Enhancing AC Microgrid Surveillance and Security with Micro PMUs

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Abstract - The development of microgrids represents a critical turning point in reducing the effects of dispersed generation and offers a strong and effective means of encouraging sustainable energy use and improving the dependability of the power supply. Essentially, a microgrid is a small energy supply system that usually consists of distributed generation (DG) sources, loads, storage units, energy conversion devices, and monitoring and protection systems. Because of its flexibility, it can be used for both integrated and islanded operations, making it a control unit that can function independently of the main grid.

***Key Words*:** Microgrid; microgrid protection; Distributed Generation.

1. INTRODUCTION

The microgrid consists of localized electric power sources coupled with clusters of small-scale loads. Its link to the main grid is flexible, permitting both integration and isolation according to necessity, with a propensity toward grid connection for optimal utility. Its versatility makes it simple to install in isolated areas and, when needed, operate as an off-grid microgrid. With the use of different Maximum Power Point Tracking (MPPT) techniques, solar photovoltaic (PV) systems that take advantage of the constant sunshine easily contribute to microgrid power supply. Of these, Perturb and Observe (P&O) systems are particularly effective [1].

The protection system of a microgrid, which can function in two different ways grid-connected and standalone is essential to its operation and is distinguished by a Point of Common Coupling (PCC) [2]. Both modes require the essential processes of fault detection and isolation, whereby faults in the main grid and microgrid are located, isolation is made possible by the PCC, and post-fault resolution reconnection is carried out.

The introduction of Distributed Energy Resources (DERs) into distribution networks represents a significant shift in the ever-changing face of power systems. Microgrids are a cost-effective, ecologically sustainable means of coordinating distributed energy resources (DERs) [3]. Microgrids are small, sustainable electric distribution systems that include programmable loads, energy storage devices, and distributed energy resources (DERs).

In the context of microgrids, this work suggests and puts into practice a centralized protection strategy designed to handle different fault levels. The unified protection scheme and MATLAB/Simulink system modeling are described in detail in the following sections. Lastly, simulation results are examined and shown to support the suggested methodology [4,5].

Microgrids serve as orchestrators of Distributed Energy Resources (DERs), efficiently harmonizing various energy sources in a cost-effective and environmentally sustainable manner. These self-contained electric distribution systems, comprising DERs, energy storage mechanisms, and controllable loads, offer a versatile solution to modern energy challenges [6]. Whether integrated in parallel with the main grid or operating autonomously in islanded mode, microgrids play a pivotal role in enhancing reliability, ensuring consistent power system operation, and optimizing power quality while minimizing losses [7].

However, the operation of microgrids is not without its challenges, particularly in the realms of protection and control. These aspects demand careful consideration to ensure the seamless and safe functioning of microgrid systems.

2. PROTECTION CONCERNS

Securing the operation of DC-DC microgrid systems poses unique protection challenges, necessitating tailored strategies to ensure system reliability and resilience. In the context of these compact energy distribution networks, several key protection concerns emerge [8].

Fault Detection and Localization: Detecting and localizing faults within DC-DC microgrid systems requires specialized techniques due to their unique topology and distributed energy sources. Rapid identification of faults in the DC distribution network is essential to prevent cascading failures and maintain system stability.

Voltage and Current Regulation: Ensuring voltage and current regulation within permissible limits is crucial for the safe and efficient operation of DC-DC microgrids. Protection mechanisms must be implemented to mitigate voltage and current fluctuations, safeguarding connected loads and equipment from damage.

Islanded Operation Resilience: In islanded operation mode, DC-DC microgrid systems must autonomously manage fault isolation and system restoration without reliance on external support. Developing robust islanding detection algorithms and fault isolation mechanisms is critical to maintain system integrity and prevent prolonged outages [9].

Coordination with Grid-Tied Systems: DC-DC microgrid systems interfacing with the main grid require seamless coordination between internal protection schemes and grid-tied systems. Ensuring compatibility and interoperability between these systems is essential to prevent conflicts and ensure smooth transition between grid-connected and islanded modes.

Cyber security Vulnerabilities: The integration of digital control and monitoring systems exposes DC-DC microgrid systems to cyber security threats. Implementing robust cyber security measures, such as encryption protocols and intrusion detection systems, is essential to protect against cyber-attacks and safeguard critical infrastructure.

A comprehensive approach that combines advanced fault detection algorithms, accurate voltage and current management methods, robust islanding protocols, smooth communication with grid-tied systems, and strengthened cyber security protections is required to meet these protection concerns. Operators of DC-DC microgrids can reduce operational uncertainty, increase system dependability, and ease the integration of distributed energy resources into the larger power grid fabric by proactively addressing these issues.

This is the main problem in the design of the protection system microgrid. Require being screen on the web and computation of short circuit fault current level for each small change in the configuration of the grid is important for the proper adaptive functioning of any protection system. This requires the application of a fast and reliable method and robust communication with a backup system [10-11].

3. MPPT TECHNIQUE

One of the most important methods used in photovoltaic (PV) systems to maximize energy output is Maximum Power Point Tracking (MPPT). Variations in temperature and sunshine intensity cause solar panels to behave differently, which also causes variations in the voltage and current generated by the PV array. The PV system can continuously track and run at its maximum power point (MPP), where the output power is maximized, thanks to the MPPT technology.

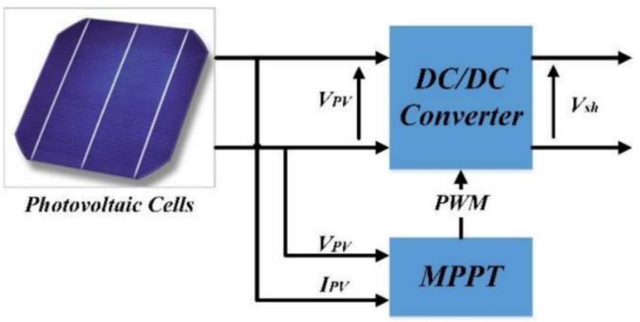

Figure 1 Block Diagram of PV System

MPPT controllers make sure that the PV system runs at the most efficient voltage and current levels, optimizing the electricity generated from the solar panels, by dynamically altering the operating point of the system. This modification improves the PV system's efficiency and performance in addition to raising its overall energy yield.

There is a certain operating point for every PV system, denoted as MPP on the I-V and V-P curves for every temperature and irradiance condition. Any variation in the barometric circumstances causes the maximum power point (MPP) to shift in position. Because of this, the tracing system was designed to continue tracking MPP, who are a crucial component of the PV system. The panel is forced to operate closer to MPP by the controller, which modifies the resistance the panel perceives. The overall structure as depicted in Figure1.

There are different MPPT techniques used for maximum power tracking. They are as follows:

1. Permutation and Observation (P&O) Method.
2. Incremental Conductance (IC) Method.
3. Constant Voltage (CV) Method.
4. Fractional Open-Circuit Voltage (FOCV) Method.

Figure 2 depicts the P&O technique that depends on varying the array's terminal voltage, or current, at regular intervals and then observing the PV's output power using the previous example point [6].

Based on the fundamental mathematical requirement (dP/dV = 0), Figure 3 illustrates the MPPT system's operation. The PV array will demonstrate a drop in output power with an increase in voltage when it operates in the right area of the MPP curve, and an increase in output power with an increase in voltage when it operates in the left area. From here on, the disturbance is retained by the system if dP/dV > 0, and it should have the opposite effect if dP/dV < 0 [12].

Until the operating point crosses the maximum power point, the cycle is repeated. Where P and V stand for power and voltage, respectively, at the PV module's output. The P&O algorithm's main advantage is its simplicity. As long as the sun's energy doesn't stray too quickly, this strategy generally operates well. The traditional perturb and observe (P&O) approach has the drawback of having low irradiation and poor efficiency at steady state; the operating point oscillates around the MPP voltage, usually with slight fluctuations, but never exceeds [14].

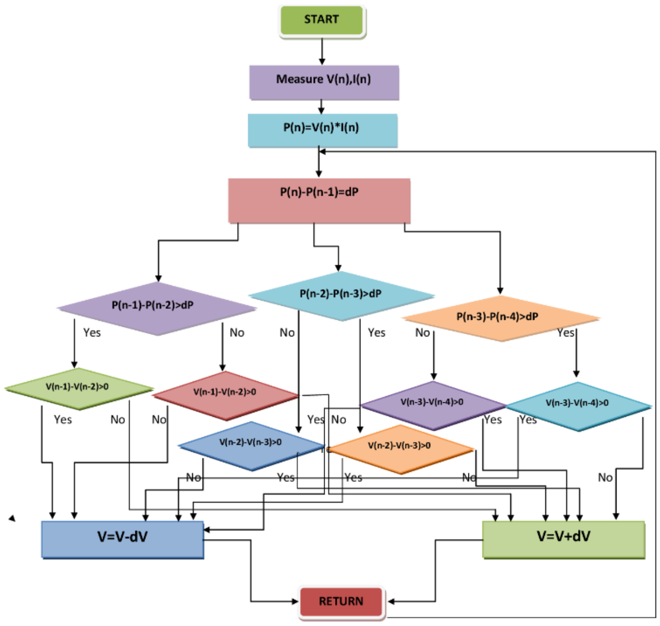

Figure 2 Perturbation and Observation method flowchart

The curve has three significant parameters specifically open circuit voltage (Voc), short circuit current (Isc) and maximum power point (MPP) [15- 16].

The photovoltaic device's I-V curve is dependent on both its internal properties and external factors like temperature and radiation intensity. The maximum power point (MPP), short circuit current (Isc), and open circuit voltage (Voc) are the three factors that affect the photovoltaic cell's P-V curve [17].

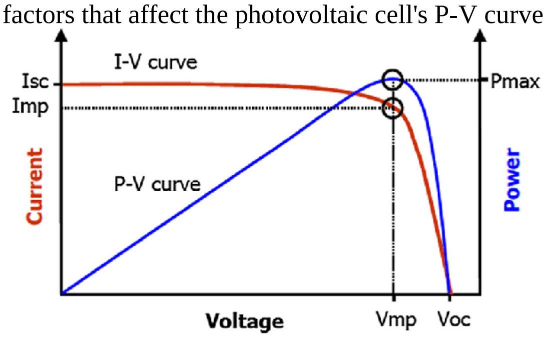

Figure 3 I-V & P-V curve of PV system

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4 SIMULATION

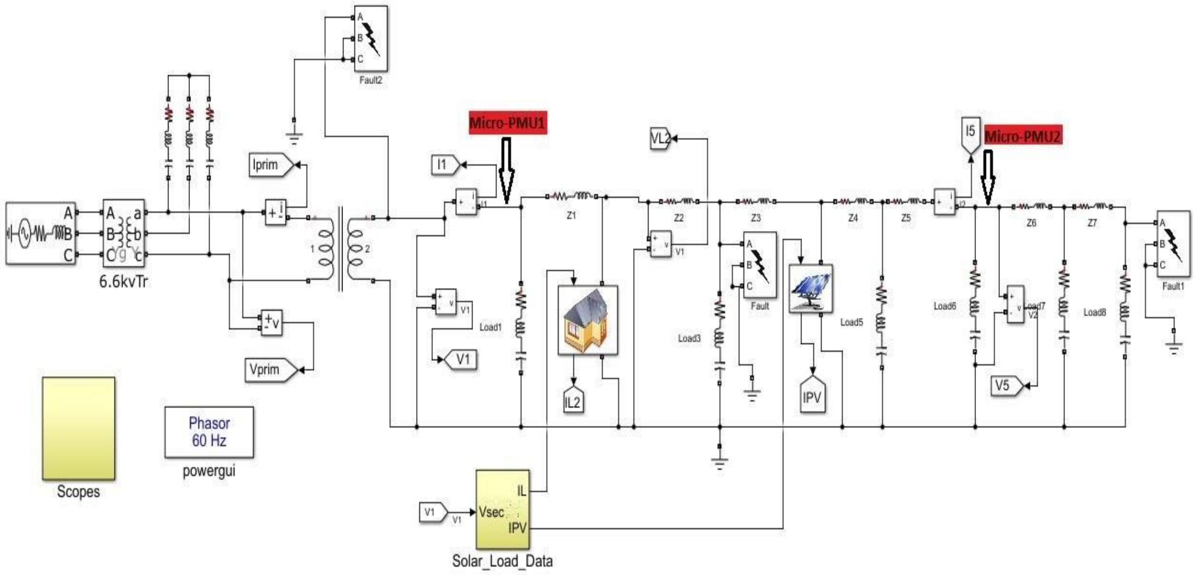
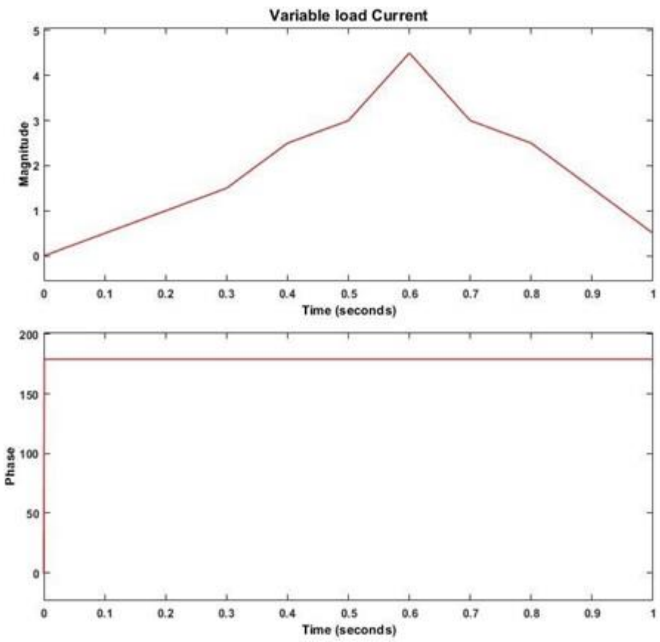


Figure 4 Single phase microgrid with two µPMUs at node 1 and 6

The perturb and observe MPPT technique is described as an algorithm. The loop is started with an initial value of 0.45, and it is then adjusted to reach the maximum power point of solar PV in relation to temperature and irradiance. Figure 6 illustrates how MPPT is linked to a boost converter, which raises voltage to a level where solar PV can operate at maximum efficiency.

In below given Simulink model of single phase AC microgrid as shown in fig 5.3. We represent solar energy generation and variable load as constant current sources. In which current injected into system by solar generation and current drawn by variable load are represented using lookup table and variation of current is shown in fig 5.4. Pole mounted transformer is used to lower maingrid voltage 6.6 kV to microgrid voltage 200 V. Fault in the system is injected using three phase fault block, Phasor voltage and current data is collected using voltmeter and ammeter as shown in below fig 5.3, which are consider as micro-PMUs.



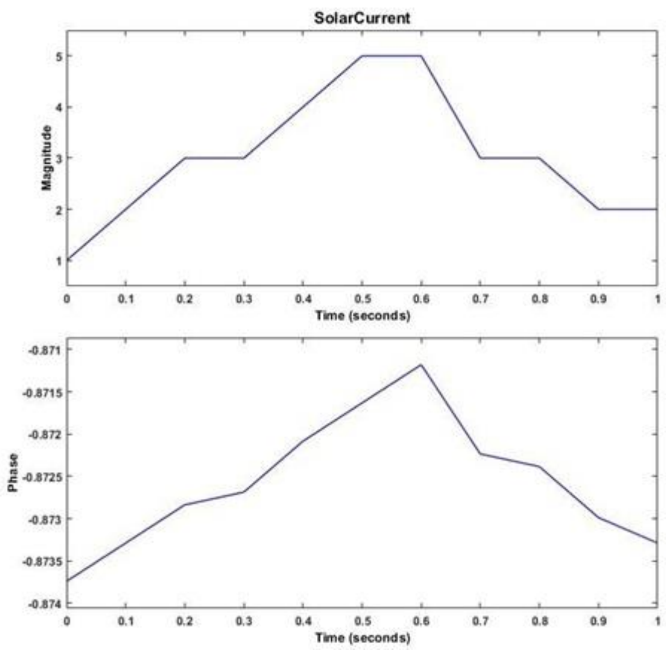


Figure 5. External solar and variable load current data

In single phase AC microgrid as shown in fig 3, load data is taken as per table I, when a fault is implemented at node 3 for 0.05 seconds with load resistance of 1ohms, we get µPMUs data as shown in fig 5.. And with the help of µPMUs data equivalent impedance is calculate based on which region of fault is identified and with µPMUs data forward and backward node voltages is calculated and faulty node is identified.

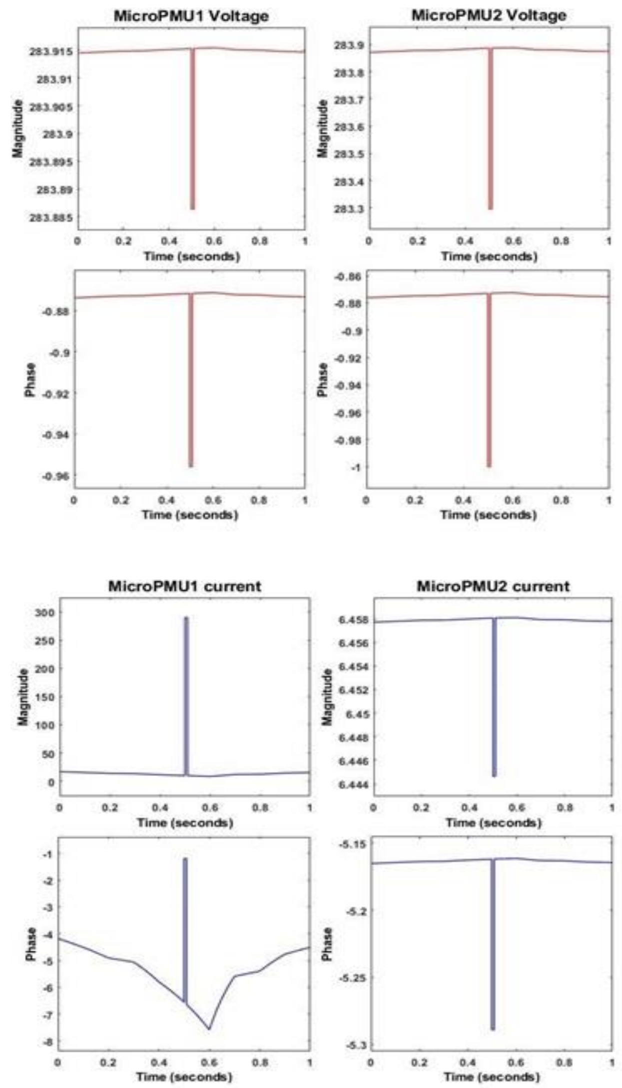


Figure5.5. µPMU voltage and current data at node 1 and 6

Table I. Load data used in single phase microgrid

Loads	Load1	Load2	Load3	Load4
Active Power (W)	1000	-900	1000	600
Reactive Power (VAr)	30	-25	30	20
Equivalent admittance	0.0169 - 0.0005i	-0.0363 + 0.0677i	0.0169 - 0005i	.0049 - 0074i
Loads	**Load5**	**Load6**	**Load7**	**Load8**
Active Power	100	1000	100	100
Reactive Power	30	30	30	30
Equivalent Admittance	0.0017 - 0005i	0.0169 - 0005i	0.0017 - 005i	0.0017 - 0005i

3. CONCLUSIONS

Most of the distribution load is of AC type, and when they are fed by AC source, about 25- 30% power is saved because of no energy conversion. So AC Microgrid helps to reduce this conversion power to a great extent because it required less conversion state. But protection of AC Microgrid becomes complex because it's characteristic different from the traditional grid. In this report, by using µPMUs, we can identify the phase where fault occurs using wavelet coefficient, and identify the region where fault occurs using impedance based technique, and identify the node of distribution network where fault occurs using forward and backward node voltages by taking a sample of current and voltage at upstream and downstream of distribution feeder. In this thesis we discuss the operation of AC microgrid for 24 hours of operation. Type of fault, and faulty node identification using discrete powergui, where solar generation and battery storage system is modelled and controlled using PQ control to maintain bus voltage across the terminal, variation of current, voltage and power at terminals where solar generation and battery storage system is connected in simulation diagram.

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