SmarterMicrogrid

Smart Microgrid Controller (SMC)

Principles of the SMC and a technical overview

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Introduction

The challenge of unreliable power

National governments and the private and public electricity utilities in their jurisdictions, have the challenges of supplying reliable and reasonably-priced electricity, in the face of serious constraints. These constraints are often complex and unpredictable. They include the lack of reliable national grid to rural, peri-urban and urban locations alike, for example due to damage to the infrastructure of generation, transmission and distribution, caused by typhoons, earthquakes and floods and other natural catastrophes.

Driven by climate change due to global warming, these catastrophes are becoming more frequent and more devastating. It is likely that this problem will only get worse in the foreseeable future.

Smart microgrids for electricity that is reliable and reasonably priced

Microgrids are increasingly recognised as the go-to solution for providing electricity to local communities in periods of unreliable grid, or for those communities for whom the grid does not even exist.

Microgrids can provide improved continuity of supply for grid-connected communities. They can also function as an important driver of economic development for rural communities without a grid connection.

A microgrid may include solar pv panels, wind turbines, hydro generation, diesel generation and battery storage, and a range of domestic, commercial and industrial consumers as well as public institutions such as schools, universities and hospitals.

A smart microgrid controller can help to minimise the capital and operating costs of such a microgrid, often calculated as the levelised cost of electricity (LCOE). A smart microgrid controller can monitor all the relevant sub-systems of the microgrid, and so help the operator to manage the Key Performance Indicators (KPI) for generation, storage and consumption, effectively and efficiently.

The World Bank estimates that in such ways the LCOE may be reduced from about 55¢/kWh to about 23¢/kWh over the next ten years (ESMAP Technical Report 014/19 - Page 17 Table ES1 - Click here for report).

This challenge exists at the intersection of the major disciplines of electrical engineering, computing and data communications. It is therefore complex to understand sufficiently and difficult to resolve. Careful attention to detail is required across all these disciplines, if a utility company is to be able to deploy a microgrid that is a fit-for-purpose solution for the range of challenges that it faces in the diverse communities that it serves.

Further, to do so at an affordable cost is also a necessary prerequisite, if such microgrid provision is to be implemented. Capital threshold is a particularly strong disinhibitor of microgrid adoption in developing nations.

Principles of a smart microgrid controller

At Smarter Microgrid Limited (SML) we have established a set of principles to address this challenge. We believe that they are both necessary and sufficient for providing the requisite capabilities to address the complex and diverse challenges of modern microgrids.

Our practical implementation of these principles will provide microgrid providers with the facilities that they need in order to satisfy the needs of serving such wide-ranging communities of consumers, efficiently and cost-effectively.

These principles help to provide microgrids that are:

1. **Affordable** even by poor communities,
2. **Reliable** in normal conditions and **Resilient** in unusual conditions,
3. **Scalable** in terms of size and **Extensible** in terms of functionality,
4. **Versatile** in current circumstances and **Adaptable** to future circumstances,
5. **Supplier-independent** in order to take advantage of competitive pricing in the supply, and upgrade, of the major sub-systems of equipment for the microgrid.

A smart microgrid controller does not satisfy these principles by accident. It takes expertise and careful attention, to design a technical architecture to support such a set of principles, and further to build the practical interfaces required to integrate the necessary components into such a technical architecture. The SMC's architecture, computer languages, components and interfaces, need to be chosen such that a worldwide community of developers can be easily engaged to develop the SMC further, to take advantage of an "open-source" approach. The challenge is also complicated by needing to do all of this so that deployment is easy as well as low cost.

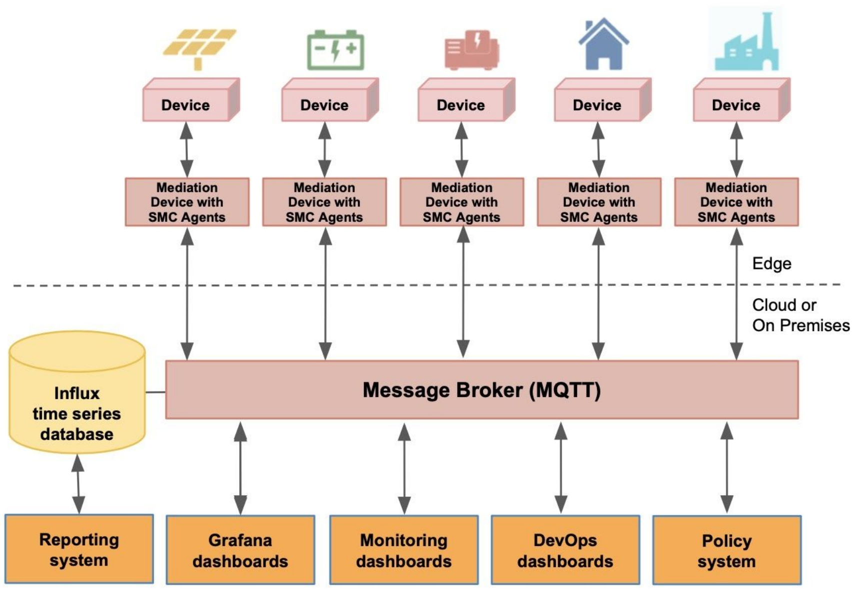
Our vision and system in trials solves this complex technical and commercial challenge. For example, the combination of Raspberry Pi, Linux and USB, and the capabilities that are developed for this platform of hardware, software and connectivity, brings powerful and inexpensive facilities to the SMC.

The solution is deployed using software-as-a-service, so it is available anywhere in the world. It can be easily deployed by local partners, with the appropriate computing and data communications expertise to install the requisite sensors on the microgrid's equipment. Such partners will also be supported online by ourselves in each aspect of the process of designing, installing and operating such a smart microgrid controller. Once the sensors are installed locally, the capabilities of the software-as-a-service will bring the smart microgrid to life, and immediately present back to the local provider, the dashboards of information from the sensors, in order to manage KPIs and LCOE.

The rest of this document now focuses on a technical overview of the smart microgrid controller, to illustrate how its architecture, components and interfaces work together to satisfy the principles that we have outlined above. Detailed technical white papers are also available for those potential partners who require a more comprehensive view of the Smart Microgrid Controller, its deployment and its operation.

Overview of SML's Smart Microgrid Controller (SMC)

A simplified diagram of the SMC architecture is shown below. The top line of the diagram illustrates the generators, storage and consumers of a microgrid, referred to here as "Devices". Devices are connected with the SMC messaging system via a set of device-specific microservices that we call "SMC Agents".



Mediation Devices and SMC Agents

SMC Agents run on inexpensive low-power computers, such as the Raspberry Pi family of Single Board Computers, which reflects SML's vital affordable-for-all principle. Together with its associated SMC Agents, this computer host constitutes what we describe as a "Mediation Device."

On each Mediation Device, SMC Agents provide added-value services which enable effective functionality and efficient operation for smart microgrids, including:

- Automation service to announce, identify, register and configure all new devices that are added to the system. This supports the scalability principle.
- Updating Mediation Devices using Over-The-Air (OTA) facilities, which supports efficiency and cost-effective operations.
- Protocol conversion from the specific local device (e.g. Modbus family of protocols), onto the SMC's messaging backbone, supporting supplier independence.
- Monitoring and control services that are easy to install and change.

The system for messaging between each component of the smart microgrid is designed to be used with a very wide range of deployed devices, from a single device to many thousands. It supports the scalability principle of the smart microgrid. Similarly, the Amazon AWS S3 platform, on which SMC is deployed, supports scalability, high availability and low latency.

The Messaging System

The SMC is built over, and exploits, the facilities provided by the industry standard MQTT network protocol for sending and receiving messages between all elements of the system. MQTT was adopted as an OASIS open industry standard in 2013 (IEC/ISO 20922). It has gained wide acceptance as the choice for IoT system application messaging. SMC uses Eclipse Mosquitto MQTT, a free and open-source version.

A short video and summary description of MQTT can be found online - click here.

MQTT is a modern “publish-subscribe” (“pub-sub”) network protocol. It was designed specifically for network connections to remote locations where network bandwidth is limited and connections unreliable - such as poor cellular or expensive satellite links. It was specifically designed to be tolerant of transient network connections, handling the asynchronous nature of publishing and receiving of messages. In addition, MQTT is lightweight in both its bandwidth usage and the very small code footprint it exerts on the hardware it runs on. MQTT is the ideal choice for supporting smart microgrids, particularly those in frontier locations or where its WAN connection might become transiently unavailable due to extreme local weather or geological events.

Pub-sub protocols provide a functional decoupling of the producers of data from its consumers; after publishing the publisher has no further responsibilities with regard to communication or usage. On the obverse, the consumer does not need to know anything about the data’s producer. One massive advantage for system developers is that new functionality can be added whenever and wherever, with only the MQTT Topic data needed to be known. This complies with and delivers on SMC’s principles of adaptability.

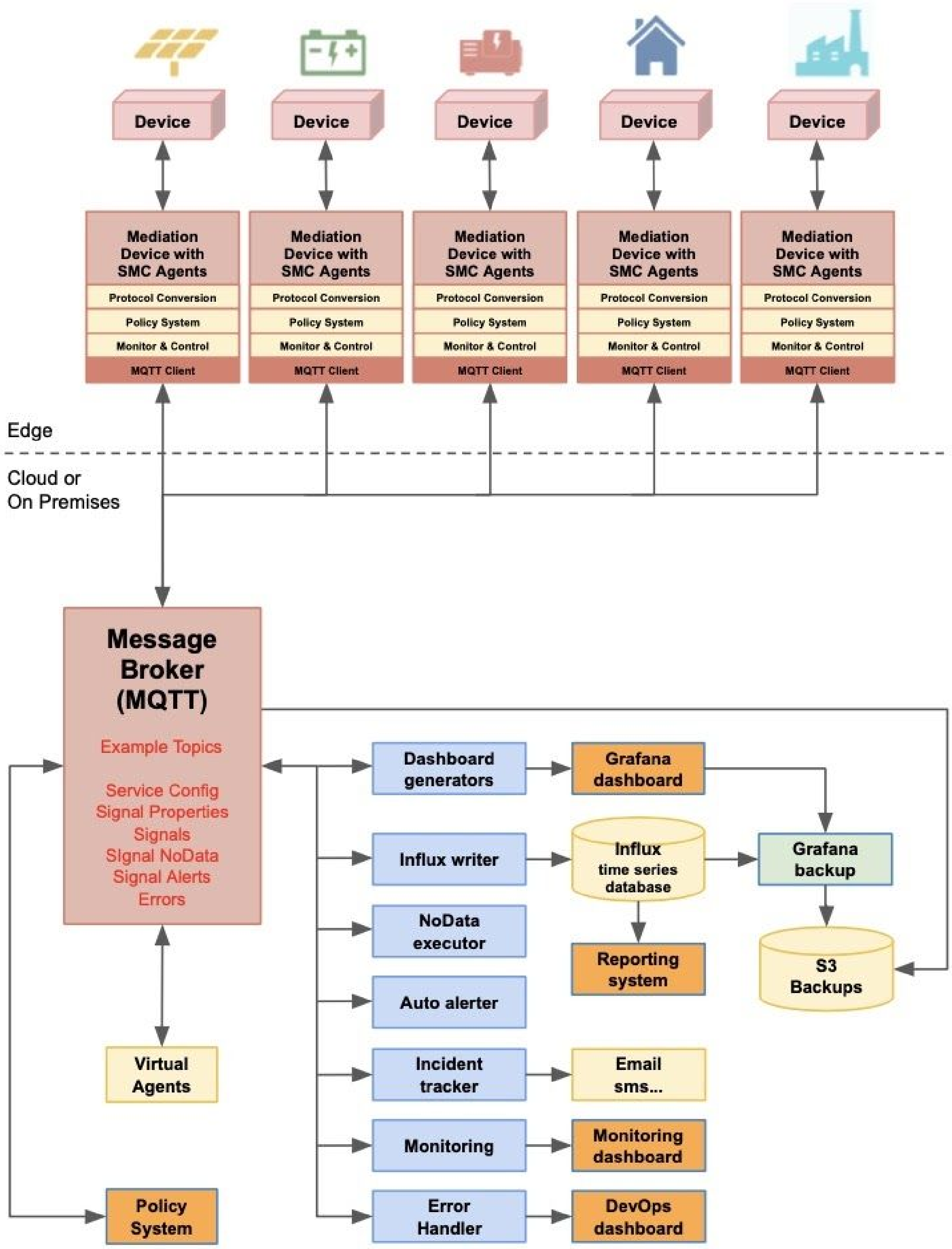
SMC implements multi level redundancy in its MQTT network. In case of failure, the Message Broker and Clients automatically hand over to an MQTT BackUp Broker. This is an example of the capabilities that help to achieve reliability and resilience in smart microgrid deployments.

Added-value microservices for more effective and efficient smart microgrid

In addition to integrating generation, storage and consumer devices into the smart microgrid, a collection of other system components are integrated as microservices into the SMC via the messaging system. These include (see diagram over following page):

- Influx Database for the time-series data from generators, storage and consumers.
- The Policy System which is based on spreadsheets and directed acyclic graphs, so it can be used by the client or provider. It enables the smart microgrid to respond to a range of priorities of the local community, as required from time to time.
- A range of outputs such as Grafana dashboards for near real-time user information, and dashboards for Monitoring and for Development. These microservices automatically create a dashboard for new devices and new attributes.
- Reports that provide historical information about generation, storage and consumption, that can be used for creating a more efficient and cost-effective smart microgrid.

Consistent with IT industry best practice for building mission-critical web-scale applications, SMC is architected as a set of cooperating microservices. The following diagram shows some of the key microservices in the SMC architecture:



Each microservice is responsible for one or more specific functions such as making the data persistent by writing it to a database. In some cases, the microservice is the final destination of the data received. In other cases, the microservice will perform some transformatory function and then publish the transformed data for another set of microservices to consume.

The set of microservices that constitute any particular individual SMC will vary depending on the functionality required of that particular microgrid installation or set of similar installations. This facilitates the 'one-size-fits-all' versatility principle at the heart of the SMC architecture. SMC is scalable in both performance and functionality.

The set of available microservices grows over time as new functionality is required. This satisfies the adaptability principle as the SMC can evolve over time as its circumstances change.

Managing many smart microgrids with varying requirements

A number of microservices are required in order to satisfy the complex manageability needs of smart microgrid deployment and operations. This is true for any individual smart microgrid, but has critical consequences in the context of deploying and operating many smart microgrids.

A particular level of operator intervention might be acceptable when a single smart microgrid is being managed, but becomes burdensome when there are tens of microgrids to be managed, and is untenable when there are hundreds of microgrids to be managed.

This overhead is compounded when the microgrids are owned by different principals, and each with varying service level agreements.

Our integration of microservices into the SMC architecture means that even core system functions can also be easily added to create smart microgrids with the requisite catalogue of valuable capabilities, such as auto alerts and incident tracking.

Furthermore, the "soft dictionaries", based on spreadsheets (for example in the protocol conversion between the equipment and the messaging system), ensure that new equipment can be integrated without hard coding, which again adds to the ease of use and cost-effectiveness, especially for the provider of many microgrids.

As well as such capabilities for integrating microgrid equipment efficiently, and responding automatically to conditions at the time, integration with other systems such as those for billing and other external data, such as the price of diesel, or upcoming weather conditions, can be efficiently integrated into the SMC.

All of these capabilities for ease of integration into the SMC, and automating the required outputs from it, make a very substantial benefit to the deployment and operation of smart microgrids, and especially so for a provider who has many smart microgrids to manage.

Conclusion and next steps

We hope that this introduction to Smart Microgrid Controller gives you an idea of the possibilities for managing your microgrids according to the principles we outlined earlier.

If you would like to discuss further the technical and commercial issues of smart microgrid control in more detail, we would be delighted to talk with you, and to share more detailed documentation and presentations.

