Book 2

Technical Specification and Requirements of Microgrid Controller

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Technical Specification and Requirements of Microgrid Controller In Microgrid Development Project at Mae Sariang District Provincial Electricity Authority

1. Introduction

This Technical Specification presentsthe microgrid controller (MGC) in the bidding document of Microgrid Development Project at Mae Sariang District, Mae Hongson. The microgrid controller will help to improve reliability of system and also maximum utilization of use local renewable resources. The microgrid controller will manage devices in the area such as DERs, Energy Storage, Solar farm, load and switching devices within the scope of MGDP. This document specifies the necessary details of microgrid controller requirements to ensure to meet the objective of the project.

2. Principal Requirement

2.1 General requirement

2.1.1 MGC shall be able to operate in all use cases as described in Section3.

2.1.2 MGC shall be able to operate to support different objective functions such as reliability, power quality, peak reduction, reduce power losses in distribution line, or Volt/VAR control, etc.

2.1.3 MGC shall be able to give weights or priority to avoid conflict between different objective functions. High priority objective function always has presidencies over lower priority objective function.

2.1.4 MGC shall be able to communicate with the existing ADDC system, the substation, the hydro power plant (monitoring), the diesel generator controller, the battery storage management system, the PV inverter (monitoring), AVRs (monitoring), and SWs.

2.1.5 MGC shall be able to perform fault location, isolation and service restoration (within the boundary of the microgrid).

2.1.6 Substation battery shall be used to provide backup emergency power when the primary power source is not available.

2.1.7 MGC shall be able to operate with and without 115 kV transmission line from HotSubstation to Mae Sariang Substation.

2.1.8 MGC shall be able to forecast on loads and generations. Weathers forecast shall be provided by bidder or agency.

2.1.9 MGC shall be able to time synchronize with CSCS and all components in the system.

2.1.10 MGC shall control circuit breaker and receive signal of protection system in substation via CSCS.

2.1.11 MGC shall be compliant to some propose part of IEC 62898-1, IEC62898-2

2.1.12 MGC shall need detailed factory acceptance test in order to verify the functional of MGC before installation at site.

2.2 Hardware Requirements

2.2.1 MGC shall have redundant server in order to be a highly reliable controller, i.e the MGC shall be able to operate with contingency of controller at least n-1. MGC which is centralized architecture shall have redundant server. MGC, which is distributed architecture, shall be able to operate when one of distributed controllers is failed. No loss station data during system fails. The fail shall occur in period less than 10 second

2.2.2 MGC controller set shall be industrial grade.

2.2.3 MGC shall have at least 3 human machine interface (HMI) monitors.

- Three monitors for operator at control room shall have screen size at least 27”.
- One monitor for monitor at electric office (EO) room shall have screen size at least 23”.
- One monitor for displaying at conference room shall have screen size at least 50”.

2.2.4 Graphic display on monitor and user interface shall support input from users at least both English and Thai language.

2.3 Software Requirements

2.3.1 The configuration of power system shall be able to be reconfigured by PEA after commissioning. PEA shall be able to add and/or remove any electrical equipment by PEA personnel. Vendor shall describe in detail the configuration tools use to configure modify microgrid controller.

2.3.2 MGC shall be able to store history operation data for at least 1 year continuously according to First in First out (FIFO) process.

2.3.3 Operating Systems (OS) of HMI and Engineering Workstation shall be latest version of Windows or Linux according to OS of MGC.

2.3.4 The Engineering Workstation at MGC control room shall include these functions:

- Real time data historian & analysis
- Communication network management
- System access control and cyber security management
- MGC monitoring, diagnostics and maintenance
- Disturbance and fault information handling, analysis and evaluation
- Engineering HMI
- Web server and interface (for equipment setting)
- Sequence of events and alarm analysis
- Data archiving, trending and historical analysis
- Automatic fault report generation and notification
- Substation Protection, Automation and Control system
- Substation status display
- Substation documentation management
- Dashboard status display of overall MGC system
- Realtime graphic of system analog

2.3.5 The operation screen displays for the monitoring and control of MGC shall include:

- Detailed equipment status and network configuration information
- GIS info graphic of MGC system and shall be able to zoom in/out
- Import GIS info graphic from database of PEA

- Visual indication of device setting, selection, operation and interlocking
- Service and measurement values, including analog measurements and their limit setting
- Alarm annunciation
- Visual record of system alarms, including fault information and events
- A means of displaying the status of devices that are not monitored automatically but are under the substation operator's control such as application of tags or labels
- Screen saver mode after 1 hour of keyboard input inactivity
- Display detailed equipment and network configuration information according to each use cases

2.3.6 MGC shall be able to display data at ADDC. It also be able to display in web service or mobile application without using public cloud. MGC shall have open source web server for display web page.

2.3.7 User interface, log report, message or related user interfaces shall be displayed in English.

2.3.8 Upgrade and patched management shall be able to be done remotely. Vendor shall describe mechanism of how and when upgrade and patched are available to PEA. PEA shall be notified immediately once the upgrade and patched are available.

3. Use cases for microgrid controller

The new substation will be built by others at Mae Sariang substation. The 115 kV transmission line will be also built. But the 115 kV transmission line will be finished later than the substation and implementation of microgrid system. In order to cover both cases, with and without 115 kV transmission line, the use case for both cases will be described as shown in Table 1and Table 2. The use cases have been described in Enterprise Architect Version 13.0. The high level diagram has been generated. It helps to understand how each use case interacts with each other. It also reveals the actor who will involve in each use case. The details of each use case have been described in this section and also in Appendix A as well.

Table 1: Use case of microgrid controller for new Substation with existing 22kV lines.

Grid Connected	Islanding
1 Transition from Grid Connected to Islanding 1.1 Intentional Islanding 1.2 Unintentional Islanding	1 Transition from Islanding to Grid Connected
2 Black Start	2 Black Start
3 Microgrid objectives 3.1 Improve reliability 3.2 Improve power quality 3.3 Peak shaving 3.4 Reduce losses in distribution line 3.5 Volt/Var Control 3.6 Constraint management 3.7 GHG emission reduction 3.8 Increase/decrease in fuel prices 3.9 PV Smoothing (a) Full sunshine (b) Intermittent sunshine (c) No sunshine 3.10 Load Shedding 3.11 Frequency control 3.12 Voltage Control 3.13 Energy Management	3 Microrid objectives 3.1 Improve reliability 3.2 Improve power quality 3.3 Peak shaving 3.4 Reduce losses in distribution line 3.5 Volt/Var Control 3.6 Constraint management 3.7 GHG emission reduction 3.8 Increase/decrease in fuel prices 3.9 PV Smoothing (a) Full sunshine (b) Intermittent sunshine (c) No sunshine 3.10 Load Shedding 3.11 Frequency control 3.12 Voltage Control 3.13 Energy Management
4 Protection 4.1 Fault Upstream of the line 4.2 Fault inside Microgrid area (FLISR)	4 Protection 4.1 Fault inside microgrid area 4.2 Fault inside Microgrid area (FLISR)
5 Communication Failure 5.1 Between ADDC and MGC 5.2 Within MGC	5 Communication Failure 5.1 Between ADDC and MGC 5.2 Within MGC
6 Maintenance (TAGGING) 6.1 Upstream of the line 6.2 Inside MGC	6 Maintenance (TAGGING) 6.1 Upstream of the line 6.2 Inside MGC
7 Heartbeat failure	7 Heartbeat failure

Table 2: Use case of microgrid controller for new Substation with new 115 kV transmission lines.

Grid Connected	Islanding
1 Transition from Grid Connected to Islanding 1.1 Intentional Islanding 1.2 Unintentional Islanding	1 Transition from Islanding to Grid Connected
2 Black Start	2 Black Start
3 Microgrid objectives 3.1 Improve reliability 3.2 Improve power quality 3.3 Peak shaving 3.4 Reduce losses in distribution line 3.5 Volt/Var Control 3.6 Constraint management 3.7 GHG emission reduction 3.8 Increase/decrease in fuel prices 3.9 PV Smoothing (a) Full sunshine (b) Intermittent sunshine (c) No sunshine 3.10 Load Shedding 3.11 Frequency control 3.12 Voltage Control 3.13 Energy Management	3 Microrid objectives 3.1 Improve reliability 3.2 Improve power quality 3.3 Peak shaving 3.4 Reduce losses in distribution line 3.5 Volt/Var Control 3.6 Constraint management 3.7 GHG emission reduction 3.8 Increase/decrease in fuel prices 3.9 PV Smoothing (a) Full sunshine (b) Intermittent sunshine (c) No sunshine 3.10 Load Shedding 3.11 Frequency control 3.12 Voltage Control 3.13 Energy Management
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6 Maintenance (TAGGING) 6.1 Upstream of the line 6.2 Inside MGC	6 Maintenance (TAGGING) 6.1 Upstream of the line 6.2 Inside MGC
7 Heartbeat failure	7 Heartbeat failure

3.1 Islanded

A microgrid needs to be capable of disconnecting itself from the main grid for the reasons such as economic operation, foreseen main grid disturbances, maintenances, testing, etc.

The microgrid needs to obtain permission from the ADDC for intentional islanding. The microgrid Energy Management System (EMS) and microgrid SCADA initiate the process of intentional islanding transition by dispatching islanding transition commands to the components in the microgrid. The microgrid EMS will estimate the microgrid load level and the available generation capacities, shed or reduce the loads with lower priorities, re-dispatch the real and reactive power outputs of each generator and energy storage unit so that there is no import/export of real/reactive power between the microgrid and the PEA main grid at PCC, and the microgrid components are managed in the islanded operation as well. After the islanding transition dispatch commands are executed, the power flow at the point of common coupling (PCC) is close to zero, and there is minimum impact on both the microgrid and the main grid when the microgrid switch disconnects at this condition. After the microgrid is disconnected from the main grid, it continues with the islanded operation. The microgrid EMS updates the islanded dispatch commands to manage the microgrid in the islanded operation. The microgrid SCADA and the primary sources perform the real-time control and operation to maintain microgrid system stability.

3.1.1 Functional requirements

1) MGC shall be able to maintain distribution network frequency and voltage while microgrid is in islanded mode.
2) MGC shall be able to add or drop generation resources to maintain system frequency and voltage.
3) MGC may have to shed load to maintain system frequency and voltage while in the islanded mode.
4) MGC shall continue to monitor the 22 KV feeder for voltage. If grid voltage is within acceptable limits established by PEA, then MGC shall connect the microgrid to the grid.
5) DMS operator shall be able to send command to MGC to reconnect microgrid to main grid.

3.1.2 Scenarios

1) Unintentional Islanded - e.g. due to loss of 22 KV feeder from Hot Substation

Usually there are large and rapid frequency and voltage deviations during a large disturbance and the microgrid needs to be capable of detecting such abnormal conditions and islanding from such disturbance, and more importantly, to be capable of disconnecting from the main grid and maintaining its stability after the islanding transition.

Once the microgrid switch detects abnormal condition based on its own measurements of frequency and voltage, and possible combined with the measurement of current, the switch opens and the microgrid islands from the main grid. The microgrid switch sends its status to the primary sources so that they can change their control modes to frequency and voltage control modes to restore the microgrid and maintains the stability of the microgrid. The microgrid switch also sends its status to the microgrid SCADA so that it can update the control commands accordingly and send the update to all the microgrid actors. The microgrid SCADA sends the main grid of microgrid status and updates the microgrid EMS with the latest measurements and status as well. After the microgrid is stabilized, the microgrid EMS calculates the economic dispatches in the islanded mode and sends them to the microgrid SCADA, which distributes them to the microgrid actors to execute.

2) Intentional Islanding by ADDC operator

The microgrid needs to obtain permission from the ADDC for intentional islanding.The microgrid EMS and microgrid SCADA initiate the process of intentional islanding transition by dispatching islanding transition commands to the components in the microgrid. The microgrid EMS will estimate the microgrid load level and the available generation capacities, shed or reduce the loads with lower priorities, re-dispatch the real and reactive power outputs of each generator and energy storage unit so that there is no import/export of real/reactive power between the microgrid and the main grid at PCC, and the microgrid components are managed in the islanded operation as well.

After the islanding transition dispatch commands are executed, the power flow at the PCC is close to zero, and there is minimum impact on both the microgrid and the AEPS when the microgrid switch disconnects at this condition. After the microgrid is disconnected from the main grid, it continues with the islanded operation. The microgrid EMS updates the islanded dispatch commands to manage the microgrid in the islanded operation. The microgrid SCADA and the primary sources perform the real-time control and operation to maintain microgrid system stability.

3.2 Grid Connected

A microgrid must be capable of resynchronizing and reconnecting to the main grid i.e. transition from islanded operation mode to grid-connected operation mode. Once in grid connected mode, Microgrid EMS calculates microgrid economic dispatch.

3.2.1 Functional requirements

1) MGC shall be able to add or drop microgrid resources while in grid connected mode
2) When reconnecting to grid from islanded mode, MGC shall be able do 2 cases:
   a) all microgrid resources must be disconnected to dead bus state, then reconnect to the grid,
   b) reconnecting the grid without interruption in microgrid area.

3.3 Black Start

During a black start procedure, a microgrid is restored to islanded operation mode after a complete shutdown. The restoration process involves the microgrid central controller (microgrid EMS and microgrid SCADA), multiple resources, loads, and switchgear. Based on the system topology, capacities and sizes of the resources and loads, and the controllability of the devices, the black start procedure can be pre-determined and implemented in the microgrid central controller and other devices. The execution of the black start can be automatic with minimal operator involvement.

First a primary source will be restored with loads matching generation capacity. The primary source is able to control voltage and frequency and form an islanded microgrid. Other resources and loads are added on following a pre-determined order with specified real and reactive power generation/consumption. After the whole microgrid is completely restored, it will be operated in the normal islanded mode. At this point it can be determined whether the microgrid will resynchronize and reconnect to the main grid or remain in islanded operational mode.

Microgrid SCADA executes the pre-implemented black start procedure by first checking if the microgrid switch is open or not to ensure that the microgrid is completely disconnected from the main grid. If not, a command will be sent to the microgrid switch controller to open the switch. The next step is to open switchgear to isolate the primary source and match loads from the rest of the microgrid. The primary source starts operation by feeding loads and controlling frequency and voltage in specified ranges. When an islanded microgrid is formed, other resources and loads will be brought to the microgrid following the pre-determined order and the devices operating procedures.

3.3.1 Functional requirements

1) MGC shall be able to connect generation sources to dead bus or live bus.
2) MGC shall be able to send control commands to BESS and DG set's controllers including operating modes, set points (e.g.kW, kVAR), start/stop, etc.
3) The MGC shall be able to black start the microgrid using any or all of the following generation resources: [1] BESS, [2] DG Sets, [3] Hydro, [4] Solar Farm

3.3.2 Constraints

1) Invariant: Dependable sources are BESS and DG sets. Hydro and PV farm are not.
2) Pre-condition: Designated feeder switches (SW1, SW2, SW3, SW4, SW6, and SW7) are open forming a microgrid with essential loads.
3) Pre-condition. CB1..CB5 are open i.e. all feeders are de-energized.

3.4 Peak Shaving

Peak shaving is primarily for economic operation of the MGDP power system**.** Utilisation of local resources such as BESS, PV/hydro generation can reduce MGDP demand resulting in reduced power transfer **(**and line loss**)** over long distances from HOT substation**.**

3.4.1 Functional requirements

1) The MGC shall implement peak shaving to reduce overall energy costs (use of lower cost resources).
2) The MGC shall use peak shaving to maintain system frequency and voltage

3.5 GHG Emission

Green house gas emission is a function to calculate an environmental impact indicator of generation mix at any given time. This can be used in conjunction with generation cost function to evaluate overall generation scheduling.

3.5.1 Functional requirements

1) MGC shall calculate GHG emission of a generation mix and take this into account in economic dispatch process.
2) The MGC shall calculate a value for GHG reduction based on avoidance of Diesel and on grid generation

3.5.2 Scenarios

1) Grid connected When grid connected, priority is given to optimize line loss, generation cost and GHG emission.
2) Islanded When islanded, MGC shall optimize GHG emission with priority given to system security and stability.

3.5.3Constraints

1) Grid, diesel generation GHG emission data (e.g. kg.CO_2eq/MWh) shall be furnished by PEA.
2) Hydro and solar generation are deemed to be zero GHG emission.

3.6 PV Smoothing

The MGDP power system has experienced voltage fluctuation problem caused by sudden change in PV farm power due to cloud transient. PV smoothing using BESS is required to limit the PV power output ramp rate to the level that can mitigate this voltage issue. This function is required on partly cloudy days where cloud transient is most likely to occur.

3.6.1 Functional requirements

1) Normally the grid connection (22 KV feeder from Hot Substation) may not be able to perform PV smoothing. The MGC shall use the BESS to assist the main grid in PV smoothing.
2) The MGC shall use the BESS for PV smoothing in islanded mode.
3) The MGC shall use the BESS to maintain voltage and frequency within limits set by PEA.

3.6.2 Scenarios

1) Grid connected
2) Islanded

3.6.3 Constraints

Amount of storage available from the BESS

3.7 Load Shedding

The MGDP shall be able to perform load shedding for stability of power system.

3.7.1 Functional requirements

The MGC shall only use load shedding to maintain system frequency and voltage.

3.7.2 Scenarios

1) Grid connected

2)Islanded

3.7.3 Constraints

1) Load shedding to match available generation capacity at black start during transition to islanding.
2) Load shedding to match steady state microgrid generation operating capacity while in islanding.

3.8 Frequency Control

This function is to balance the generation and loads in a microgrid therefore to maintain the stability of the microgrid by controlling its frequency. It is fast real-time control in the time scale of sub-second. The function is realized by one or more primary sources that are responsible for the frequency control. It is determined by the microgrid SCADA if a microgrid source is operated as a primary source or as other source, and the frequency setting point is also sent by the microgrid SCADA to the primary sources.

3.8.1 Functional requirements

1) System frequency shall be maintained by MGC when in islanded scenarios. In grid connected scenarios, the main grid shall maintain system frequency.
2) MGC shall add or drop generation resources to maintain system frequency

3) The MGC shall shed load to maintain system frequency if all generations sources have been used
4) One or more microgrid sources is assigned to be primary sources that regulate the frequency. The microgrid source control modes and frequency setting point are in the microgrid control commands which are sent by the MGC.

3.8.2 Scenarios

1) Islanded

One of more microgrid sources is assigned to be primary sources that regulate the frequency of the microgrid while it is islanded. The microgrid source control modes and frequency setting point are in the microgrid control commands which are sent by the microgrid SCADA to all microgrid actors periodically in the range of 1-10 seconds or better

The microgrid SCADA receives the real-time measurements from the microgrid actors periodically in the range of 1-10 seconds or better, and then determines the microgrid source modes based on the latest load level and the microgrid source available capacities as well as the economic dispatch commands from the microgrid EMS. The microgrid SCADA sends the updated control commands to the microgrid actors. The sources that are assigned as primary sources also receive the frequency setting point. The microgrid switch sends the frequency measurement at PCC to the primary sources. This frequency measurement is sent periodically by the microgrid actors to the primary sources to control the microgrid frequency. After the primary sources receive the control commands from the microgrid SCADA and the frequency measurement from the microgrid switch, they will execute the commands.

2) Grid Connected

When a microgrid is grid-connected, it relies on the main grid to maintain the frequency at the rated value.

3.8.3 Constraints

The allowable system frequency range shall be specified by PEA.

3.9 Voltage Control

This function regulates voltage at PCC within a specified range. It is fast real-time control in a time scale of sub-seconds. This function is realized by one or more primary sources that are responsible for controlling voltage. It is determined by the microgrid SCADA if a microgrid source is operated as a primary source or other source, and the voltage setting point is sent by the microgrid SCADA to the primary sources.

3.9.1 Functional requirements

1) The MGC shall be able to supply VAR's from BESS to maintain voltage levels.
2) The MGC may implement load shedding to maintain system voltage levels specified by PEA.
3) The MGC shall add or drop generation resources to maintain voltage levels specified by PEA.
4) The MGC shall be able to send control commands e.g.set points to the voltage regulators on the 22 KV feeder from Hot substation to maintain voltages within the limits set by PEA

3.9.2 Scenarios

1) Grid connected

A microgrid can perform voltage control in both grid-connected and islanded operations, but there objectives and strategies can be different. When a microgrid is grid-connected, it can receive a voltage profile from the ADDC to maintain the PCC voltage in a specified range, or a power factor profile, which requires the microgrid to correct its load power factor if needed. When a microgrid is islanded, it determines the voltage profile at PCC by itself to meet the requirements of all the microgrid components.

The microgrid SCADA receives the real-time measurements from the microgrid actors periodically in the range of 1-10 seconds, and then determines the microgrid source modes based on the latest load level and the microgrid source available capacities as well as the economic dispatch commands from the microgrid EMS. After receiving the voltage/power factor profile and the periodic measurement status updates from the microgrid actors, the microgrid SCADA determines the control modes of the microgrid sources and sends them to the sources as well as the voltage/power factor profile. They are in the microgrid control commands which are sent by the microgrid SCADA to all microgrid actors periodically in the range of 1-10 seconds.

The microgrid SCADA sends the updated control commands to the microgrid actors. The sources that are assigned as primary sources also receive the voltage/power factor setting point. The microgrid switch sends the voltage/power factor measurement at PCC to the primary sources. This voltage/power factor measurement is sent periodically by the microgrid switch to the primary sources to control the microgrid voltage/power factor. After the primary sources receive the control commands from the microgrid SCADA and the voltage/power factor measurement from the microgrid switch, they will execute the commands.

2) Islanded

A microgrid can perform voltage control in both grid-connected and islanded operations, but their objectives and strategies can be different. When a microgrid is grid-connected, it can receive a voltage profile from the ADDC to maintain the PCC voltage within a specified range, or a power factor profile, which requires the microgrid to correct its load power factor if needed. When a microgrid is islanded, it determines the voltage profile at PCC by itself to meet the requirements of all the microgrid components.

The microgrid SCADA receives the real-time measurements from the microgrid actors periodically in the range of 1-10 seconds, and then determines the microgrid source modes based on the latest load level and the microgrid source available capacities as well as the economic dispatch commands from the microgrid EMS. After receiving the voltage/power factor profile and the periodic measurement status updates from the microgrid actors, the microgrid SCADA determines the control modes of the microgrid sources and sends them to the sources as well as the voltage/power factor profile. They are in the microgrid control commands which are sent by the microgrid SCADA to all microgrid actors periodically in the range of 1-10 seconds.

The microgrid SCADA sends the updated control commands to the microgrid actors. The sources that are assigned as primary sources also receive the voltage/power factor setting point. The microgrid switch sends the voltage/power factor measurement at PCC to the primary sources. This voltage/power factor measurement is sent periodically by the microgrid switch to the primary sources to control the microgrid voltage/power factor. After the primary sources receive the control commands from the microgrid SCADA and the voltage/power factor measurement from the microgrid switch, they will execute the commands.

3.10 Energy Management

The microgrid EMS is part of the microgrid controller, and the interface/agent between the distribution management system (DMS) and the microgrid. The microgrid EMS manages the power flow, power transaction, energy generation and consumption, voltage/reactive power, and battery charging/discharging in a microgrid. The objective of Microgrid EMS is to coordinate among multiple DERs, storage/battery, main grid and responsive loads to improve the system reliability and reduce the total operation cost.

A microgrid has two operation modes, i.e., Grid-connected mode and Islanding mode. The operation conditions, system constraints, and operation objectives could be different in different modes. In Grid-connected mode, the microgrid EMS communicates with the distribution system, manages the microgrid to comply with the utility policies and regulations, makes operation decisions based on the internal conditions as well as the utility requirements, and provides ancillary services under the distribution system's commands. In islanding mode, the primary objectives of the microgrid EMS are to maintain the stability, to regulate the voltage and frequency within certain ranges, and to optimize the microgrid overall performances.

3.10.1 Functional requirements

1) When possible, the MGC shall dispatch generation to reduce losses in distribution network.
   1.1) The MGC shall give priority to renewable energy resources such as solar and hydro
   1.2) Generation cost merit order for dispatching is : Grid, hydro, solar, diesel.
2) The MGC shall add generation resources based on price of energy produced by the sources of generation.
3) Where possible the BESS system shall use renewable sources of power to charge the battery.
4) The BESS shall be used for PV smoothing.

3.10.2 Scenarios

1) Grid connected

In Grid-connected mode, the microgrid EMS communicates with the distribution system, manages the microgrid to comply with the utility policies and regulations, makes operation decisions based on the internal conditions as well as the utility requirements, and provides ancillary services under the distribution system's commands.

2) Islanded

In islanding mode, the primary objectives of the microgrid EMS are to maintain the stability, to regulate the voltage and frequency within certain ranges, and to optimize the microgrid overall performances.

3.11 FLISR

FLISR is designed to reduce outage impact and duration i.e. reduce SAIFI and SAIDI by using

- automatic sectionalizing and restoration, and
- automatic circuit reconfiguration

By coordinating operation of field devices, software, and dedicated communication networks to automatically determine the location of a fault, and rapidly reconfigure the flow of electricity so that some or all of the customers can avoid experiencing outages.

For any fault in one section, FLISR first

- opens closed switches to isolate the faulted section, and then
- restores the non-faulted sections by reclosing feeder breakers and/or closing open tie switches to other feeders.

3.11.1 Functional requirements

1) SW's shall report any fault detected to MGC.
2) FLISR application shall determine location of the fault.
3) FLISR application shall isolated faulted feeder section based on fault location.
4) FLISR application shall try and restore service to as many customers as possible after the fault has occurred.
5) MGC shall communicate with SW's located at distribution feeder switches SW1 through SW13 via IEC61850 Protocol.

3.11.2 Constraints

1) Automated FLISR actions typically take less than one minute, while manually validated FLISR actions can take five minutes or more.
2) FLISR operation shall be an auto-restoration mode where execution of restoration sequences is fully automated and does not require manual validations.However, FLISR shall be able to operate as automated or manual mode as PEA required.

3.12 Tagging

Functional. Refer to PEA's Tagging and safety procedures

4. Generation Resources and System Components in MGDP

4.1 Solar farm

Microgrid SCADA receives operational parameters (power, reactive power, voltage, current etc.) from solar farm local controller. Microgrid SCADA can send command for grid connection/disconnection.

4.1.1 Functional requirements

1) The MGC shall connect the solar farm to the microgrid by remotely controlling the solar farm SWs (SW 11, SW12).
2) The MGC shall only connect the solar farm when it is in automatic mode.
3) The solar farm operator can place the solar farm in manual or automatic mode.

4.1.2 Constraints

1) Contracts with the solar farm owner may limit when the solar farm can and cannot be taken off line.
2) Solar farm power output is not dispatchable and, by terms and conditions of PPA, is not controllable by microgrid controller.

4.2 Run-of-River Hydro

Hydro generation reports operation status/mode, operational parameters to microgrid SCADA as well as receives control commands such as start/stop for successful operation of the microgrid. Microgrid SCADA will not dictate power and reactive power generation. The hydro generator will operate autonomously.

4.2.1 Functional requirements

1) The MGC shall communicate with SW (SW13) of the hydro power plant via IEC61850 protocol.

4.2.2 Scenarios

1) Limited power can be produced between the rainy and dry seasons.
2) No power can be produced during the dry season.

4.2.3 Constraints

1) Amount of power produced from the hydro plant is proportional to the amount of rain during any given period.
2) The MGC cannot dispatch the hydro plant but it can send command to connect or disconnect the plant.

4.3 Diesel Gen Sets

Diesel generation will be required to supply/absorb active/reactive power for successful operation of the microgrid. Local controller will be operating autonomously under supervision of the microgrid SCADA.

4.3.1 Functional requirements

1) The DG Operator shall be able to place the DG sets in either manual or automatic mode.
2) The DG's shall be capable of "Load Following" to maintain system voltage and frequency.
3) The MGC shall be able to send set point commands (kW, kVAR or PF) to the local controller.
4) The MGC shall only start/stop the DG's when they are in automatic mode.

4.3.2 Constraints

1) Diesel gen-sets may not be identical in model/make and operating capacity.
2) Existing diesel plant controller detailed technical specification will be given.

4.4 BESS

BESS shall provide power and reactive power as requested by functional requirements under multiple scenarios. The key functions are PV smoothing, peak shaving, voltage control, spinning reserve and frequency control.

4.4.1 Functional requirements

1) BESS shall be able to operate in all four quadrants of P/Q spectrum.
2) The BESS may be used for peak shaving.
3) The BESS may be used for PV smoothing.

4) The BESS shall be capable of "Load Following" to maintain system voltage and frequency.
5) The MGC shall control both power and VAR output from BESS to meet system power and VAR requirements.
6) If renewable energy sources are not available batteries shall be charged from the grid during "off peak" periods.
7) Priority shall be given to charging the BESS from renewable energy sources.

4.4.2 Constraints

The level to which the batteries are discharges shall be specified by PEA. This constraint is to maximize battery life.

4.5 Voltage Regulators

This use case performs information exchange activities with microgrid controller including; Send operational parameters (voltage, current, tap position) to microgrid SCADA. Receive information/command sent by microgrid SCADA e.g.voltage set point etc.

4.5.1 Functional requirements

1) The MGC shall communicate with the voltage regulators via DNP protocol through ADDC.
2) The number of voltage regulator taps/day shall be limited to the number set by PEA

4.6 Feeder Switches

Feeder switches send operational parameters and their status to microgrid SCADA. Microgrid SCADA sends control command to feeder switches as requested by various microgrid functional requirements.

4.6.1 Functional requirements

1) The SW shall be able to open and close the switch based on commands from MGC.
2) The SW shall detect faults at the associated switch.
3) The SW shall report status of switch to MGC.
4) The MGC shall communicate with the SW's located at the feeder switches via IEC61850 protocol.
5) Control of the switch from the ADDC DMS must be enabled by the MGC.
6) If the MGC fails control of the switches is passed to the ADDC DMS.

4.6.2 Scenarios

1) Switches are controlled from MGC.
2) Switches are controlled from DMS.

5. Performance Requirements

Functionality	Performance requirement
1. Automatic transition between Grid connected and islanding	Overall transition time < 1 minute
2. Load shedding	Overall load shedding time < 1 minute
3. Frequency control	Able to maintain frequency +/- 0.5Hz
4. Voltage control	Able to maintain voltage +/- 5% from nominal voltage
5. FLISR	Able to isolate and restore the power in < 45 seconds

6. Specification of microgrid controller

The proposer shall describe at least on concept, architecture, performance characteristic of microgrid controller. The details of specification of hardware and software of microgrid controller have to be described in details. The necessary development tool for microgrid controller in study mode shall be described.

7. Factory Acceptance Test

Factory acceptance test must be performed to ensure that the microgrid controller can perform all specified use cases and meet performance requirements indicated above. Result of factory acceptance test relevant to specified use cases and performance requirements shall be provided to PEA.

8. Field Demonstration of Controller Functionalities

Prior to a final commissioning, a site automation testing must be conducted to demonstrate that the microgrid controller can meet the above performance requirements. This will help to verify that the devices respond correctly to simulated events, e.g., fault and loss-of-voltage, on the feeders.

9. Training

Training is required to prepare the PEA's personnel to assume full responsibility for the coordination and supervision of the Contractor’s field work and for future PEA maintenance of the microgrid controller, including their repair by replacing printed circuit boards, modules, and assemblies. All training shall be conducted in English and/or Thai, using microgrid controller Interfaces and test systems delivered by the Contractor. Maintenance tools and test equipment delivered by the Contractor shall be used in the training. All training material shall be provided by the Contractor. The PEA shall be permitted to reproduce any of the training materials and to tape training sessions for internal use. The maintenance training shall include:

1) Theory of operation of microgrid controller.
2) Block diagrams and data flows.
3) The use of microgrid test systems and other associated test equipment.
4) Troubleshooting to printed circuit board or replaceable part level.
5) Printed circuit board/module/assembly replacement procedures.
6) Microgrid controller installation, startup adjustment, reconfiguration, and expansion.
7) Testing of microgrid controller and test system communications between the MGC and PEA SCADA system.

8) Orientation and coordination of microgrid controller and test system documentation such as manuals, configuration and assembly drawings, schematic diagrams, and parts lists.
9) Diagnostics and verification of the proper operation of the field test systems.
10) Theory of operation of the field test systems and, to the extent practical, troubleshooting and repair of the test systems.

Appendix A

Example of use cases for microgrid controller