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ResearchArticle

Detection and Mitigation of Power Quality Problems based on Phasor Measurment Units and Renewable Energy Systems#

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Abstract: Power quality problems constitute a headache for power systems engineers. The detection and mitigation of these problems increases the reliability and availability of the system. Phasor measurement units are devices introduced to assess the health of the power system. Furthermore, renewable energies turn out to be not only sources of energy but can be used as medicines to the power quality problems as well. In this work, phasor measurement units are employed to monitor the power system and renewable energy systems are used to mitigate the power quality problems occuring in the grid. A controller must detect, classify and issue a control signal to the renewable energy system to compensate and/or attenuate any deviation in the system performance as compared to the healthy situation

1. Introduction

Nowadays, PV and wind energy systems are most widely used as standalone energizing units and their integration with the grid also increases. In addition to the benefits of voltage support, diversification of power sources, reduction in transmission and distribution losses and improved reliability, power quality problems due to both PV and wind energy systems are also of budding concern [1].

Renewable energy sources (RES) integrated at distribution level is termed as distributed generation (DG). The utility is concerned due to the high penetration level of intermittent RES in distribution systems as it may pose a threat to network in terms of stability, voltage regulation and power-quality (PQ) issues [2-8].

Phasor measurement units (PMU) are power system devices that provide synchronized measurements of real-time phasors of voltages and currents. Monitoring real-time angle differences has many potential applications in power systems. Simply placing PMUs in various substations can help prevent blackouts by real-time monitoring by system operators. System operators can be warned of potential problems more quickly during critical situations, where seconds can make all the difference in detecting and dealing with dangerous cascading events. Operators neighboring a highly stressed system would also be more alert to potential dangers originating outside of their control area. If a cascading problem were to arise, PMUs would be very useful in determining where and how to perform system separation to limit the effect of the system disturbance [9].

This work demonstrates; through LABVIEW software simulations, the deployment of Phasor measurement units to collect information about the power system so that power quality problems are cured once they are detected.

2. PMU Overview & History

The phasor measurement unit (PMU) has revolutionized the way electric power systems are monitored and controlled. This device has the ability to measure current, voltage, and calculate the angle between the two. Phase angles from buses around the system can then be calculated in real time. This is possible because of two important advantages over traditional meters – time stamping and synchronization. The algorithms behind phasor measurement date back to the development of symmetrical Component Distance Relays (SCDR) in the 1970's. The major breakthrough of SCDR was its ability to calculate symmetric positive sequence voltage and current using a recursive Discrete Fourier Transform. The sampling process is described in Figure 1. The recursive algorithm continually updates the sample data array by including the newest sample and removing the oldest sample to produce a constant phasor [9].

$$X = X_r + jX_i = \frac{\sqrt{2}}{N}\sum_{k=1}^{N}\left(x_k \cos\frac{2\pi k}{N} - j x_k \cos\frac{2\pi k}{N}\right)$$

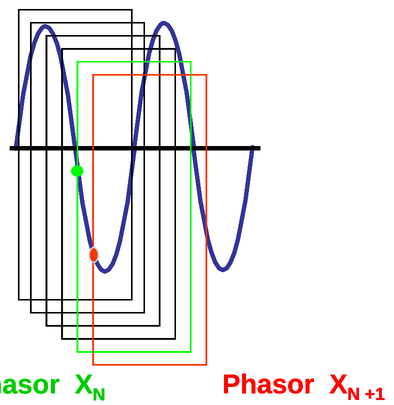

Figure.1 *Sampling Process of first PMU algorithms*

The advent of the Global Positioning System (GPS) in the 1980's was the second breakthrough that enabled the modern PMU. Researchers at Virginia Tech's Power Systems Laboratory in the mid 1980's were able to use the pulses from the GPS satellites to synchronize and time stamp the phasor data with an accuracy of 1.0 μs. With the addition of effective communication and data collection systems, voltage and current phasors from different locations could be compared in real-time. Figure. 2 shows the functional block diagram of a PMU [9].

PMUs have come out of their academic infancy *with* commercial viability. They are now commercially produced by all major IED providers in the power industry, including ABB, GE, Siemens, Arbiter, UCS, Macrodyne, SEL, and Seifang.

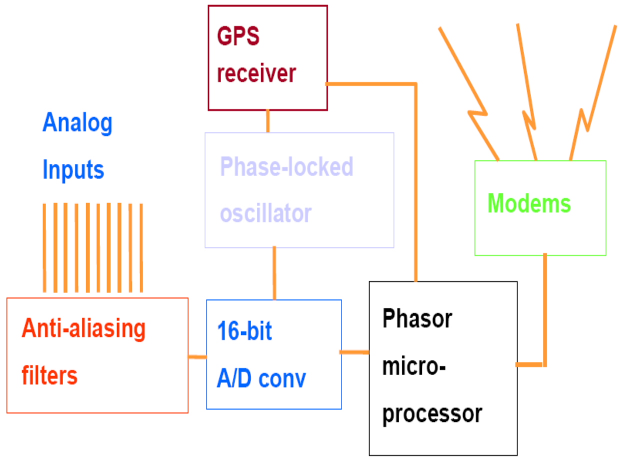

Figure. 2 *PMU Functional Block Diagram*

To aid the maturing of the industry, an important standard has been developed by the IEEE. The IEEE SYNCHROPHASOR [14] standard, c37.118-2005, was developed from an earlier version, the IEEE 1344-1995 [9].
It ensures PMUs from different manufacturers operate well together. Initial cost of PMUs in the early 90's was about $20k. The price has since dropped to $3k for the simplest units. However, installation costs remain high, between $10k-50k depending on the utility and location. [9]

3. System Description and Simulation

The block diagram show in Figure.3 illustrates the principle of operation of the proposed PMU-based power quality detection and correction system.

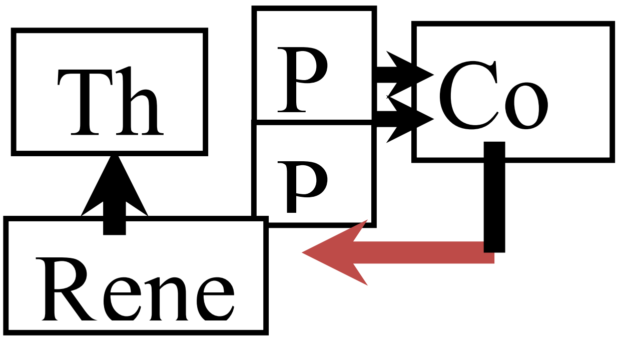

Figure. 3 *Block diagram of the proposed system*

The Phasor measurement units sence the state of the power system and transmit synchronized data to the control center. The data is assessed and compared against the healthy state data. If a power quality problem is detected using the comparison with the normal operation state, the data is passed through a classifier that is able to indicate the nature of the problem so that an appropriate action is taken [10].

In this work, the analysis and simulations were limited to the overvoltage and undervoltage cases where the renewable energy block system either compensates the missing energy or intakes the excess energy and uses it for battery charging. The following figure shows the Labview front panel of the simulated system.

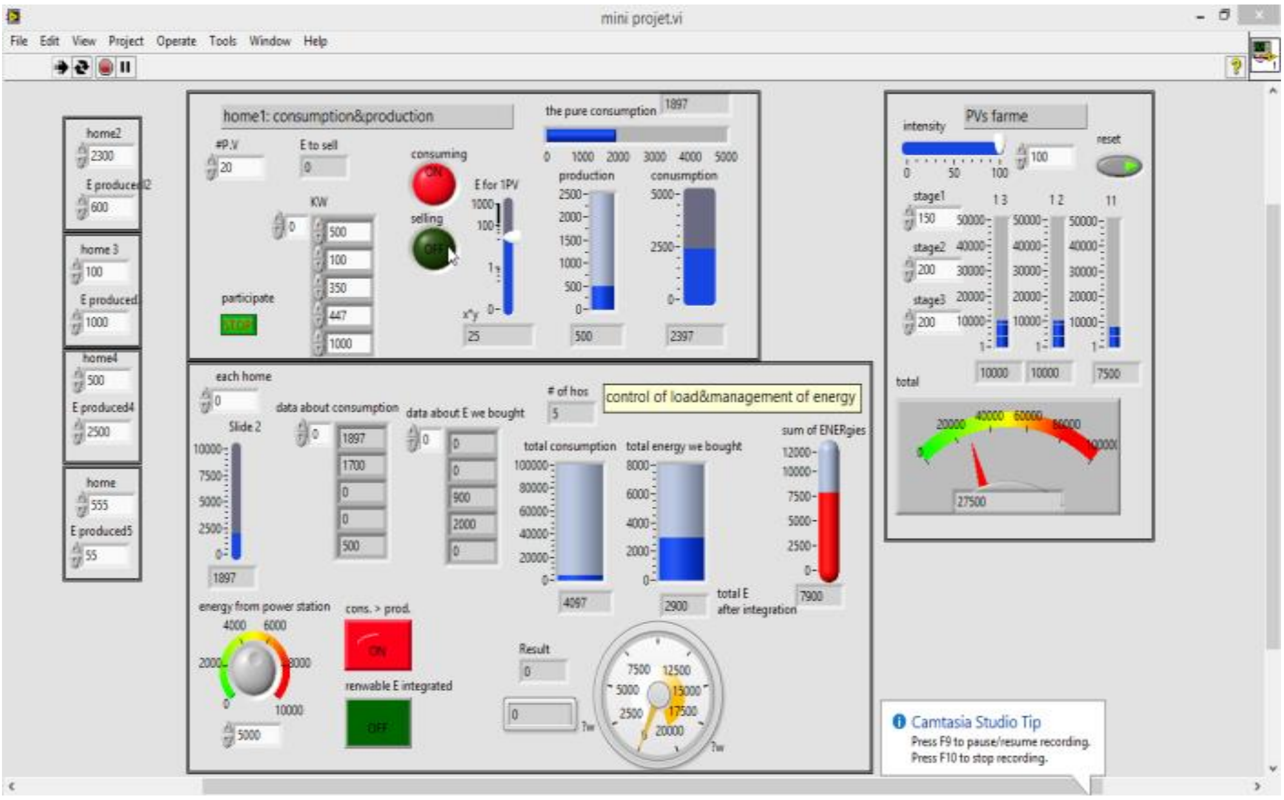

Figure. 4 *The simulated system*

The system is made up of a renewable energy block where the state of the batteries is displayed at the control center. A system of LEDs is used as indications on the state of the system. In case a problem is detected, a red LED turns on and the renewable energy block is activated in either the generating state in case an undervoltage is sensed or in the battery charging state in case an excess of power is detected.

4. Conclusions

Power quality problems constitute a headache to power system engineers. The detection, classification and correction of these problems are necessary to keep the system healthy and avoid system shut down and equipment deterioration. Renewable energies constitute a solution that may be adequate to cure these problems. On the other hand, Phasor measurement units have modernized power systems and introduced the technological advances in all aspects of this field. This work is a start up to demonstrate how PMUs can be used in tandem with renewable energies to deal with power quality problems. This work has been limited to overvoltage and undervoltage problems. It is envisaged to enhance the system by considering more power quality problems such as voltage unbalance.

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