# Wi-Fi Enabled LabVIEW based Central Protection Center for Microgrids

**O.V.Gnana Swathika, K.T.M.U. Hemapala**

***Abstract*****:** ***Microgrid is a local conglomeration of sources and loads that operate based on point of common coupling (PCC) status. This paper proposes a wireless Central Protection Center (CPC) that remotely monitors a microgrid that acts with PCC closed. The data acquisition takes place on a LabVIEW based operator console. The microgrid is initially bifurcated into smaller zones, to facilitate easier monitoring. The CPC monitors as well as captures the current operating status of the individual zones of the microgrid. Overcurrent coordination of relay (OCR) is a highly constrained optimization problem and an optimum relay setting using Dual Simplex Algorithm is required to minimize time dial setting of overcurrent relays which eventually facilitates it achieving minimum time of operation of relays and swift fault clearance. If an overcurrent fault is diagnosed by the CPC, then an optimum overcurrent relay coordination scheme is adopted by the zones of the microgrid.***

***Index Terms: Central Protection Center (CPC), LabVIEW, Microgrid, Zonalised Protection, Overcurrent Protection.***

## I. INTRODUCTION

Microgrids are the solution for growing power demand with depletion of conventional energy sources. Microgrids in islanded mode facilitate a self sufficient distribution network. It can operate in grid connected or islanded mode. In grid-connected mode, the consumers in the microgrid receive supply predominantly from the utility or main grid. The study of modes of operation of a microgrid: steady state and transient mode is essential in order to understand the working and also in developing a monitoring scheme for the same [1]. Microgrids contain several distributed energy sources (DERs) connected to it. The dynamics of DERs pose severe changes to the existing networks [2]. The intervention of distributed generators (DGs) poses substantial fluctuation in voltage and frequency of the network.

Also the transition to the grid-connected mode from the islanded modes and vice versa prove to be crucial for protection engineers [3]. The protection engineers must propose an adaptive relay setting scheme during these transitions. Since the microgrid system need not be radial in nature, it is important that a good protection scheme with fault clearance that aids in minimum consumer disconnection is derived.

There are various protection schemes and strategies devised to overcome the challenges [4]. The integration of DGs in microgrids leads to problems in protection coordination that are difficult to solve using conventional methods. An advancement to the current scenario in this sector is improvement in communication techniques and devising of efficient communication based protection schemes [5-6].

Due to dynamic reconfiguration of microgrids, significant protection issues occur. The current magnitudes during fault conditions also vary depending on the microgrid operating mode [7-8]. The overcurrent protection is much required for system protection and is solved using optimization techniques in the form of a linear programming problem [9-10]. Incorporating the protection scheme in a zonalized fashion helps in fault detection and clearance in microgrids. This distribution network should be continuously monitored for overcurrent faults [11].

The fault protection schemes should include primary as well as backup protection [12]. In any network, there are a set of devices which play the main role in its protection system. These are relays and circuit breakers. The relay is a device which senses abnormalities, in this case, overcurrent condition and gives a signal to the circuit breaker to trip. From the instant a fault occurs and the relay senses it to the instant the fault is cleared is observed as the operating time of a relay [13]. Suitable time grading is utilized to provide appropriate primary and back up protection schemes. The operating time of the backup relay takes into account the operating time of relay and the coordination time interval as well. There are various methods using which the time multiplier settings and time of operation of relays are optimized, such as Dual simplex method [14-17], Big M method [16] and Genetic Algorithm [17]. The CPC acts as adaptive monitoring and fault clearance system in microgrids. It reliably identifies the current status of microgrid and provides suitable corrective measures as and when required [18].

**Fig. 1. Central Controller for Microgrid**

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Suitable communication protocols are used to attain real-time monitoring of the microgrid according to the variations in the system facilitating preventive maintenance, and fault detection. Remote monitoring is also done using various communication protocols. Wireless medium maybe used to monitor and take corrective actions when required on the plant [19]. LabVIEW may be conveniently employed for electrical power systems. The users of LabVIEW construct virtual instruments that are utilized for activities like: data acquisition from remote location and control [20]. Certain design methods of data acquisition based on LabVIEW using general acquisition board avoid various issues of realization and programming. Based on that, a data acquisition system controlled by computer is developed in [21]. A remote data acquisition system requires the acquisition board and the host system to be connected to the same internet connection. Nowadays the remote front panels have web browser where we can monitor and control any VI remotely [22]. Real-time signal detection is a part of the monitoring system which is also developed by designing VIs using LabVIEW [23]. The design of hardware and software of data acquisition system includes the design of the circuit, data acquisition card, signal analyzing and the system monitoring [24]. Supervisory Control and Data Acquisition is a popular system wherein different remote locations are centrally monitored with data collection/logging facilities and controlled using a site operator. The SCADA systems consists of a hardware setup phase and a software development phase. The hardware setup consists of a real time embedded evaluation board and a host system. The continuous input signals are fed to the host system using a data acquisition board and the user is allowed to monitor and control system parameters using LabVIEW [25]. The wireless monitoring unit involves minimum installation and system costs.

This paper proposes a Wi-Fi based central protection center that is capable of monitoring and acquiring data from the microgrid. The CPC is able to identify faults in the network. Also it provides optimized TMS values to the overcurrent relay and also attains fault clearance in a grid-connected microgrid network. Section 2 discusses about the proposed Wi-Fi based CPC for the grid connected microgrid system. It discusses the realization of the hardware prototype with technical specifications. Section 3 discusses about several test cases with faults at different locations.

## II. PROPOSED WIFI BASED CPC FOR MICROGRID PROTECTION

Fig. 2 represents the proposed methodology of CPC for microgrids. A test system is chosen. The system is segregated into zones in order to monitor it conveniently. The load flow analysis is performed on the considered system to identify the key system parameters. Further the short circuit analysis is done to analyze the system fault current for faults at different locations.

Data acquisition (DAQ) includes sensors, measurement devices and computer with programmable software. Development boards are computer boards that are utilized to realize and validate electronic modules. They also evaluate programs for embedded devices. In this paper, National Instruments myRIO-1900 is considered as real-time embedded evaluation board. It is a portable reconfigurable I/O (RIO) device that is used for various applications. myRIO-1900 supports serial and Wi-Fi based data acquisition. Wi-Fi enabling allows for fast and easy integration into remote embedded applications. myRIO-1900 is configured using Wi-Fi and this is done by setting up a common internet enabled network between the CPC system and the evaluation board. The connection of myRIO-1900 with the host system using Wi-Fi is shown in Fig. 3. The Wi-Fi characteristics of the embedded evaluation board are specified in Table 1.

The board is interfaced using LabVIEW software. The microgrid test system is divided into zones and individually realized on LabVIEW. Each zone includes a collection of buses at which the values of current are recorded and continuously checked. On the front panel, as shown in Fig. 4 the current values acquired from different locations in a zone are displayed and corresponding LEDs are placed for these points to detect and indicate occurrence of an overcurrent fault. It also displays information about the protection scheme. The zones are monitored sequentially and within each zone at any instant of time all the key parameters of buses are acquired. This eventually aids in zonalized protection.

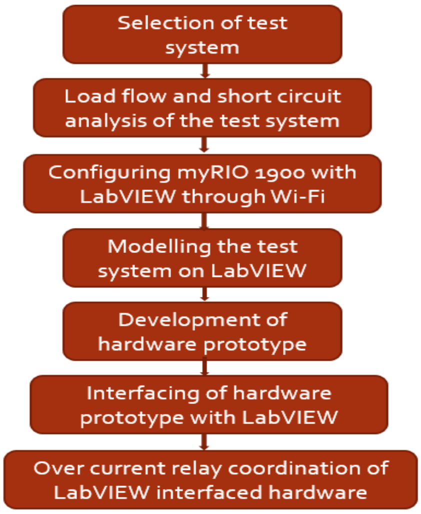


**Fig. 2. Flowchart for Proposed Methodology**

**Fig. 3. Connection of myRIO-1900 with host system**

**Table 1** Wi-Fi characteristics of myRIO-1900

| ***Characteristics*** | ***Specification*** |
|---|---|
| Radio mode | IEEE 802.11 b,g,n |
| Frequency band | 2.4GHz |
| Channel width | 20MHz |
| Outdoor range | Up to 150m (Line of sight) |

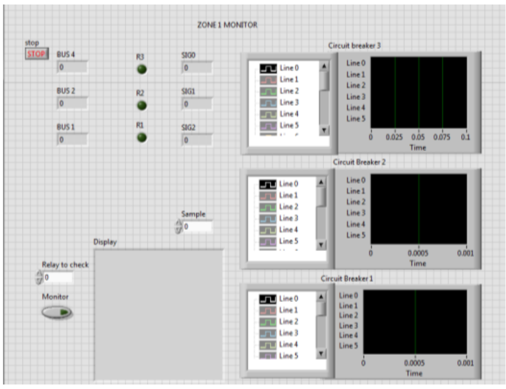


**Fig. 4.** Front Panel of CPC

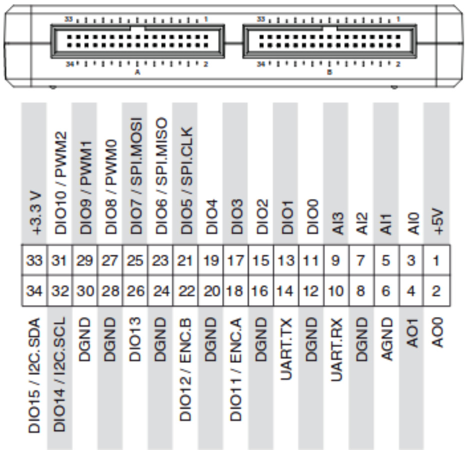


**Fig. 5.** Primary/Secondary Signals on MXP Connectors A and B.

**Table 2** Analog input characteristics

| ***Analog Input*** | |
|---|---|
| Aggregate sample rate | 500 kS/s |
| Resolution | 12 bits |

**Table 3** MXP connector characteristics

| ***MXP connector*** | |
|---|---|
| Configuration | 4 single-ended channels/ connector |
| Input impedance | >500 kΩ at 500 kS/s 1 MΩ power on and idle 4.7 kΩ power off |
| Recommended source impedance | 3 kΩ or less |
| Nominal range | 0 V to +5V |
| Absolute accuracy | ±50 mV |
| Bandwidth | >300 kHz |

In the hardware prototype, each LED signifies a bus in the test system. Fig. 5 shows the pin diagram for the MXP connectors A and B. The LEDs in the hardware prototype are interfaced to the digital outputs of myRIO. With respect to the MXP connectors, DIO lines from 0 to 13 is connected to a 40 kΩ pullup resistor to 3.3V. The DIO lines 14 and 15 are further connected to 2.1kΩ pull-up resistors to 3.3V. An LED glow in the hardware indicates the overcurrent fault location. The primary and back-up protection sequence along with the optimum operation times of each breaker is calculated using dual simplex algorithm. Data acquisition to CPC occurs wirelessly through myRIO-1900. During this period of monitoring of each zone if a fault is identified at any location, it is immediately notified to the myRIO-1900 and the hardware prototype. Further the appropriate trip sequence of overcurrent relays are also displayed in the front panel.

## III. RESULTS AND DISCUSSION

Fig. 6 shows a 21-bus test system. The microgrid system is further bifurcated to four zones:

Bus 20 to Bus 4 are included in Zone 1. Bus 20 to Bus 9 are included in Zone 2. Bus 20 to Bus 11 are included in Zone 3. The last zone 4 includes Bus 20 to Bus 16.

Fig. 7 shows the hardware prototype of the proposed WI-Fi Based CPC system. Fig. 8 displays the CPC front panel for the first zone of the test system. The current values at different bus locations are showcased in this panel. Glowing of LED indicates fault location and the 'Display' window shows the details of time of operation and TMS for primary and backup relays.

Fig. 9 showcases the block diagram developed in Lab-VIEW for one zone in the system. Block '1' shows the outputs from the analog input channels of myRIO-1900 which contains acquired data of current values. Block '2' shows the comparison of bus current values with the pick-up current values obtained from short circuit analysis. Block '3' contains optimum time of operation and TMS values calculated using dual simplex algorithm for different faults in the zone. Block '4' shows the signaling of fault through the digital output to the hardware circuit.

**Case 1**: No fault condition

Fig. 10 depicts zone 2 monitoring and protection system. For three bus locations: Bus 9, Bus 5, and Bus 3, the current values are displayed. It is observed that no LED glows indicating that no fault is detected by the CPC.

**Case 2**: Downstream fault

Fig. 11 depicts zone 4 monitoring and protection system. For three bus locations: Bus 16, Bus 12 and Bus 7, the current values are displayed. It is observed that the 3rd LED (R6) glows to indicate the occurrence of fault near Bus 7.

**Case 3**: Mid-section fault

Fig. 8 depicts zone 1 monitoring and protection system. For three bus locations: Bus 4, Bus 2 and Bus 1, the current values are displayed. It is observed that the 2nd LED (R2) glows to indicate the fault is detected near Bus 2.

**Case 4**: Fault near the source

Fig. 12 depicts zone 3 monitoring. For three bus locations: Bus 11, Bus 10 and Bus 6, the current values are displayed. It is observed that the 1st LED (R8) glows to indicate the occurrence of fault near Bus 11.

Fig. 13 shows the hardware setup for the system. On the breadboard circuit, LEDs are used to represent different locations in each zone. The glowing of LED indicates the fault location and the labelled circuit breaker denotes the primary protection scheme which operates to clear the fault as also displayed in the front panel. For the above cases the fault detection in the four zones is observed.

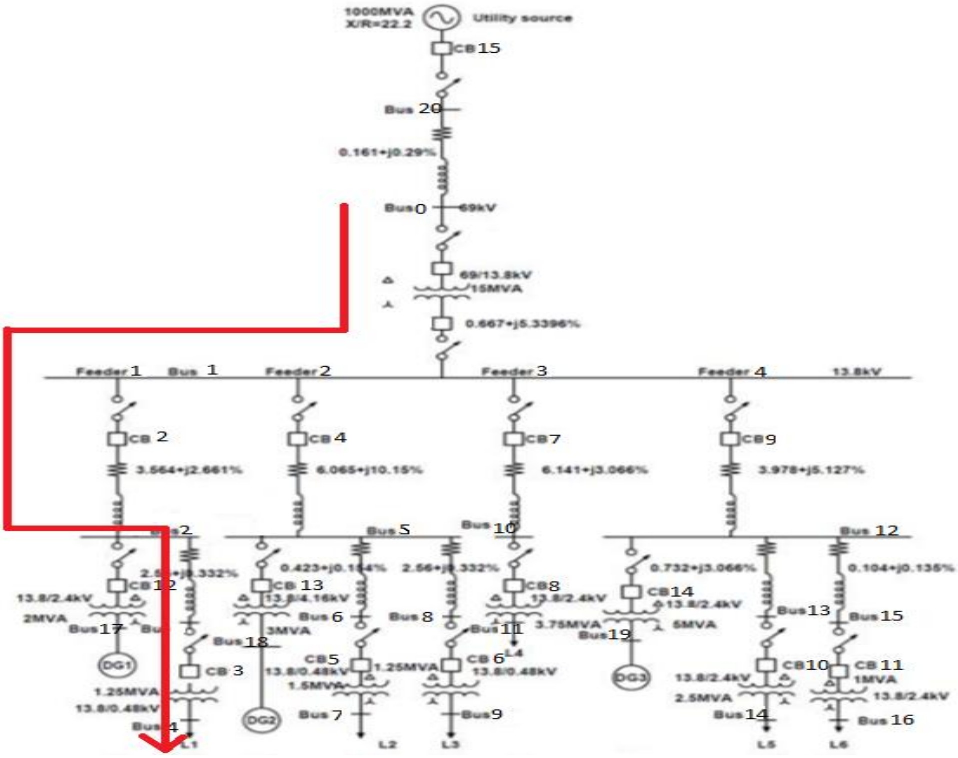


**Fig. 6.** Single line diagram of 21-Bus Test System

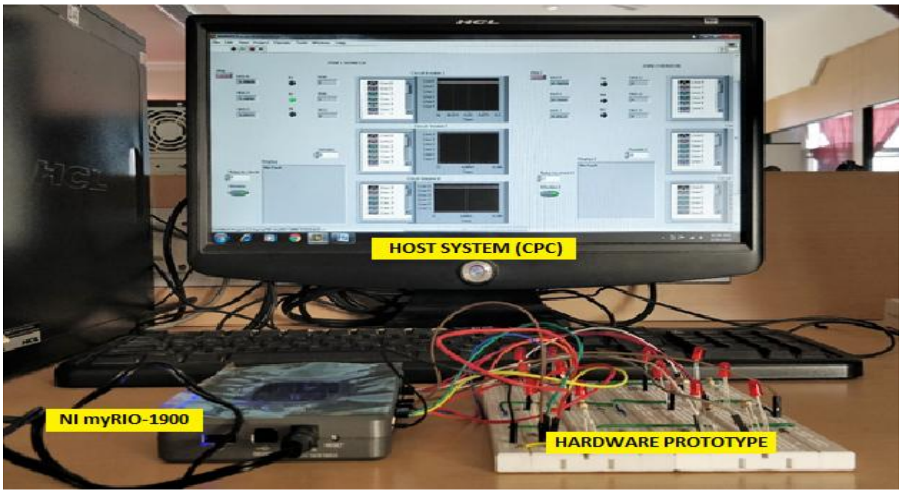


**Fig. 7.** Hardware setup of Wifi Enabled Labview Based CPC for Microgrid

BUS 4: 0.788574; BUS 2: 0.361328; BUS 1: 0.26001; SIG0: 0; SIG1: 1; SIG2: 0; Sample: 0; Relay to check: 1

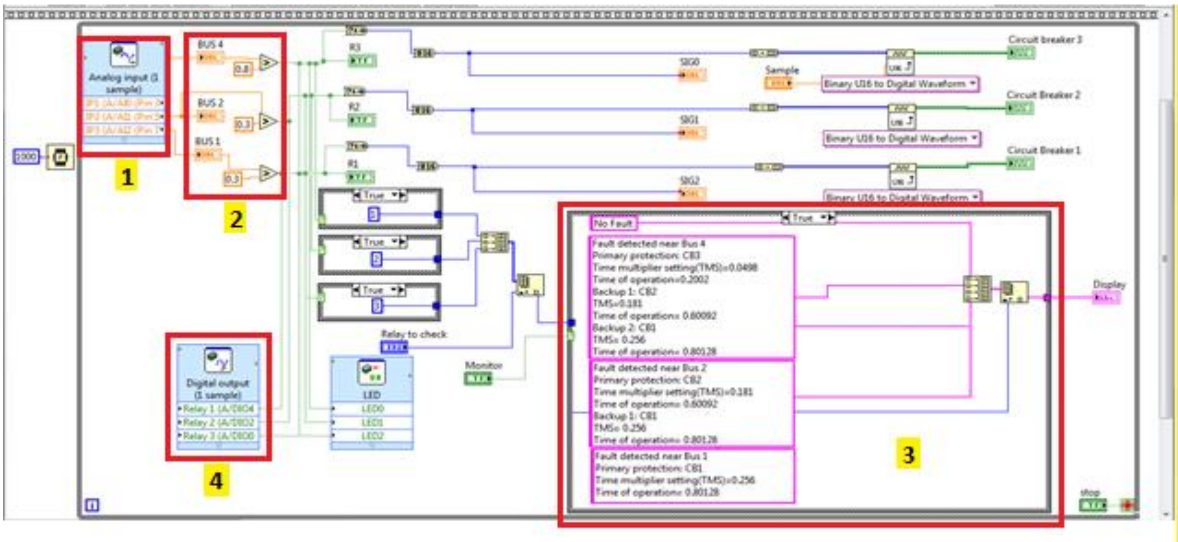
Display:
Fault detected near Bus 2
Primary protection: CB2
Time multiplier setting(TMS)=0.181
Time of operation= 0.60092
Backup 1: CB1
TMS= 0.256
Time of operation= 0.80128

**Fig. 8.** Zone 1 Monitoring and Protection System

BUS 9: 0.78735; BUS 5: 0.36132; BUS 3: 0.26001; SIG0 2: 0; SIG1 2: 0; SIG2 2: 0; Sample 2: 0; Relay to check 2: 0

Display 2:
No Fault

**Fig. 10.** Zone 2 Monitoring and Protection System



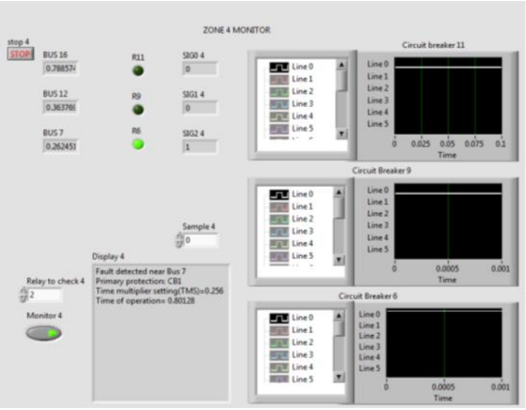
No Fault

Fault detected near Bus 4
Primary protection: CB3
Time multiplier setting(TMS)=0.0498
Time of operation=0.2002
Backup 1: CB2
TMS=0.181
Time of operation= 0.60092
Backup 2: CB1
TMS= 0.256
Time of operation= 0.80128

Fault detected near Bus 2
Primary protection: CB2
Time multiplier setting(TMS)=0.181
Time of operation= 0.60092
Backup 1: CB1
TMS= 0.256
Time of operation= 0.80128

Fault detected near Bus 1
Primary protection: CB1
Time multiplier setting(TMS)=0.256
Time of operation= 0.80128

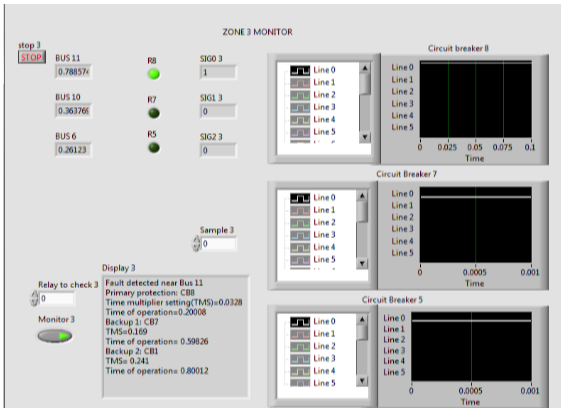
**Fig. 9.** VI in Lab-VIEW to Monitor and Protect Faults in Zone 1



BUS 16: 0.788574; BUS 12: 0.363768; BUS 7: 0.262451; SIG0 4: 0; SIG1 4: 0; SIG2 4: 1; Sample 4: 0; Relay to check 4: 2

Display 4:
Fault detected near Bus 7
Primary protection: CB1
Time multiplier setting(TMS)=0.256
Time of operation= 0.80128

**Fig. 11.** Zone 4 Monitoring and Protection System



BUS 11: 0.788574; BUS 10: 0.363769; BUS 6: 0.26123; SIG0 3: 1; SIG1 3: 0; SIG2 3: 0; Sample 3: 0; Relay to check 3: 0

Display 3:
Fault detected near Bus 11
Primary protection: CB8
Time multiplier setting(TMS)=0.0328
Time of operation=0.20008
Backup 1: CB7
TMS=0.169
Time of operation= 0.59826
Backup 2: CB1
TMS= 0.241
Time of operation= 0.80012

**Fig. 12.** Zone 3 Monitoring and Protection System

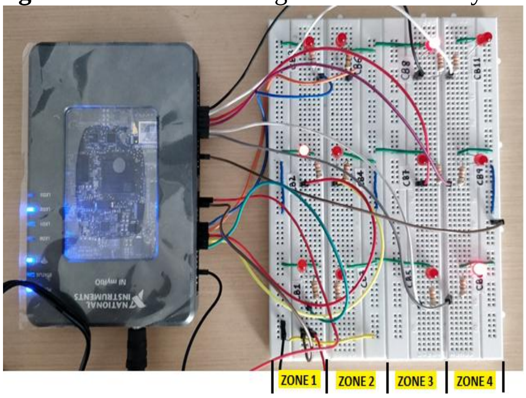


**Fig. 13.** Hardware Validation of Fault Detection System.

## IV. CONCLUSION

The major challenge faced in microgrids is in identifying a suitable protection scheme. In this paper, a novel CPC is proposed which monitors the microgrid using wireless data acquisition system. NI myRIO-1900 is used for data acquisition, and the interfacing is done on LabVIEW. The data is acquired at the CPC using Wi-Fi, and is displayed on the front panel.

The zonalised protection is incorporated in CPC where each zone is sequentially monitored continuous monitoring is done for each zone sequentially. If an overcurrent fault is detected, subsequent optimum overcurrent relay coordination is employed on the hardware prototype. This proposed CPC maybe conveniently extended to larger microgrid networks.

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