for the following reasons:

- Adding a future link
- MGCC upgrades
- Vendor specific upgrades (firmware and software upgrades)
- End of lifetime

The Owner shall specify requirements in the technical specification to ensure C&P system can accommodate modifications to the control & protection, SCADA system, communication system and HMIs for the control upgrades foreseen due to future link and MGCC upgrade.

The Owner shall also specify spare capacities in the C&P system and cubicles. As per Cigre TB847, in case cyber system hardware spares are purchased with the initial contract delivery, end of life of this hardware shall be evaluated (e.g., firewalls of a type, which is close to its end of active manufacturing life, would not be accepted for a delivery).

The Owner should consider investing for a long-term maintenance and service contract and patch management service contract with the Vendor for each link. Owner can use a third party and independent partner to develop and provide long-term service contract for the MGCC. This will ensure fast response time and reliable services.

The Owner should consider invest in replica control system. Replica control system can be used to test control upgrades. Vendors can be granted remote access privileges to the replica controller to provide faster and cost-effective upgrade service.

The Owner should consider investing in a comprehensive training package customized for the as built system to train Owner's employees to perform in house control upgrades. However, this may void warranty provided by the Vendor and this may also need access to Vendor's source codes and licenses for special software packages.

The Owner should consider investing in additional spares for the C&P equipment to extend its lifetime.

The Owner shall specify requirements in the technical specification to ensure spare laydown area is available in the Control and Protection rooms. This area can be used to keep new cubicles during complete C&P upgrades to reduce outage time.

C&P system shall be redundant and modular design to do firmware and software upgrades without need of an outage of the link as much as possible.

G.7.4 Cyber Security

Requirements identified in the current version of the NERC Critical Infrastructure Protection (CIP) standards shall be followed.

Specific and unique regional cyber incident reporting requirements shall be clearly identified in the technical specification.

Owners shall incorporate the latest developments in supply chain cyber security requirements and factory malware testing standards, into the technical specification.

Physical and electronic security controls shall be in place during commissioning and security and penetration tests shall be part of acceptance testing protocols for the Meshed Ready system.

The Owner shall have a formal change management program with full version and revision tracking is in place during factory acceptance testing and during commissioning. Replica simulator of the MGCC is recommended for testing and implementation of software changes/patches and formulation/training of recovery plans.

The Owner needs to identify cyber technical support approach after handover. Owner shall identify responsibilities for evaluating and installing patches and maintaining software licenses both during commissioning and after handover for the Meshed Ready system.

Secure remote access to cyber assets in MGCC systems shall have a multi-layered defense-in-depth strategy where all access from outside the local network into the control system and vice versa, must be adequately protected by applying several security measures. Means to monitor and log the remote access sessions shall be used.

The Owner shall consider invest on service contract to provide remote account, access and password management and administration.

G.8 Offshore Substation Physical Requirements

Additional space offshore must be enabled to allow for the additional cabling required.

The Owner shall include the addition of two additional cable run-offs that are each capable of safely accepting a 230 kV subsea cable. The cable runoffs are to be sized to ensure the safe installation and operation of the cables.

The Owner shall ensure that sufficient space on the cable deck is allowed to safely pull, strip and connect the two 230 kV cables.

Owner shall include in their cable lay plans sufficient space for two 230 kV cables to be installed without disturbing the existing infield or export cables.

The battery limit for the developer's Meshed Ready system will be at the termination the GIS for the meshed cable.

G.8.1 Transformer Requirements

The design of the offshore substation shall include space for a transformer to be installed, maintained, and operated. The developer will be responsible for the installation of the transformer prior to the installation of the Meshed grid.

The transformer shall be designed such that it can be removed or replaced in the event of a failure of the equipment.

The transformer shall be designed such that the 230 kV connection can be conducted during the mesh implementation stage.

G.9 Frequently Asked Questions (Not for inclusion in the final RFP)

G.9.1 What is the specific equipment needed to support the Mesh Ready Phase for the AC Meshed Ready footings?

The "Mesh Ready Phase" is deemed to include everything with the exception of the cables. The same special, power and monitoring should be applied as is done for other cable bays, or technical components of the systems in use for the infield cables.

G.9.2 Why the design switch from 66kV to 230kV between the draft circulation in December 2021? What are some similarities and differences or relevant issues in design considerations?

The 66-kV was initially proposed to limit the changes in design specifications between the inter-array cabling specifications and the meshed cablings specifications. With 230 KV, the additional specifications, including switchgear specifications are identified in section G.4. The 230V cables will be able to transmit the required 300MW over one cable. This will reduce the amount of cable runoffs and routing issues increasingly faced by Projects. that are mentioned here.

G.9.3 What are the impacts of harmonics and interaction between windfarms? How can this be mitigated and planned for?

Section G.7 outlines the need for AC and DC resonance studies to identify possible interaction issues and these studies should be done in early design stages as additional components may be required off-shore in the case that issues are detected. As per Cigre Technical Brochure 619, depending on the length of the off-shore HVAC cables and the parameters of the HVDC-transformers and coupling inductance, parallel resonance in the frequency range of 100Hz to 1000Hz can occur. Such a resonance can have the following consequence:

- Slowly decaying or even increasing over-voltages during the sudden energization of a wind power plant transformer (parallel resonance)
- High harmonic voltages because of harmonic current injections from the wind power plant (parallel resonance)
- High harmonic voltages because of high amplification factors for harmonic voltages emissions of the offshore HVDC converter (parallel resonance).

For mitigating such problems, there are the following potential solutions:

- Soft energization of the off-shore wind farms by ramping up the off-shore voltage with all transformers connected
- Installation of high-pass or C-type filters on the off-shore platform
- Built-in filter function in the HVDC controllers for providing sufficient damping

G.9.4 Why not transfer more than 300 MW between farms? Seems like low transfer given the scale of regional network?

300MW of transfer in two directions effectively allows for 600 MW of energy transfer from any individual station, assuming individual offshore stations will be approximately 1-1.5 GW in size, this is 40-60% of its total capacity. Increasing the meshed grid size also increases the capital costs of each windfarm. As the meshed network does not increase the total capacity of the energy transfer to shore, there are some diminishing returns to increasing the size of the meshed grid further than 300 MW. The scenario where any individual windfarm, with an advantageous POI has spare capacity over 600MW and other stations have more than 600MW of power that they are capable of delivering is rare.

G.9.5 Why is HVDC considered the most suitable technology for offshore wind integration? Will NYSERDA Allow HVAC alternative solutions?

ORECRFP22-1 states all alternative proposals must adhere to HVDC and Meshed Ready requirement. The Public Service Commission (PSC) Orders on Power Grid Study Recommendations require NYSERDA to consider HVDC technology for export radial cables due to preserving New York's limited amount of available cable corridors and landing points to shore. In utilizing HVDC technology, significantly less cables are needed to deliver the same amount of power to shore.

Furthermore, HVDC is the preferred technical solution to transfer power onshore from an offshore Meshed Network for advanced power flow control. NYSERDA envisions an offshore meshed system which can further optimize the power delivery of the offshore system. By ensuring that all Projects utilize HVDC technology, the offshore grid is isolated from the onshore grid, this allows the offshore control of energy to be unaffected by changes on the onshore side. HVAC radial interconnection may introduce further design requirements not contemplated in the current technical specifications:

> *AC interconnection between offshore meshed network and onshore power system will introduce additional challenges and thus economical and technical feasibility will have to be further evaluated for the development of meshed ready system including hybrid AC/DC radial interconnection as both onshore and offshore networks are now tightly coupled with an AC link. For example, the fault on the offshore network will now be fed by the strong onshore AC network. This requires the design of the offshore platforms for such a high fault current handling capability. Additionally, the offshore design will have to be designed for wider frequency and voltage ranges that are typically considered in the onshore system operation.*

G.9.6 What is the desired sizing of each radial HVDC tie? Should they be sized based on the respective wind farm capacity, or is it desired to be oversized for future mesh transfer capability. Are Proposers required to reserve capacity on the HVDC export cable to accommodate power from the meshed link?

The HVDC Radial line should be sized for the individuals project lease, Oversizing the cable is not expected. All projects are expected to deliver their expected power to shore. The meshed grid is to help redirect power to more available locations, no requirement to increase the HVDC capacity is needed in the scope of ORECRFP22-1.

If the Proposer believes that due to the Project's specific injection situation, it is commercially viable to construct larger cables with additional capacity, this should be explained in the Proposal narrative and mentioned in the interconnection plan as a consideration to supporting the growth of the industry and supporting future integration of at least 9 GW of offshore wind to New York.

G.9.7 What is to occur in the event that the interlink is not used? How will this impact Project economics?

Section 4.2.1 of ORECRFP22-1 states *OREC pricing and contract terms for this solicitation are based on a singular delivery point for Projects designed with radial interconnection and a Meshed Ready design.* The project economics should be unaffected should the interlink not be utilized. The Public Service Commission (PSC) Order on Power Grid Study Recommendations urges NYSERDA to consider preserving future optionality in offshore grid design in current solicitations.