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A Novel Approach in Defining Interoperability Standards for Microgrids

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Abstract

Future Microgrids are developed for integration with upcoming Smart Cities. The microgrids developed are decentralized and are expected to operate in islanding mode than grid-connected mode. The increased reliability and power quality requirement of an islanded microgrid requires advanced planning. In the process of planning, the interoperability of devices and components of a microgrid play a crucial role. The devices and components of different companies are presently developed and manufactured in a non-standardized environment. This paper presents a novel approach in defining interoperability standards for microgrids through experimentation at Humber College, School of Applied Technology. Experimentation is carried out using the embedded controller architecture classification into three groups (Von-neumann, Harvard and Super-Harvard Architectures) and further sub classified into CISC and RISC architecture. Presently, the experimentation was completed on simulation and emulation level on a generic computer architecture. The same experimentation will be validated in the lab in-future.

Index Terms : Industrial Internet of Things (IIoT), Internet of Everything (IoE), Internet of Things (IoT), Interoperability, Virtual Private Network (VPN).

I. Introduction

Microgrids are mostly operated in grid-connected mode. The developments and projected developments in the smart cities underlines the necessity for island operating microgrids [1] [2] [3]. The operation and control of a microgrid can be shared in a grid-connected mode with the single-machine infinite bus system. However, in an islanding mode of operation, the microgrid controls are solely responsible for the reliable power supply with acceptable power quality. The operation of control of a microgrid in islanding mode is carried out mostly by single Original Equipment Manufacturer (OEM) company's components and devices. However, if the microgrid is to be setup by an Engineering Procurement and Commissioning (EPC) company in the future with different OEMs components and devices as the projected growth of microgrids is around 21 billion dollars US by 2020 [4], the microgrid may not be functional and if functional the liability is not defined in case of a microgrid failure as the interoperability standards for different OEMs devices and components when interconnected in a microgrid is not yet defined [5] [6] [7] [8].

The novel approach in defining interoperability standards for microgrids is to analyze the timing signal of different OEMs communication between different components and devices of a microgrid. The communication is mostly proprietorial and hence limits the avenue for interoperability. In case, of defining the standard for timing signal of a processor (Von-neumann, Harvard and Super-Harvard Architectures) either in normal or encoded mode of operation will provide the basis for further defining different standards for interoperability. The other alternative is to use a standard encoder for the timing signal other than the proprietorial encoding of the communication signal by individual OEM.

The lab at Humber College has simulation and emulation results for defining interoperability standards for microgrids and the hardware testing and prototyping will be carried out in-future. The functional architecture for an operating microgrid in islanding mode is shown in Figure 1.

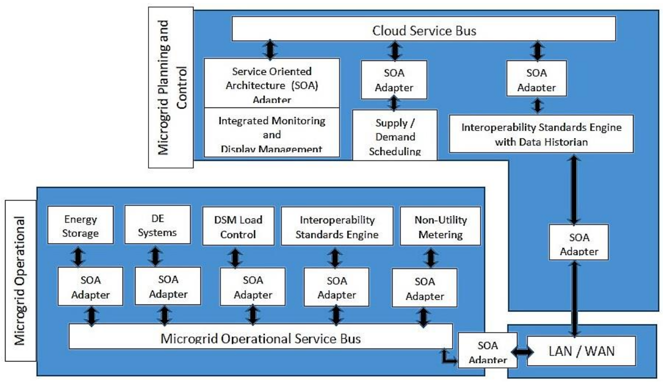

Figure 1. Functional Architecture of Islanding Microgrid at Humber College

II. Literature Survey

This section describes about the literature reviewed and used for this research work by the author for experimentation and analysis on interoperability. The section is sub-divided into three parts – past developments, present and future developments in microgrids.

A. Past developments in Microgrids

Navigant Research has continuously tracked the developments in microgrids and the past research on microgrids shows a slow development in the early 2000 to a rapid increase in the development from 2010. Reasons for the slow developments in the early 2000 are economical and technical. The economical reason is the proposed shift from centralized power generation, transmission and distribution to decentralized power generation and utilization. The capital costs and funding required for the shift was a concern for the slow growth of microgrids in early 2000. The technical reason for the slow growth of microgrids in early 2000 are the non-availability of control and communication devices and circuits for the decentralized microgrids. With the advancements in technology and the willingness to shift from centralized power economy to decentralized, the developments in microgrids are rapid from 2010 onwards.

B. Present developments in Microgrids and IoT

With the developments in IoT, one of the greatest beneficiary is microgrid, the usage of microgrid in grid-connected mode is wide spread and encouraged for newer installations (buildings, airports, commercial complexes etc.,). However, the islanding mode of operation of microgrid is still under prototyping for wide spread usage.

C. Future developments in Microgrids, IoT and IIoT

Projected growth of microgrids for 2020 is around 21 billion USD by Navigant Research. The advancements and projected advancements in IIoT and IoE makes it possible to further grow the microgrid market in terms of technical developments. The economic perspective of ROI (Return of Investment) on microgrid capital makes it a viable solution for future installations. Microgrids in islanding mode will be the widely installed microgrids keeping in view of the proposed net-zero regulations by different municipalities.

III. Lab Setup and Interoperability Experimentation

The laboratory setup at Humber College is divided into two sections. First section is simulation with analysis (stage 1) and second section is prototyping and hardware analysis (stage 2). As described in the abstract and explained in the introduction of this paper, the purpose of this research is to define interoperability for microgrid components. The research is to ease the transition from microgrids owned and operated by OEMs to regulated installation, operation and maintenance of microgrids by OEMs and EPCs

A. Simulation and Analysis

This section describes the simulation and analysis with emulation of microgrid communication protocols in a laboratory setting (standard condition) and extending it to working conditions. In the laboratory setting the experimentation was carried out on generic computers with von-neumann architectures and the interconnectivity was carried out using market available free cloud services. The reason behind the usage of cloud services is to further extend the decentralized unified control from different places to a single location. Data centers will play an important role in unifying the decentralized interoperability locations to a single location.

B. Prototyping and Hardware Analysis

This section describes about the prototyping of microgrid in an islanding mode of operation. The hardware analysis will be carried out using different OEM devices and components for microgrids. The emulation was carried out only for the cloud control of interoperability devices and components using performance analysis of traffic for load balancing and multicasting in a networked data center on a von-neumann architecture computing devices.

The three basic digital modulation techniques emulated for performance analysis of interoperability devices and components are:

- Amplitude-shift keying
- Frequency-shift keying
- Phase-shift keying

The reason for using the basic digital modulation techniques was to analyze the performance in a digital transmission environment as opposed to an analog transmission environment, because most of the present and future microgrid devices and components are designed for digital compatibility, preferably for proprietorial usage.

The emulation testing of network management was carried out to find out the behavior of the microgrid interoperability network in different network sizes.

C. Self-defining Networks – Software and Hardware

Self-defining Networks (SDNs) are the most radical and the latest developments in IIoT [9] [10] [11]. In practice, only software defined networks are in use. This research work has ventured into hardware defined networks with interoperability of microgrid devices and components as a means. The hardware defined networks will be able to self-define the network for optimal operation of microgrid in an interoperability environment.

IV. DATA CENTER AND INTEROPERABILITY

This research also explores the possibility of established data centers performing tasks related to standards matching in an online environment as the present day updating of software is carried out. However, the standards matching and interoperability is a liability involving work environment and hence dedicated data centers with subject matter experts can monitor the decentralized islanding microgrids at a unified location.

Server loading variation experimentation using Johnson Algorithm for Load Balancing in Software defined SDNs [12] further validate the role of load balancing in both software and hardware defined SDNs.

V. RESULTS AND CONCLUSIONS

The preliminary results of the research work on interoperability are presented in this section of the paper. Table 1 shows the preliminary results through analysis and data collected analysis.

TABLE 1. RESULTS

Ease of Communication between different OEM devices and components in test mode	Projected increase in cost of Microgirds		Communication Errors and Correction	Projected increase in usage of Electricity generated by Microgrids per sq. kms
	Installation	Operation and Maintenance		
25%	72%	85%	3%	35%
75%	45%	55%	1.4%	49%
90%	13%	10%	0.3%	85%

In concluding the preliminary results and expected in-future results on interoperability, the preliminary results are promising and in-future results will hold a major role for the regulators like Professional Engineers Ontario (PEO) in implementation of the standards and technical bodies like IEEE in making the public across the globe aware of the advantages of the standards and their positive impact on the planet against climate change. The developed standards will complement the carbon taxation implemented by different countries.

In Canada, the decentralized electric power generation and utilization with unified controls will help in the economic growth of Canada as the present population is very miniscule against its habitable land mass. The capital investment for centralized power generation, transmission and distribution will be huge for further expansion as against decentralized power generation and utilization.

The detailed experimentation results without actual testing setup validate the growth of IIoT and the market share of different OEMs in market and open avenues for IoE. Data center roles for achieving the goal of error-free and intrusion-free VPNs for unified control of standardized microgrid is a reality. The experimental setup (stage-2) of the lab at Humber College will validate the results obtained through simulation and emulation.

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