MICROGRID CONTROLLER STANDARDS FOR INTEGRATION AND INTEROPERABILITY

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ABSTRACT

This paper presents standards that are intended to provide a functional specification and a procedure for testing the core functions of the microgrid control system in microgrids that can operate in both grid connected and islanded modes. Such microgrids are typically embedded in distribution systems. The functional specification can be extended to isolated and remote microgrids and community microgrids, which are not designed to operate in an island mode. This paper discusses the standardization initiatives carried out within the IEEE Standards Association, as well as the context of these initiatives and relates them to the integration of distributed energy resources (DER) in distribution systems.

INTRODUCTION

The focus of this paper is the crucial role that standards can play in facilitating the technical integration of microgrids from a control system perspective. The paper does not discuss design and implementation issues of microgrids or address the business case for microgrid deployment. It is assumed that the microgrids meet minimum functional requirements described in this paper [1, 2, 3, 5]. The standards discussed in this paper provide a framework for the specification of microgrid control systems and their testing. They are a response to one of the challenges in deploying microgrids, namely the lack of minimum control system requirements generally applicable to microgrids of diverse configurations and designed for different applications. This absence of standardization makes it necessary to design and develop a control system for each microgrid, which increases costs, lengthens development time, and hinders interoperability between the control systems offered by different vendors.

A microgrid has specific roles and features [1]: (a) it is an effective method of integrating distributed energy resources (DER), including renewable energy resources, conventional and alternative distributed generation, and electric energy storage, in combination with load management and demand response; (b) it uses a local control system, which dispatches the DER according to specified rules, and manages the transitions between grid-connected and islanded modes, as required.

In addition, in grid-connected mode, a microgrid meets interconnection requirements and agreements specified by the distribution system operator.

The benefits of installing microgrids can include resiliency to exceptional atmospheric events, enhanced security of the energy supply to loads within the microgrid, and the aggregation of DER from the perspective of the distribution system operator [2, 3].

The standards presented in this paper provide a functional specification for the core functions of the microgrid control system. These are functions which must be implemented in microgrids that meet the following definition [4, 11]: a group of interconnected loads and distributed energy resources with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid and can connect and disconnect from the grid to enable it to operate in both grid-connected or island modes.

There has been significant interest and activity in the subject of microgrids in the past ten years [6]. In the USA, in the fall of 2013, the U.S. Department of Energy (DOE), Office of Electricity, saw a need for a standard for microgrid controllers [6]. Among others, the DOE required standards against which to test the various microgrid controllers that were part of its demonstration projects. The standard was necessary as a requirement in response to request for proposals [4]. There was also the recognition of a steep rise in the number of microgrids being deployed and interconnected with distribution utilities. Rules for interconnection and interactive operations with the utility at the point of interconnection were required not only (a) to insure that optimal benefit could be made available to both the grid and microgrid owners, for example in terms of voltage support, but also, and more importantly, (b) to ensure that the operation of the microgrid would not be disruptive, especially when disconnecting and synchronizing back to the grid.

At the same time the National Institute of Standards (NIST) was working with the Smart Grid Interoperability Panel on interconnection issues related to distributed generation, mostly solar. Initially, this work was centred on inverters for solar, and storage and the revision of the IEEE Std 1547 [10]. This revision recognized the role of DER in contributing to the energy supply and to grid support.

It was also recognized that microgrids were a means of aggregating DER, allowing a more flexible management of DER and other assets at the point of interconnection through the microgrid control system.

This paper discusses the standardization initiatives within the IEEE Standards Association that resulted in, IEEE Std 2030.7 Standard for the Specification of Microgrid Controllers [7, 11] and complementary guidelines developed by other technical organizations such as the IEC [12, 13, 14]. It provides the background to microgrid control system standardization and guiding principles of IEEE Std 2030.7, which includes a functional specification for the control system, and its companion IEEE Std P2030.8, which deals with testing.

MICROGRIDS – AN AGGREGATION TOOL

Microgrids are an effective and efficient solution for aggregating generation, storage and loads into a single entity that can serve a number of purposes, from the optimization of resources to serve loads within a specified boundary to setting the power flow across the point of interconnection with the distribution utility, participating in markets, and islanding for resiliency.

A microgrid is an aggregation of DER and loads within clearly defined electrical boundaries, Fig. 1, that acts as a single controllable entity with respect to the grid and can connect and disconnect from the grid to enable it to operate in both grid-connected or island modes. The control system requirements for aggregation include:

(1) Energy management function – for local management of DER, particularly variability and intermittency of renewable DER. This can be done using storage or load management (load curtailment and demand response). This function dispatches assets to supply the load and to meet contractual agreements at the point of connection to the grid.

(2) Function overseeing the transition between grid connected and islanded modes – for connecting, disconnecting, black start, system restoration services, and supplying local critical loads in the event of the failure of the distribution grid. These features improve the reliability, security and resilience of the electric power supply to the loads within the microgrid.
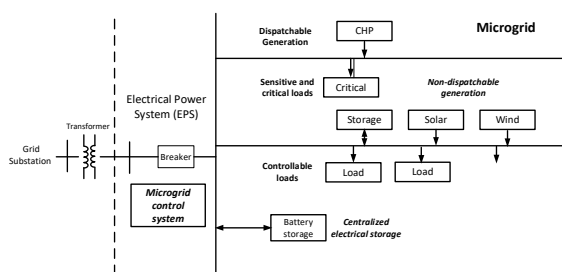
(3) Function managing the interactions with the grid – for power exchanges (real and reactive power) and DMS interaction with benefits to the DSO and TSO. One of the important features and benefits of creating a microgrid is to locally manage DER and loads and present to the DSO a defined net power consumed or fed back into the grid. The recent interest of the TSO to monitor and control DER is directly associated with the impact that aggregated DER can have on the transmission system, particularly its loading and capacity. This would facilitate the ability of the TSO to manage the transmission grid and generation dispatch. Other functions include the provision of ancillary services: supply or real and reactive power (voltage support), frequency regulation and support among others.

CONTROL SYSTEM STANDARDIZATION

A major task in the development of standards for microgrid control systems is defining core functions for the control of microgrid assets, including DER, and of switching and regulating devices under its control. The aim is to provide a baseline for the design, configuration of microgrids from the control perspective, and allow interoperability of the offerings from different vendors.

IEEE Standards

(1) IEEE Std 2030.7 – Standard for the Specification of Microgrid Controllers – This standard enables interoperability of the different control functions needed to operate the microgrid through cohesive and platform-independent interfaces. This approach will allow for flexibility and customization of control algorithms without sacrificing or limiting potential functionality.

(2) IEEE Std P2030.8 – Standard for the Testing of Microgrid Controllers – This standard complements IEEE Std 2030.7 and addresses the testing requirements for conformance.

Functional specification – Std 2030.7

The core functions proposed are composed of functions whose role and hierarchy in the microgrid control system structure are between the lower and higher-level functions as illustrated in Fig. 2.
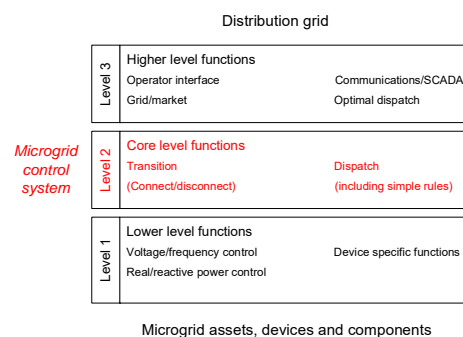

Fig. 1. Microgrid structure and components.

Fig. 2. Microgrid control system core functions.

The functional description and specification of the core functions is summarized below:

(1) Dispatch function – It maximizes the use of the assets, including the DER, and ensures that the operation of the microgrid meets minimum requirements, both for the internal operation and as seen from the point of interconnection to the distribution system. A dispatch order is a set of commands sent to the microgrid assets, devices and components; the commands may be simple rules, or be based on the optimization of predetermined operating modes of the microgrid. Optimization may include the minimization of the cost of electricity. The operating rules may be different in grid-connected and islanded modes; under steady state conditions, the dispatch function executes its commands at regular intervals (typically 15 min or less); during transitions, see below, it executes emergency dispatch orders, on an interrupt basis, to ensure that transitions take place in an orderly manner, dispatching assets and curtailing load.

(2) Transition function – It manages transitions and operates in the following four situations: (a) unplanned islanding, resulting from a loss of distribution grid power; (b) planned islanding, resulting from a request from the distribution grid operator to disconnect; (c) reconnection / resynchronization; (d) black start as required following a transition to islanding. Disconnection from the grid can be carried out without interruption or require a shut-down and restart (black start); this can be in the form of a black start using one of the microgrid assets, either a dispatchable generator or a storage device; the transition function provides the signal to switch the dispatch function from one mode to another, the dispatch function then being responsible for reconfiguring the control system functions during the transitions as a function of the new mode of operation.

CONFORMANCE TESTING

Approach to the testing of core functions – P2030.8

The purpose of this standard is to for conformance of the core functions allowing verification of interoperability between the offerings of different vendors and facilitating the development and deployment of cohesive and platform independent interfaces. A standardized and generic set of testing procedures can facilitate the wide adoption of a standardized microgrid control systems.

The proposed testing approach for the microgrid control system includes the following elements and steps:

(1) Defining test scenarios – Scenarios allow testing the core functions under well-defined and representative conditions; they allow testing of individual core functions or the combination of the two core functions, as in the case of transitions, where the transition function initiates an emergency dispatch order, particularly in the case of an unplanned islanding event. These scenarios assume a generic microgrid configuration.

(2) Defining performance metrics – These need to consider applicable standards related to electric distribution systems [10], applicable distribution grid requirements and grid codes, and relevant and applicable instrumentation and measurement techniques.

Metrics – P2030.8

In the testing procedures, based on specified scenarios allowing a comprehensive testing core functions, the variables measured are voltages and currents, the derived quantities are frequency, real and reactive power, and power quality indices (voltage sags and swells, flicker). These are measured at the Point of Interconnection (POI) to the grid. The standard only deals with the steady state and transient responses of voltage, frequency, and power exchanges at the POI. In islanded mode, representative points within the microgrid are selected.

The allowable operating ranges and requirements for voltage and frequency at the POI are those that apply to DER connected to a distribution grid and specified by standards [10] or by utility grid codes.

Islanded microgrids can operate under relaxed voltage and frequency constraints, depending on equipment design.

Testing environment – P2030.8

The testing environment can range from a fully numerical/software environment to a fully hardware (full scale) installation. An accepted and readily implementable environment is Real Time Simulator (RTS) with a Hardware in the Loop (HIL) approach for testing elements of the microgrid control system, Fig. 3. It shows a set up in which the control is a hardware controller (C-HIL), the Battery Energy Storage System (BESS) is tested at full voltage and power, and the microgrid is represented in the RTS.
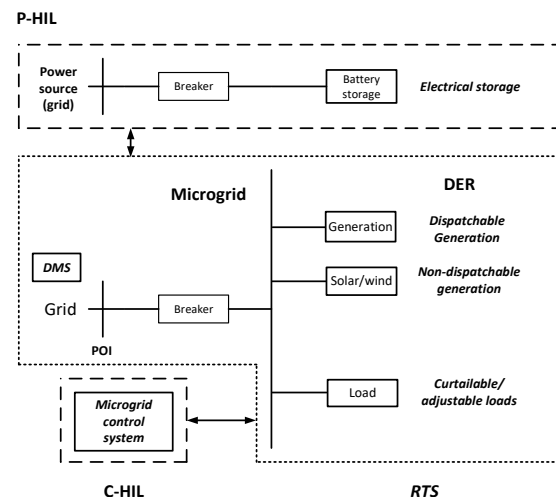

Fig. 3. P-HIL and C-HIL implementation block diagram – example.

APPLICABILITY OF THE STANDARDS

The standards presented in this paper have been written to facilitate their application to the most common microgrids, including: (a) isolated, island and remote microgrids, for which only the dispatch function applies; (b) embedded microgrids, operating either connected to the main distribution network or islanded if the distribution system fails or a request is made by the distribution system operator to island, for which both the dispatch a and transition functions apply; (c) community microgrids, developed by consumers to meet their energy needs using local energy resources (DER); they may not designed to operate in an island mode and only the dispatch function then applies. Another option to manage DER is to aggregate them using a DER Management System (DERMS) and integrate the DERMS into the Distribution Management System (DMS).

The approval of IEEE Std 2030.7 in December 2017 has had major significance for stakeholders across the microgrid sector: (1) industry, equipment suppliers and consultants now have a common basis for defining control system functionality from a technical point of view and (2) policy makers and regulators have a benchmark and definitions for the operational capabilities of the microgrid itself. Requests for proposals (RFP) and regulatory rulings are major beneficiaries of standards, as evidenced by the inclusion of IEEE Std 2030.7 as a requirement for microgrid demonstration projects by the California Energy Commission, and by its inclusion in utility microgrid projects, such as the PECO Berwyn microgrid at a critical operations facility.

The PECO Berwyn microgrid is a location where the microgrid controller standard will be applied to define the parameters for interaction with the utility distribution management system (DMS) and DERMS, adding another level of interaction and interoperability.

More information on the role and applicability of IEEE Std 2030.7 can be found in the description of on-going DOE projects [4, 8, 9], which formed the basis of the IEEE SA microgrid initiatives.

DISCUSSION

IEEE Std 2030.7 has standardized the basic or core functions of the microgrid control system. Because its specifications have been approved as a standard rather than a guide, it provides crucial support for the further deployment of microgrids. The functional specification defined in the standard will provide a common guide for microgrid consultants and developers, and a reference for utilities integrating microgrids. Not only does the standard provide a functional specification for the control system, it also facilitates the interconnection of microgrids to electric grids, where benefits can accrue to both microgrid and utility customers.

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