Republic of the Marshall Islands Energy Future

Electricity Roadmap

Technical Note 10: High Level Requirements of Future RMI Renewable Energy Integration and Control Systems

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Summary

In order to achieve the RMI's ambitious GHG reduction targets, large amount of renewable energy generation will need to be integrated into the islands' power systems. To make this integration safe, and ensure reliability of the grids, sophisticated control systems for dispatching and monitoring of different generation and load sources are necessary.

This technical note outlines the scope of such a control system and presents some of its high-level structure.

1 Present Status in RMI island power systems

There are three types of power systems in RMI, small (household), medium (island wide for up to several hundred people, such as Jaluit and Wotje) and large (islands of Majuro and Ebeye).

Household systems are off-grid, simple, off-the shelf systems, which are controlled via the provided solar/battery inverter. No significant changes to these systems types are anticipated.

Medium island systems are currently run with central diesel generator stations that are staffed and manually controlled.

Majuro and Ebeye are also supplied from a central diesel generation power station and all engines are manually dispatched and controlled. Majuro power station also includes monitoring software which meters and records its performance.

In both medium and large systems, there is currently no remote monitoring or control of the distribution assets.

2 Future challenges

The RMI will see more renewable development over the coming decade. Compared to traditional diesel-power systems housed within a single building, renewable energy assets are distributed, usually across multiple sites over the island.

Power output of diesel generators is stable and predictable if the fuel supply is stable, while renewable energy is often unpredictable intermittent solar and wind resource and it requires much closer management and far more frequent scheduling than diesel generators.

Renewable energy generation requires enabling technologies to be safely integrated into a grid. Previously, diesel generators were the sole technology capable of providing all grid services, whereas future systems will depend on a precise symphony of the different technologies requiring their coordinated control.

Renewable generation will be connected into parts of the distribution grid, so the distribution grid itself needs to be more closely managed, particularly in regard to voltage.

As the control of renewable technologies becomes fully automated, due to their complexity and rapid changes to dispatch scheduling, there will be an increased requirement for comprehensive data collection and time-stamped event logging as the primary means for both operational review and fault finding.

Future challenges can then be summarised as:

- Renewable generation cannot be accurately predicted, and therefore generation scheduled, so corrective actions in generation dispatch need to happen on a second-by-second basis and under automatic control;
- Assets will be distributed across larger distances, so their primary management will become through supervisory control and data acquisition (SCADA) system;
- Operators will have a difficulty inspecting the assets visually (as, for example, it is not apparent when renewable generation such as solar panels are operating or not),

hence the primary means for operational review and fault finding will be through data recording and event logging;

- Finding an appropriate mix of renewable and enabling technologies needs to happen coincident with the generation scheduling to ensure appropriate inertia and fault power, and
- Visibility will be required over the distribution lines, or at least the parts of distribution lines with distributed generation assets connected, due to voltage boundaries and loading limits.

For all the above reasons, it becomes clear that manual monitoring and control of future renewable systems are not practical and that sophisticated computerised automatic control systems will need to take over the day-to-day, hour-to-hour, and second-by-second control of the system from the hands of operators.

3 Future control systems

3.1 Basic requirements

Answering to the challenges outlined in the previous paragraph, a control system appropriate to RMI's networks will need to have the following basic characteristics:

- Able to be configured and supported by MEC staff, hence use of preferred manufacturers, common communication protocols, simplicity over redundancy and fail to safe configuration;
- Metering and monitoring capability, through a SCADA system, for both generating assets and the distribution grid;
- A single point of collection and presentation of all remote monitoring data;
- Time-stamped event logging with automatic time synchronisation across the network;
- Fault recognition and alarming system including integration of protection relay indications and events;
- Single point over-arching, master control system capable of calculating and scheduling groups of generation assets on a second-by-second basis,
- Data logging and management reporting system; and
- Ability for remote (off island) interrogation and software update enabling manufacturer or future group centre maintenance and fault-finding support.

3.2 Modern control systems - Introduction

Very much like human beings, control systems need to be able to see a situation, be able to compute or find a solution, and execute an action. Therefore, four basic components each modern control system has can be classified as:

- 'Eyes' – or monitoring equipment on site capable of interpreting physical phenomenon, digitizing it, and sending that data to
- 'Brain' – or a central computer system capable of receiving larger amount of input data, processing it, and finding the correct solution, and from there, issuing commands to

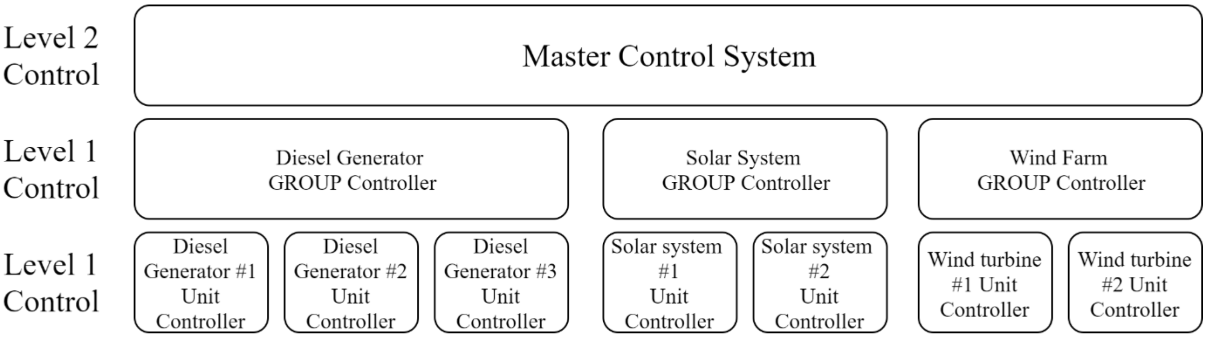
- ‘Hands’ – or equipment capable of receiving digital commands and performing physical actions, such as opening or closing circuits, starting or stopping a generator or pitching wind turbine blades.
- ‘Nervous system’ – or communications infrastructure capable of reliable linking all eyes, hands and brain of a control system.

In hardware terms, those four components mean that the following infrastructure needs to be built, expanded and managed during construction and operation of renewable assets:

- Metering, Monitoring and Control equipment - is usually supplied with modern generators. As an example, diesel generators are equipped with modern controllers which monitor and report their operation and can control those generators if requested. Solar inverters monitor performance of solar panels they control, can communicate that status, and can curtail solar production or start/stop power flow into the grid.
- Central System Control (sometimes referred to as Master control, or SCADA – Supervisory Control And Data Acquisition system) - is usually in a form of industrial software running on industrial, ruggedized, very reliable computers capable of showing the plant status and receiving control inputs, usually in the form of control positions or set-points.
- Communication Network – is a fibre optic, copper or radio/microwave network which extends from the Central Control system to all metering, monitoring and control devices in one power system, most commonly through a network of remote terminal units (RTUs) or intelligent electronic devices (IEDs).
- (Optional) Information screens – which visually present renewable power system status for stakeholder management purposes. These informational screens could be overview screens in utility boardrooms, government cabinets, or utility/country websites, which are real-time and may have historical information available for uploading and further processing (i.e. carbon reduction reporting).

3.3 Renewable island control system structure

In addition to its basic components and characteristics, control systems are usually multi-tiered. This simply means that, like an organisational structure, there are controllers of units, group controllers, and finally, general managing controllers, as presented in the figure below.



This structure helps the sectionalisation of the system and provides for easier maintenance.

Unit controllers are devices which control only one generating source, such as one diesel generator, one solar array (inverter), one wind turbine, one string of batteries. They monitor all detailed information from a unit such as voltages, currents, temperature, state of charge, pressures, lube oils status, individual alarms, etc. Their commands usually focus on operating low-level devices such as valves, switches, breakers, etc.

Group controllers look at groups of devices that operate in concert, such as several diesel generators at one site, or all wind turbines in a wind farm. The group controller receives high-level monitoring information from unit controllers, such as total power or energy produced by a unit. When they issue commands, it is usually in the form of set-points or modes of operation they want each unit to be in.

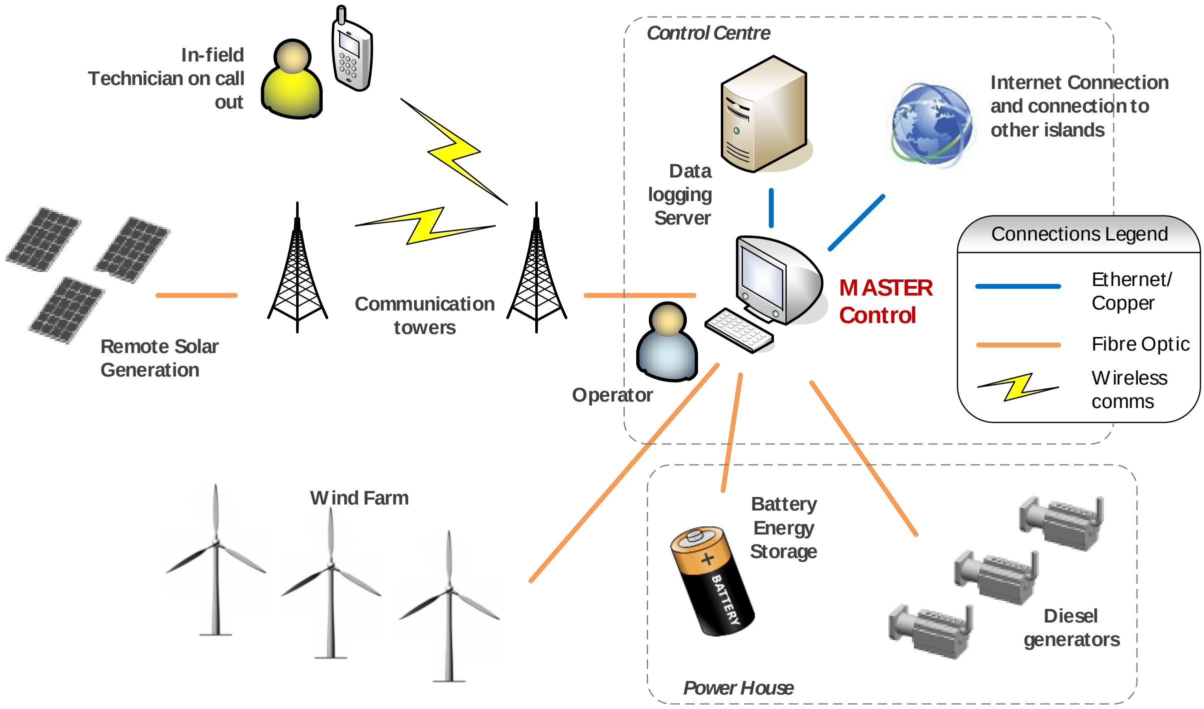
The Master controller looks at diesel generation, solar generation, wind generation and customer load by polling the group controllers. Then it makes high level decisions, such as whether a battery needs to be discharged to cover the gap in generation, or should diesels be called upon, which generating resource has priority over other, etc. Commands it issues are also high-level, such as set-points or operating modes or commands such as enabling diesel off mode and running the system on renewable energy only.

For a complex renewable system to properly operate, utilisation of all three levels of control systems are necessary.

3.4 Example of Future Control System in Majuro's context

The Figure below presents a high level functional outline of an island-wide control system network.

The control centre is a room with operator screens and computer servers monitoring the power system and collecting data. It is the centre of the future control system as it makes critical system decisions and is the primary interface to the plant controls and status. It generally consists of a Master Controller, data logging Server and connection to other locations such as internet (for publishing real-time system data) or connections to other island systems. This room can be either inside the new power station or the MEC offices; it needs secure communications connection to the rest of MEC's assets and requires physical security and cyber security.



Using communications network infrastructure, the Master Controller can communicate with generating assets, collecting information and issuing commands. Modern communication infrastructure utilises three ways of communication; copper ethernet (also known as the 'blue' network cable) for nearby connections, fibre optic cables for remote connections, and wireless communication such as radio or microwave links where running fibre-optic cable is not practical. The Master Controller is directly linked with all generating asset controllers, batteries, generators, wind turbines and solar panels. Communications infrastructure provides the Master Controller with ability to gather information from remote assets and send commands back in timeframes from milliseconds to a few seconds.

MEC can use existing telecom communication paths to communicate to remote assets. Spare fibre optic cores in Majuro's telecom system and existing connection points along the island could be utilised to provide these communication pathways to MEC. It is common to use dedicated fibre pairs for these links as well as separated Ethernet domains for better cyber security.

An automated Master Control system will not need an operator in front of it at all times, which implies that the Majuro power station does not need to be manned at all times. In a case of emergency, an automated call out to an on-call operator could be issued to inform them of an emergency and/or which system needs to be looked at.

3.5 What benefits will the future control system bring?

A control system could bring many benefits to an island power system, including:

- Constant optimisation of diesel generator scheduling, and ensuring best fuel utilisation;
- Full overview of all assets, including:
  - Network infrastructure, power losses, and power flows,
  - Diesel generation,
  - Diesel fuel farm operations,
  - Renewable energy generation
  - Batteries and state of charge,
  - Run-hours and batteries cycles for maintenance and replacement planning;
- Operators are no longer needed to constantly monitor the system and are free to join maintenance operations and improve utility's operations;
- Better fault tracking leading to shorter power outages;
- Ability to integrate large amounts of renewable energy with the existing system;
- Increase and maintain system security;
- Provide visibility of the RMI's renewable energy efforts on the internet, mobile apps, etc.

4 Establishing a framework for the future control system

RMI has embarked on a pathway of integrating large-scale renewable generation into its island power systems. Each project and each technology will bring its requirements for control. Therefore, it is necessary for RMI to draft a plan and a standard for creating a future control system, so technology providers will know how to properly connect to it and so operation of those technologies would be streamlined under MEC's control.

The second thing that is necessary is to establish is a partnership with the national telecom office (NTA) which will provide communications pathways in Majuro, Ebeye, and other island systems enabling the utilities to collect information nation-wide.

In order to manage equipment familiarity and training with limited skilled personnel, MEC need to standardise on a limited set of manufacturers and communication protocols. The Master to RTU communications protocol needs to be tolerant to communication drops and include event time-stamping within the protocol (i.e. time-stamped at the remote end).

Finally, control centre offices within island utilities need to be sourced, equipped and their personnel trained and involved in future renewable energy projects.