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FAULT DIAGNOSIS OF GRID-TIED HYBRID RENEWABLE ENERGY SYSTEM USING PHASOR MEASUREMENT UNIT

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Abstract: In order to safeguard a power system that serves two areas of a network, the planned study would center on developing a model of a Phasor Measurement Unit (PMU) using simulation software. When it comes to power system monitoring, protection, & control, PMUs have shown to be very dependable and efficient. The case study focuses on protecting a power system in a linked two-area network against a three-phase failure, and it uses a Simulink-based model of the PMU. We compare the PMU's performance to that of traditional analogue protection methods. The PMU is an innovative digital protection system that uses real-time phasor data measurement to outperform traditional approaches in terms of accuracy and speed. Based on the findings, it is clear that the PMU greatly improves system protection during faults, operating within 0.1 ms instead of the customary 35 ms. Due to the increased complexity caused by the integration of renewable energy resources, the study also delves into the PMU's fault detection capabilities for grid-tied microgrids. The PMU's capacity to identify faults and respond quickly in these dynamic systems highlights its vital role in today's power system environment, where grid stability & the prevention of blackouts are paramount.

I. Introduction

the power system's management structure was likewise extremely secure and risk-free. Having said that, the power system's management efficiency decreased as the growing growing power demands from the power grid, which is complicating the power system [1]. As the market's competitive nature has led to higher power system utilisation, the strain on the power system has also grown. Power system monitoring, protection, and management became more complicated and challenging as renewable energy resources supplanted old, non-renewable energy sources in power generation [2]. Improving the current grid's dependability and efficiency requires measuring and monitoring data in real-time [3]. Constant upgrades are being made to wide area monitoring systems (WAMS) that are already in use worldwide to keep electrical systems safe from blackouts through synchronised monitoring, protection, and control [4]. Wide area monitoring system (WAMS) digital bidirectional communication between suppliers and consumers makes the grid smarter [5].

A vast array of PMUs distributed across various geographical regions make up the wide area monitoring system (WAMS) [6]. Using an extremely precise time reference, such as GPS, which provides a 1 pulse/s signal with a synchronising efficiency of less than 1 μs, PMU is able to provide synchronised measurements of voltage or current phasors, as is well known. [7, 8]. An approach to integrating the PMU into MATLAB is laid out in [9]. In an effort to lessen the design complexity, a Non-Recursive DFT based approach is introduced for the purpose of developing the PMU [10]. An previous proposal [11] calls for a review of PMU.

Research on the modelling of phasor measurement units is in its infancy compared to that devoted to the efficient deployment of PMUs. The suggested study adds to the existing body of knowledge by developing a PMU model in Simulink and then applying it to a two-area network power system to safeguard it from a three-phase fault. Comparing the PMU with the usual protective approach is also part of the investigation.

II. Proposed system Design

a) Phasor Measurement Units (PMUs)

An equipment that measures electrical characteristics inside the grid & produces synchronized synchrophasor outputs to Coordinated Universal Time (UTC) is called a Phasor Measurement Unit (PMU). A typical way to show a sinusoidal signal:

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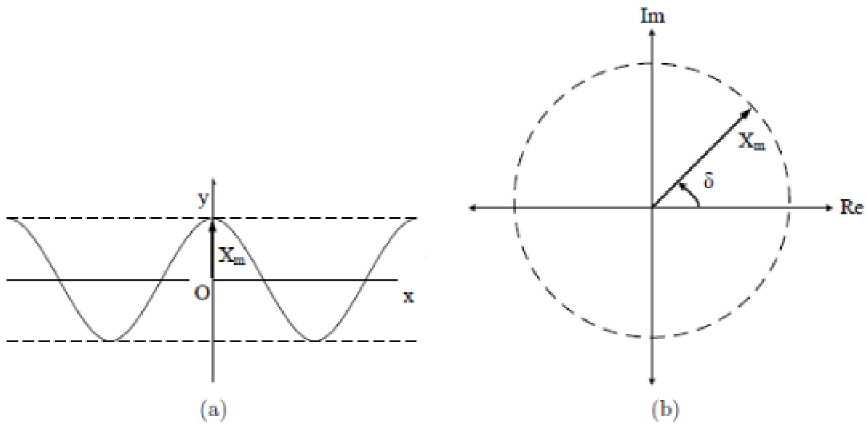

Figure 1Signal Representation in (a) Sinusoidal Form, (b) Phasor Form

The usual notation for this is a phasor, which can be expressed as

$$\mathbf{X} = (X_m/\sqrt{2})e^{j\delta}$$

The square root of x(t) is represented by magnitude of Xm, whereas the offset at the nominal system frequency synchronized to UTC is denoted by Figure 1(a) shows the simplified version, whereas Figure 1(b) shows the simplified version. Synchrophasor is the name given to the output of a Phasor Measurement, Unit (PMU).

The setup shown in Figure 1.4 is the basis for a generic PMU model. The three-phase voltages and currents at their respective network locations constitute the PMU inputs.

An anti-aliasing filter is applied to the input values; cutoff frequency of this filter is defined by the sample rate that has been chosen for sampling process. To follow the Nyquist criteria, the cutoff frequency is typically set at half of the sampling rate in most realistic applications [20]. After this step, the anti-aliasing filter's outputs are sampled at a predetermined rate. The underlying premise of this procedure is that the sample is in sync with an absolute time standard, such UTC in real-world applications.

Complex demodulation follows sampling; this involves generating sine and cosine components separately by multiplying the input with a quadrature oscillator. Theoretically, this is stated in (1.3) & (1.4), where the reference signal x(t) at the mth sampling time is specified as the synchrophasor X: [21]:

$$X(m) = (\sqrt{2}/G_n) \sum_{k=-N/2}^{N/2} x(m+k)W(k)\exp(-j(m+k)\Delta t\omega_0)$$

$$G_n = \sum_{k=-N/2}^{N/2} W(k)$$

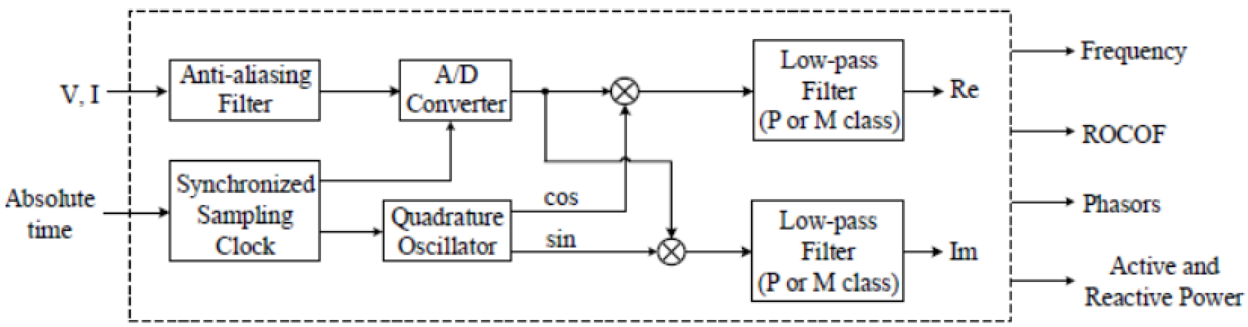

Figure 2 Diagram of PMU Model

After connecting to the grid, microgrid operates according to P-Q control. Microgrid islanding breaker (Sid) connections to the grid side show up in Figure 2. When operating in grid-connected mode, the current and voltage readings from the PMU may be used to determine the actual and reactive power demands. The power needs will be met by the microgrid in accordance with the parameters specified by the PMU. Thus, the microgrid may operate in either a standalone or grid-connected mode, depending on the power direction & control techniques used. Instantaneous extraction of grid demand (ig) is achieved by loading the microgrid bus. Currently, electricity is being sent from the grid to the load. The PMU will update the microgrid control on the bus's updated total power demand as soon as it detects the current demand.

Afterwards, the microgrid controller modifies the power that is sent to the load. Based on the updated microgrid output current (i2), load power need will be met by the microgrid. Last but not least, electricity will go from the microgrid to the load. The following requirements must be met for this system to operate:

1. it could only start when linked to the grid

2. The microgrid will distribute electricity to loads according to the dispatchable generation that is available.

3. Once the microgrid reaches its rated power capacity, a situation known as power clipping, the process comes to an end.
4. Upon detection of islanding, microgrid control system stops power dispatch from the PMU and switches to voltage-frequency control, allowing the system to operate in islanded mode.
5. If the PMU fails, the system switches to direct control by the grid operator.

Using this method in conjunction with data from non-collocated PMUs may also handle the present need for temporary load increases throughout the feeder system. To lessen transmission-level emergencies, it may also be used to provide reactive and active power support. As a result, existing and future microgrids will be able to be used more effectively, and the strain on networks at the transmission level will be reduced.

b) PMU Communication system

At Virginia Polytechnic State University, Arun Phadke & Thorp first introduced phasor measurements in 1988, which allowed for phasor estimates of voltage and current.

These phasors are defined by reference time signal, which is generated from GPS. By which synchronized phasor measurements are produced for the power system. The northeastern United States was hit hard by a power outage in 2003. For complete power grid visibility, the US-Canada outage task team recommended PMU in its final report from February 2004. From 2010 to 2013, the number of PMUs deployed in the US increased from 166 to 1,126. In order to measure phasors in sync, high-speed power devices called PMUs are used.

All three quantities—voltage, current, and phase angle—are measured using phasors. In addition to measuring actual & reactive power, PMUs may also monitor frequency and the rate of change of frequency (ROCOF). The synchronized readings show that PMUs take voltage & current waveform readings in real time, with GPS serving as a reference for accurate timing signals.

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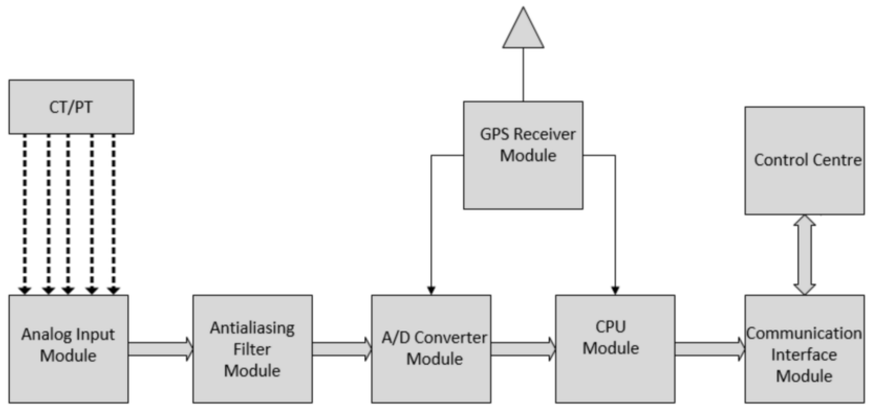


Figure 3 Functional Block Diagram of PMU

The phasor measuring unit (PMU) takes readings of the current and voltage waveforms at predetermined intervals. Using a PLL system allows for synchronization to be achieved. Using synchronized phasor measurements raises the bar for power system monitoring, protection, & control. The PMU's functional block diagram is shown in Figure 3.

c) **Test system implementation**

You can view the model in Figure 4. Every part of the model of the phasor measurement unit is essential.

1. Potential Transformer
2. Low Pass Anti-Aliasing Filter
3. DFT-Based ADC Sequence Analyser
4. Complex to Magnitude
5. and Phase Angle Conversion
6. Display Module

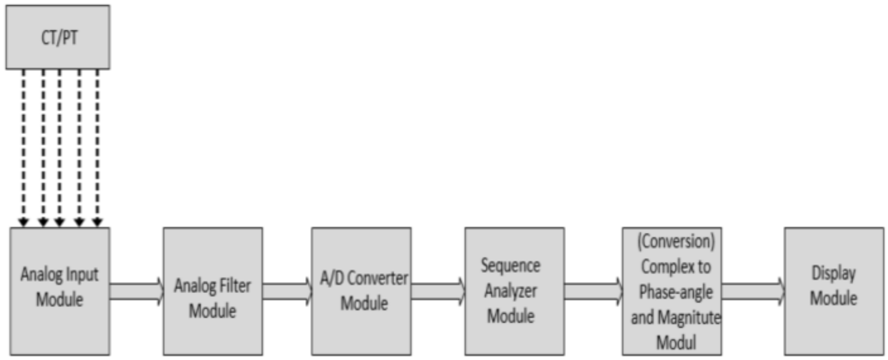


Figure 4 Representation of phasor measuring unit

d) Potential Transformer (PT)

Analog inputs are measured using the potential transformer. Connected to the low-pass filter are the outputs, while the inputs go to the specified spot for the PMU.

i) Antialiasing Filter

Sampling and quantization are the two main steps in digitizing an analogue signal. If the sampling frequency is more than twice the original signal's highest frequency, then the sampled data may be used to reconstruct the signal. This is known as the sampling theorem of Nyquist. Data loss occurs when it becomes difficult to recover whole information from a sampled signal due to an inadequate sampling rate that does not follow the Nyquist theorem. An aliasing mistake describes this problem. This error is corrected by using an anti-aliasing filter. One end of the low-pass anti-aliasing filter is linked to the potential transformer, while the other end is linked to the analog-to-digital converter.

ii) Analogue to Digital Converter (ADC)

Directing the anti-aliasing filter's output to analogue-to-digital converter samples and quantizes the analogue input signal, converting it into a digital signal. In order to create a complex signal, the DFT block processes the sampled signal. The ADC's output is sent to the sequence analyzer.

Sequence Analyzer

A MATLAB function is used in the development of the sequence analyzer. The voltage sequence components are calculated by the sequence analyzer using the sampled data acquired from the ADC. The following is an expression for the sequence components:

$$V_{a0} = \frac{1}{3}(V_a + V_b + V_c)$$

$$V_{a1} = \frac{1}{3}(V_a + aV_b + a^2V_c)$$

$$V_{a2} = \frac{1}{3}(V_a + a^2V_b + aV_c)$$

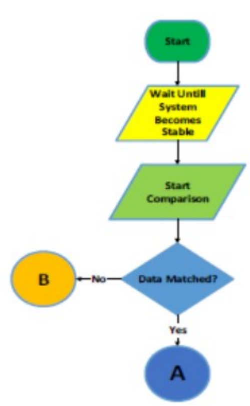
$$a = -0.5 + 0.866i$$

Each component of the zero sequence, positive sequence, and negative sequence is represented by Va0, Va1, and Va2, respectively. In terms of phase components, we have Va, Vb, and Vc.

e) Quantization of Phase Angle and Magnitude from Complex. To get the magnitude & phase angle of the voltage's different sequence components, we use the complex to magnitude and phase angle conversion block.

f) The display block is the phasor measuring unit's screen, which allows users to observe a variety of measurements.

e) Innovative Controller



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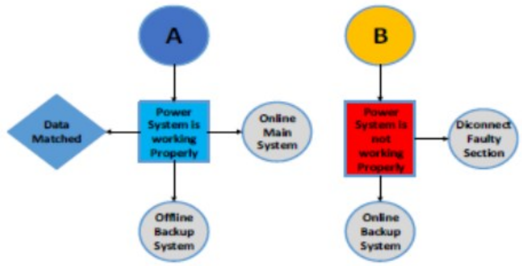

Figure 5 Flow Chart of Novel Controller

A power system controller is someone who keeps an eye on the grid and makes sure it doesn't go down. Communicating with the controller is phasor measuring unit's output. It is determined by the algorithm operating within the controller whether the power system is functioning as intended or not. The controller swiftly takes control steps to prevent harm to power system in case of a failure. Two control outputs & one input characterize the controller. Here is the outcome.1. It must be connected to main power supply and have an output.2, which must be connected to backup system. In the event of a power outage, output.1 will cut power to faulty section of the system.2 connects the secondary power source to main power source, which increases the dependability of the power system and guarantees that the load will always have power. In Figure 5, you can see the controller's flowchart.

III. Simulation Result:

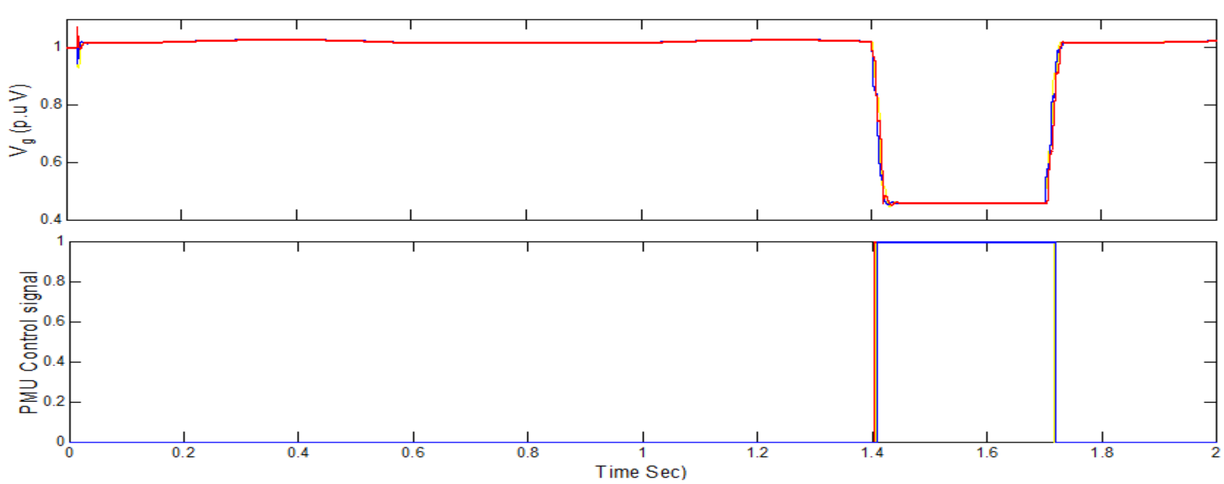

Figure 6 Grid side voltage of proposed system

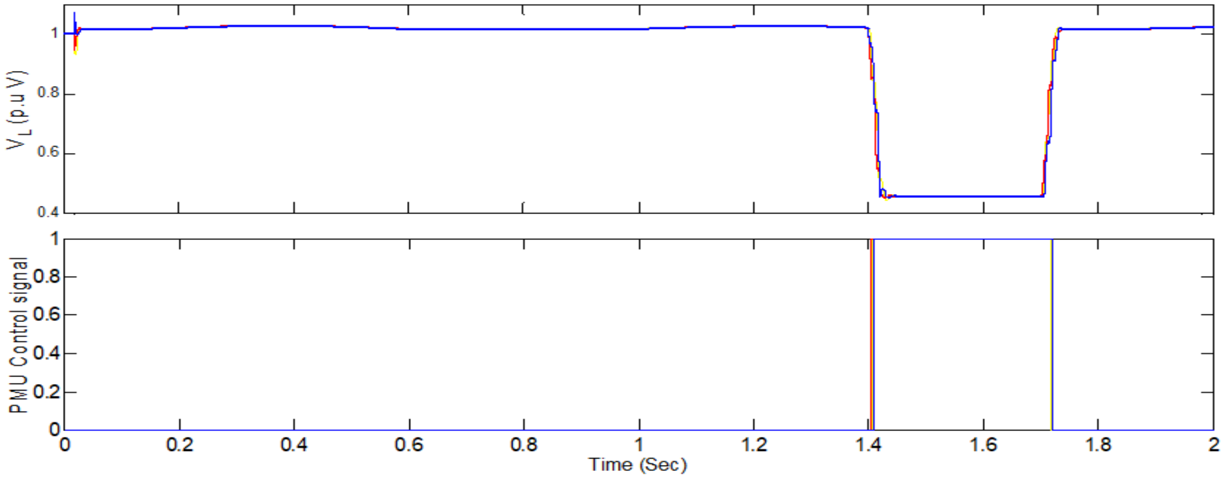

Figure 7 Load Voltage of proposed system

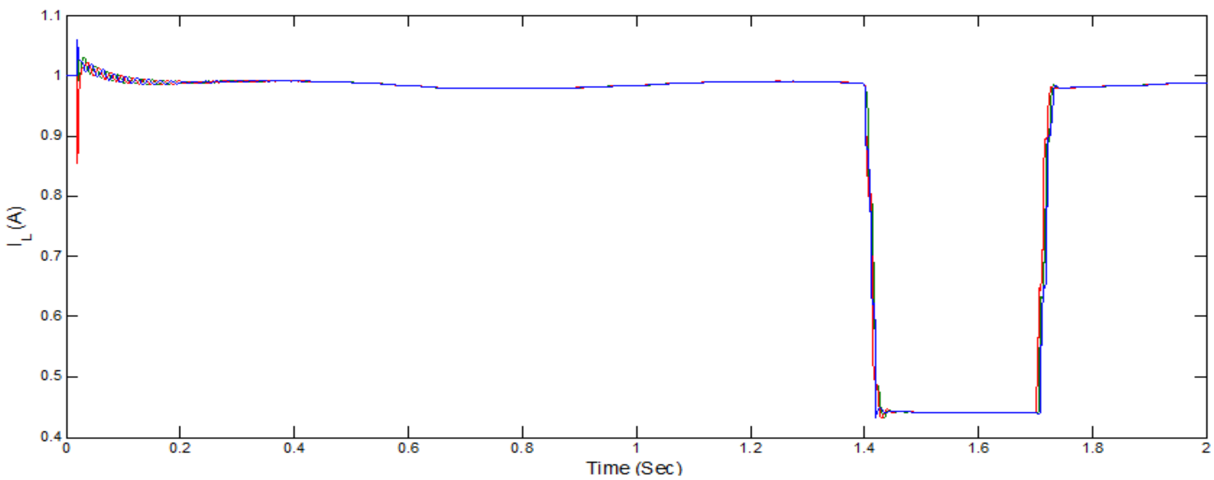

Figure 8 Load Current of proposed system

IV. Conclusion:

In grid-tied microgrids, where integration of renewable energy sources presents extra obstacles, the research found that PMUs are very effective for controlling, monitoring, and protecting power systems. In comparison to more traditional forms of security, the PMU model developed in Simulink outperforms the competition. The PMU's digital design enables real-time phasor data comparison and continuous monitoring, which greatly accelerates fault detection and reaction times. The PMU prevented possible blackouts and system damage by responding to a three-phase failure with a 0.1ms delay, compared to 35ms with conventional analogue techniques. Since renewable energy sources are inherently unstable, PMU's capacity to quickly identify problems in grid-connected microgrids is even further evidence of its significance in today's power systems. The importance of the PMU in improving the system's resilience, efficiency, and dependability has been shown by this study.

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