VOL. 10, NO. 5, March 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

DEVELOPMENT OF REAL TIME MONITORING SYSTEM UNDER SMART GRID ENVIRONMENT

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ABSTRACT

Real time monitoring of power system is essential for its continuous and reliable operation. This paper presents a low cost, low power consuming system that can be used for quick and accurate power system parameter monitoring under smart grid environment. The designed system will continuously measures, processes and display the power system parameters like voltage, current, phasor difference, power factor, power consumption using ultra low power microcontroller. Measurement of power system parameters of resistive and inductive loads are monitored using PIC16F877A microcontroller. Sampling theorem is used to calculate the phase difference between voltage and current utilizing zero crossing detectors. Simulations of the voltage, current, phasor difference were done using NI Multisim software.

Keywords: smart grid, power system parameters, NI multisim, sampling theorem, zero crossing.

1. INTRODUCTION

India's electrical infrastructure is considered untrustworthy though it is the world's third largest electricity producer and consumer. The northern grid collapsed in 2001 and most of northern and eastern India peoples were affected severely by the power outages on July 30 and 31, 2012. The constant growth of the electrical network and the need for stringent security and reliability levels of the power system infrastructures lead to the development of smart electrical grid. Real time monitoring of the power system is an important aspect of Smart grid system. It involves measuring the voltage and current waveforms in real time and the detection of the power system disturbances that occur during the operating condition [1]. The AMR system proposed in [2] consists of ARM cortex, RF transmitter, receiver with current, voltage sensors which incurs more space and cost. This paper describes the development of real time power system parameters monitoring system based on PIC16F877 Controller and zero crossing detectors. The purpose of real time monitoring system is to improve the declining meter efficiency in meter readings hence this proposed system components are simple and low cost.

2. SMART GRID INFRASTRUCTURE AND MOTIVATION

Smart Grid is one of the leading technology that incorporates information and communications technology into every feature of electricity generation, distribution and consumption in order to minimize environmental impact. It will link power plant to the end consumer in homes, business and industries to bring energy efficiency and reliability. A Smart Grid consists of the following components: a) demand side management, generation side management and transmission and distribution grid management. Figure-1 shows the basic components of Smart grid [6]. AMR system is used to collect the real-time power information of terminal users, achieve the goal of orderly power usage and monitoring. Advanced Metering Infrastructure (AMI) is a core infrastructure for the implementation of Smart Grid system [3]. It is used to gather and utilize metered data in more intelligent and cost-effective manner. AMI provides the promising capability of two way communications where data can be sent to a meter and/or customer as well as retrieve the data from it [4].

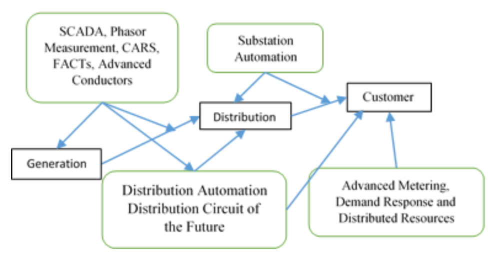

Figure-1. Major components of smart grid.

Smart grid provides the choices to all the customers to decide their time and amount of power consumption based upon the tariff at specific time period. [5]. Because of the weakest electric grid infrastructure, India loses huge amount for the electricity sold. Smart Energy management is the only option to resolve this vital issue. This provides unique opportunity for building the real time monitoring system. The features of smart grid are shown in Figure-2 [7].

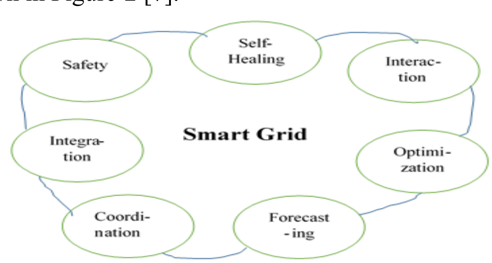

Figure-2. Features of smart grid.

3. PROPOSED SYSTEM

The block diagram representation of the proposed monitoring system is shown in Figure-3. CT and PT are used to senses the current and voltage of the load. The rectifier circuit (OPAMP+diode) converts AC to DC. Zero crossing detector circuit detects the voltage zero crossing point and current zero crossing point. After the zero crossing of voltage and current signals, square-wave which created in between the zero crossing of voltage and current are given to PIC microcontroller. Rectified DC voltage and current are read by the PIC microcontroller using ADC ports. Power factor is measured using the microcontroller by manipulating the acquired signals from voltage and current sensing circuit. Real power is calculated as

$$P = VI Cos\,\phi \qquad (1)$$

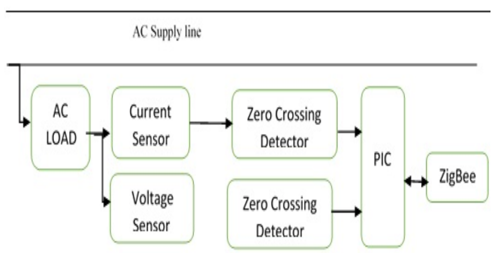

Figure-3. Electrical parameter monitoring system.

a) Design details

Micro C based software is developed to calculate voltage, current, phase angle, power factor, energy and tariff.

b) Functioning of the monitoring system

Sampling of the current and voltage can be done for functions changing in space, time, or any other dimension, and similar results are obtained in two or more dimensions. Consider f (t) be a continuous function of the sample, for which the function that differs with time. Sampling will be achieved by measuring the value of the continuous function for every T seconds

$f(nT)$ for integer values of n (2)

Let f_s be the sampling frequency or sampling rate. It is the average number of samples obtained per second.

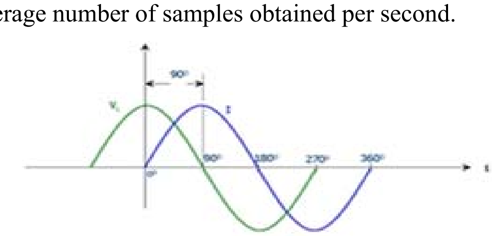

Figure-4. Phase angle detection.

The calculations are completed for the ideal sinusoidal voltage in programming the microcontroller. T is the time period of the signal. Total time period of sinusoidal divided into microseconds. One part of entire sinusoidal signal's time interval is calculated and equal to One degree. At 50Hz a full cycle (360degrees) takes 20ms, so a half cycle takes 10ms. 10ms into 180 time slots of 180 samples, then each time slot equals 1 degree, so 10/180ms = 55.5µs per 1 degree. The measurement limits of the phase angle are between 0 to 90 degree.

4. SIMULATION RESULT

In this section, simulation details are presented for resistive and inductive load for power system parameter monitoring using the proposed approach. The power system parameters like voltage, currrent, difference were simulated using Multisim software.

The current signal is obtained from the secondary of 10:1 current transformer whose primary is connected in series with load. This CT is also used to measure zero crossing of current signal to obtain the voltage parameter. The microcontroller is connected to the secondary ofa 20:1 potential transformer for which the primary is connected in parallel to the load circuit. Zero crossing of voltage signal is measured from the secondary of PT. LS7408 is used to compare the output of zero crossing detectors which are in turn connected with CT and PT. Figure-5 shows the sensing circuit developed using NI Multisim software.

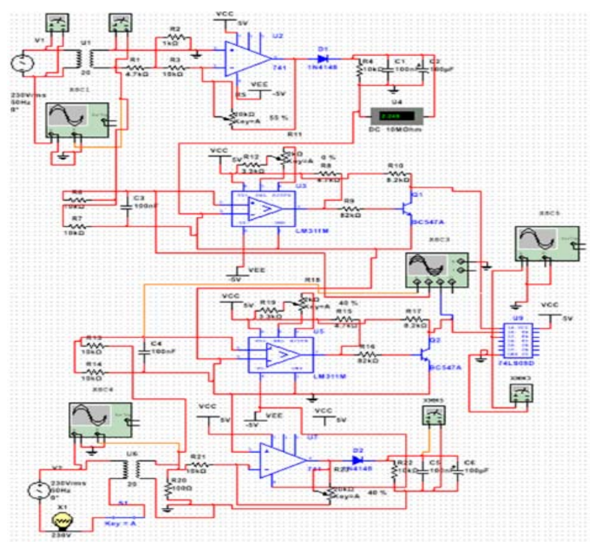

Figure-5. Sensing circuit developed using multisim.

Figure-6 shows the four channel output to calculate the phase angle by measuring zero crossing between voltage and current of the two LM311 (zero crossing detector), one of them is used for current signal and other one is used for the zero crossing detection of voltage and current. Square pulses are generated in between the crossing intervals of voltage and current.

VOL. 10, NO. 5, March 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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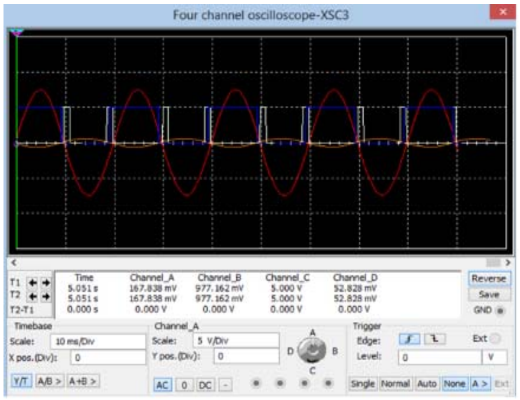

Figure-6. Simulation result for phasor difference.

5. HARDWARE IMPLEMENTATION

The hardware details are explained in this section.Figure-7 shows a resistive (R) and inductive load (L) connected to the power supply. PT is connected in parallel to the load. CT is connected in series with the load. From the secondary of CT and PT signals were obtained and fed to the microcontroller (PIC 16F877A). Received signals were converted to digital form by using internal ADC. Zero crossing signals were detected using dedicated GPIO. The parameters are calculated and displayed.

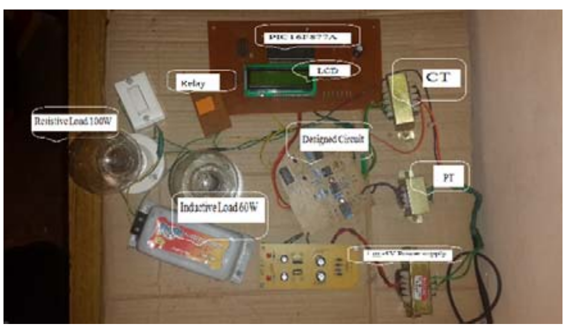

Figure-7. Photograph of the developed hardware.

Figure-8 shows the measured electrical parameter in the LCD Display when only resistive load is connected and display unit shows 101W as reading.

Figure-8. Meter readings under resistive load condition.

Figure-9. Meter readings under Inductive and resistive load.

Figure-9 shows the measured electrical parameter in the LCD display when there are inductive and resistive loads connected. It shows 161W as the reading of loads. Here 100W is consumed by resistive load and 60W is consumed by inductive load.

Phase angle measurements with of resistive and inductive loads were done and the results are displayed. One can clearly see a gradual raise in the phase angle and reduction in power factor, when inductive load was added.

Table-1. Comparison between resistive and induction load results.

Parameters	Resistive load	Resistive & Inductive loads
Voltage (V)	230V	233V
Current (I)	0.44A	0.71A
Phase angle (Φ)	8°	31°
Power factor (Cos Φ)	0.990	0.857
Power (Watts)	101W	161W

The comparison of various parameters available in the Table-1 shows that, the developed hardware is well suited for the smart grid environment implementation in domestic side.

6. CONCLUSIONS AND FUTURE WORK

The reliability of the smart grid depends on the embedded intelligent devices used. The proposed and demonstrated work explains the method of sensing the voltage, current, phase angle consumed by the loads with the help of voltage and current sensing circuit. The voltage and current, square pulse generated using zero crossing detectors are sent to the PIC micro controller. The measured voltage, current, real power, power factor, phase angle, power consumptions of the load are viewed through LCD display. This provide the end user, real time monitoring capability, thus giving a choice to take decision whether to consume power at a given point of time. This real time information is vital in a smart grid environment, where electricity prices vary dynamically according to the demand.

The future work of this project is to develop PIC microcontroller based smart device that measures and display energy consumption for major home appliance and also tariff details. Interfacing of PIC microcontroller with Raspberry Pi using wireless communication could be done. Once the data's received from PIC, Raspberry Pi can process the data and it will be uploaded into web server. Based on the data provided in real time one can control the appliances virtually from anywhere in the world using internet.

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