Real Time Monitoring and Analysis of Smart Micro-Grid using Phasor based Sensors

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ABSTRACT

Bidirectional power and energy flow between electrical energy consumers and the conventional grid has grown substantially with the development of nonconventional energy sources including solar, wind, and biomass. It enables buyers to do a lot more than use the energy it produces, but it also makes it possible to send any surplus back into the grid. Micro-Grids are intelligent, fast, and efficient as a result of the development of smart sensors and other software tools in engineering applications, which allow for real-time monitoring and analysis of electrical parameters and the prediction of future events. To successfully apply PMUs in micro-grid dynamic security monitoring and control, one must first understand the dynamic behavior of these devices. Acquiring data in real time, monitoring it, and exercising control over its properties at the load side are all tough tasks for the researchers working on the reliable operation of micro grids. Phasor Measurement Units (PMUs), which are some of the new technologies for phasor measurements, are equipped with sophisticated signal processing algorithms. Some of the popular algorithms are non-recursive DFT and Recursive DFT. These PMUs are used for real-time measurements of the parameters of Micro-grids. In this study, an experiment was carried out by creating a micro-grid setup with several AC loads and they all were connected to PMU. The real time data was collected and analyzed with the help of PCM600 platform. The data collected was time synchronized with GPS and hence proved more accurate as compared to other technologies.

Keywords— Phasor, Phasor measurement Unit, DFT, Micro-Grid

I. INTRODUCTION

The problems of power outages and "load shedding" are more prominent in modern society. These can be avoided with proper monitoring and control of the existing power grid. A PMU can be used to keep an eye on the power grid and make sure it's running well. [1] Through the network, PMU readings can be transmitted. Reliable, high-quality power at a reasonable price [2] is the result of a modernized power grid that uses digital processing and communication technology to detect changes in the network at a local level and respond appropriately. With better detection thanks to a state estimation-based approach to problem diagnosis, the system can repair itself. Despite their initial design for use in power transmission systems, PMUs are finding a wide range of new applications in power distribution systems (DNs). True, there is a lot of effort being put in by scientists to study and build PMUs that are appropriate for a wide range of frameworks, including those typically found in distribution grids. Dealing with significant disturbances that produce widespread blackouts in the power system network is essential, and phasor measurements are a key tool for doing so [3]. PMUs are vital for evaluating the power system's state and for protecting and controlling networks. Recent years have seen a flurry of research effort focused on the specification and characterization of algorithms for PMU measurements. Algorithm performance under the test conditions stated in [1] has been carefully studied, and a variety of signal processing approaches have been used (for a review, see [5]).

As an added bonus, the IEEE C37.242-2013 [4] standard has been released to facilitate PMU calibration, installation, and testing. In particular, the manual specifies, in great detail, the actions to take in order to conduct the tests. There are just a handful of articles in the literature [5–7] that discuss the difficulties encountered while taking PMU readings with unbalanced three-phase input voltages or currents. Unbalanced or even single-phase loads and generators are a common operating condition for DNs [8], hence PMUs intended for this application should be built and defined with unbalance taken into account. Because the standard [13] mandates a single frequency and ROCOF output for each three-phase set of input numbers, this is a topic that can be especially relevant for frequency and ROCOF measurements.

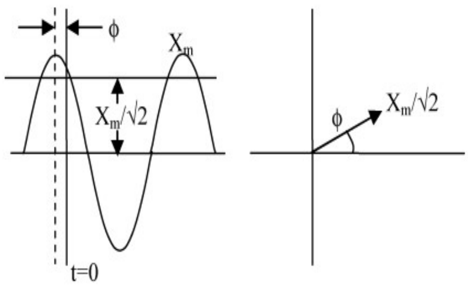
For instance, the standard's Annex C recommends using discrete derivatives of the phase-angle to compute such measures from the positive sequence synchrophasor measurement. Due to this, estimates may be impacted by a negative sequence component. Following the development of the PMU by Arun G. Phadke and J. S. Thorp [2] in 1988, real-time measurements of phasor currents have progressed toward the determination of absolute time references provided by GPS [3].

Even if SCADA was used at first, it is no longer widely used. Still, there were some drawbacks, such as the fact that the measurements weren't time synchronized, the fact that all we get are magnitude and phase angle measurements of the signal, and the fact that we can only monitor and manage things on a local level. The PMU is an innovative technological advancement that addresses these problems. PMUs supply accurate measurements of phasor magnitude and phase angle that are synced with time. When the sampling rate is increased to between 10 and 60 samples per second, the observability changes rapidly. [9] A huge region is under their constant surveillance. Synchronized data analysis can be used for grid monitoring, allowing event sequences to be deduced. The PMUs are GPS-synchronized time keepers that are spread out across the WAMS system.

A PMU can perform a variety of tasks. These instruments offer phasor parameters including magnitude and phase angle in real time. The frequency can also be estimated using PMUs. There is an examination of the electrical components such as the circuit breakers, switches, and other parts. Performance monitoring units (PMUs) are also used to track how well other grid-connected gadgets are functioning.

Blockages in the transmission of data [4] and power outages/load shedding can be avoided by constant grid monitoring. A PMU's fundamental block diagram can be shown in Figure 1 [5]. Multiple methods exist for calculating phasor parameter estimates. Algorithms based on the discrete-Fourier transform (DFT), sliding DFT algorithms, and recursive methods are just a few examples [6]-[8]. Sine wave harmonics are utilized in voltage and current signal analysis. In order to sample them, we employ the sampling frequency. Using the right DFT method, we may get an approximation for the phasor parameters.

Keeping the grid's data in sync is crucial for ensuring reliable power delivery across a wide area. There has been an increase in the use of PMUs and other monitoring devices for electrical power grids in recent years [15–18]. Their ability to detect voltage and current amplitudes, phase angles, frequency, and the Rate of Change in Frequency (ROCOF) in a synchronized fashion makes them useful for wide-area measuring systems. Furthermore, future scenarios of the Smart Grid paradigm are expected to still rely heavily on PMUs due to their high measurement reporting rate. The PDC relies on precise data collected from PMUs, which are present in every electricity grid.



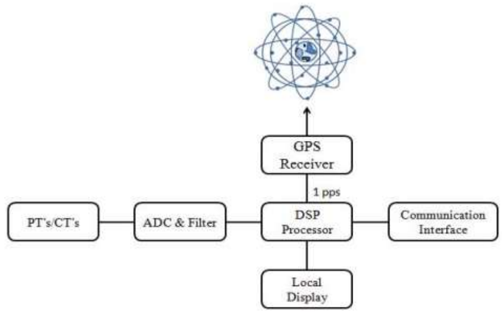


Figure 1(a): Phasor representation of a sinusoidal Signal [3]   Figure 1(b): The block diagram of PMU [1]

With the advent of the micro-grid, renewable energy sources are gaining popularity. Power for these micro-grids comes from their own mini-grids. It relies heavily on decentralized, locally controlled energy sources that can also provide power to nearby homes and businesses. Both grid-connected and island modes are available for use with Micro-grid.

II. METHODOLOGY

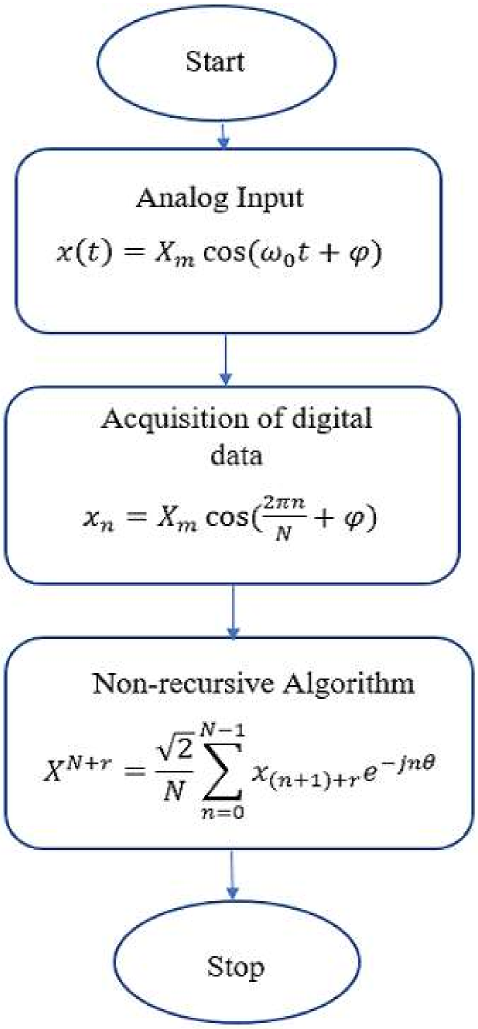


Figure 2. Flow chart for phasor calculation algorithm of Micro-grid parameters

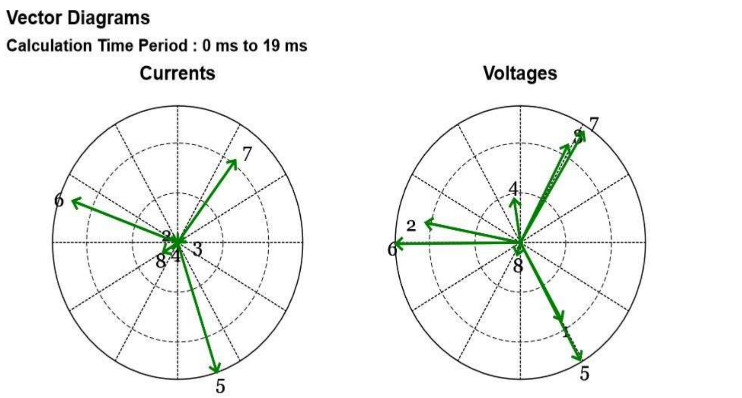
A non-recursive DFT technique for predicting voltage and current has been developed using notions from phasor-based measurement. In order to identify the most recent changes in phasor estimates in the first window, non-recursive DFT is recommended because to its numerical stability, lack of reliance on out-of-date phasors, and emphasis on forward progress. Sampled information from an analogue signal is required for phasor computation. Each cycle brings a new phase angle but keeps the same magnitude. Phase estimation's control flow is depicted in Fig. 2. Here, we take an analogue input signal, denoted x(t), and transform it into a digital output signal, denoted xn. There are N samples taken every cycle. Here, n ranges from 0 to N minus 1, while r can take on any of the values from 1 to 9. Since computing the phasor is an iterative process, it must be done again for each new data window of a predetermined duration as new samples are collected and older ones are discarded. The algorithm along with GPS enabled technology enables the Micro-Grid owners to accurately monitor and analyze the parameters in real time which enhances situational awareness.

III. EXPERIMENTAL PROCEDURE

Figure 3. Micro-grid prototype with various loads connected to the PMU

As illustrated in Fig.3, the load for Bay 1 is a three-phase induction motor with a capacity of 3.5 horsepower that is provided by a three-phase autotransformer rated at 8.5 kVA. Similarly, a three-phase star linked 440 V Rheostat is utilized as the load that is supplied by a three-phase autotransformer that is 8.5 KVA for Bay 2, as illustrated in Fig 3., both of which exhibit Bays that should have the loads attached to them.

IV. RESULTS AND OBSERVATIONS



No.	Name	RMS	Angle	No.	Name	RMS	Angle
1	BAY01 IL1	0.212(A)	257.1°	1	BAY2 UL1	42.095(V)	300.3°
2	BAY01 IL2	0.239(A)	137.6°	2	BAY2 UL2	49.473(V)	169.1°
3	BAY01 IL3	0.203(A)	5.7°	3	BAY2 UL3	51.943(V)	62.0°
4	BAY01 IN	0.042(A)	228.1°	4	BAY2 ULN	20.771(V)	98.9°
5	BAY02 IL1	29.449(A)	288.3°	5	BAY1 UL1	63.001(V)	299.0°
6	BAY02 IL2	26.36(A)	160.1°	6	BAY1 UL2	63.991(V)	180.5°
7	BAY02 IL3	22.359(A)	52.5°	7	BAY1 UL3	61.152(V)	58.1°
8	BAY02 IN	4.045(A)	212.0°	8	BAY1 UN	5.958(V)	254.0°

Figure 4(a). Phasor data obtained due to connection of several loads in the Micro-Grid

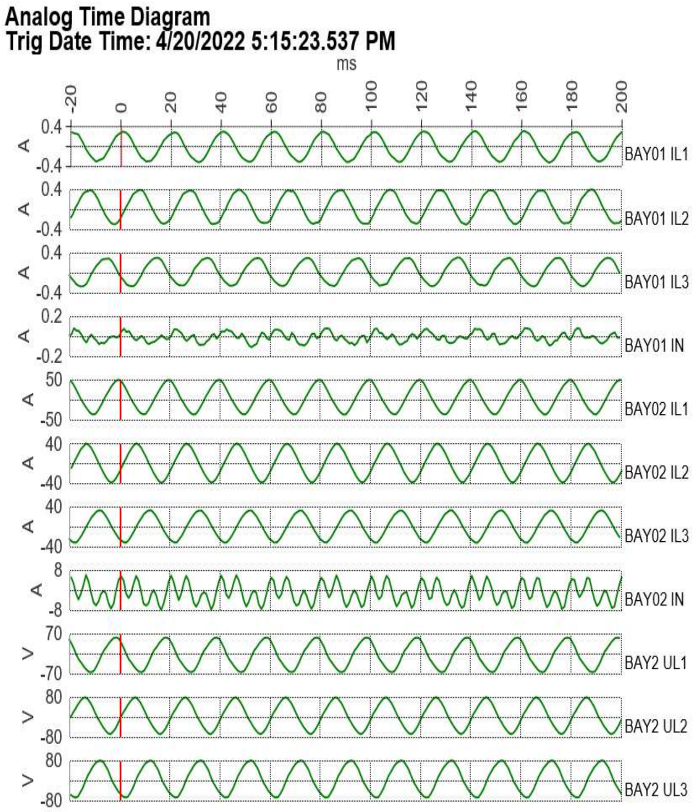


Figure 4(b). Current Waveforms obtained due to three phase induction motor and three phase rheostat load in Micro-Grid

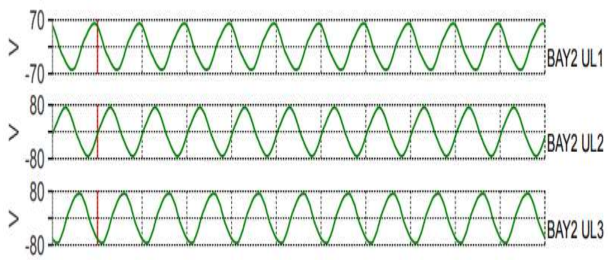


Figure 4(c). Voltage Waveforms obtained due to Rheostat load in Micro-Grid

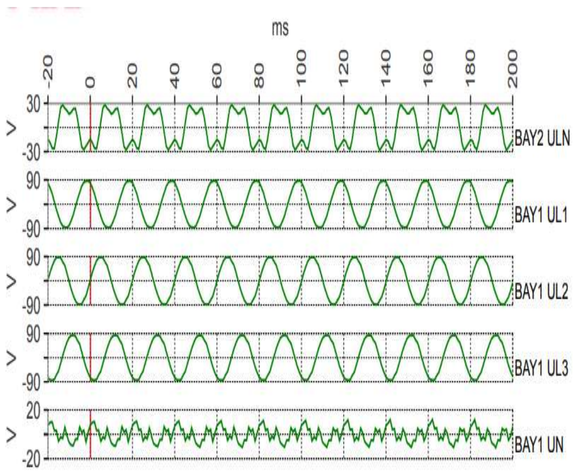


Figure 4(d). Voltage Waveforms obtained due to 3 phase induction motor load in Micro-Grid.

IED Short disturbance report data and recording time are displayed in Fig 4(a). We can perceive that there are discrepancies in the phase current, phase voltage magnitude, and phase angle of the loads connected to Bays 1 and 2 based on the phasor data collected from the PMU. Phase currents for an induction motor are denoted by IL1, IL2, and IL3, while the neutral current is denoted as Bay01IN. The Rheostat load's phase currents are denoted by IL1, IL2, and IL3, while the neutral current is denoted by IN. The induction motor load consists of three volts: phase voltages Bay1 UL1, phase voltages Bay1 UL2, and neutral voltage Bay1UN. Phase voltages are shown by Bay2 UL1, UL2, and UL3, while neutral voltage is indicated by Bay2 UN. When looking at the voltage and current waveforms obtained from the load side (Fig 4(b), 4(c), and 4(d), respectively), it is easy to see that there are some disturbances existing in the phases based on the magnitudes and angles of the neutral point voltages and currents which are time synchronized through GPS.

V. CONCLUSION AND FUTURE SCOPE

PCM600 software has been used for testing and verification of the phasor estimation technology. Phasor data in real time has been recorded using Phasor measuring unit (PMU). When compared to other technologies, the dynamic and time-stamped phasor information (both magnitude and phase angle) provided by the PCM600 platform-compatible phasor measurement unit (PMU) allows for prompt action to be taken against clearing the faults on the load side. PMUs have great potential as Micro-grid analyzers, and that potential is only growing. Time-synchronized detection of various short- and open-circuit defects in Micro-grid loads powered by renewable energy sources enables contingency and transient analysis. Prediction of various contingencies could be accomplished with the help of real time data (obtained from PMUs) and novel machine learning tools.

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