An Embedded Application: Electric Power Quality Monitoring System

Dinesh G. Badshe and S. V. Pattalwar

Abstract- **Poor power quality has a tremendous impact on end-users equipments and on high tech manufacturing processes, is a major cause of unscheduled downtime. Power quality and reliability take on many different facets with issues of voltage dips, outages, grounding, noise, harmonics, transients and many more, all contributing to the problem and the confusions [1]. Previously equipment was generally simpler and therefore more robust and insensitive to minor variations in supply voltage. But now equipments, which are used, are more sensitive to the power quality. If poor power quality supply is feed to such equipments it may result in the misoperation or damage. There is an increase in concern among electric consumers about the quality of power they are receiving. It is, therefore, essential to monitor power quality to check the quality of power supplied and know how the loads affect the power quality of the system.**

The advent in the IC technology has brought revolution in the field of processors and the controllers. So a microcontroller with advanced features can be used for a proposed power quality monitoring system.

This paper proposes a low cost, low power consuming microcontroller based system, which continuously evaluates the performance without interfering with it, and finally displays and record the power quality parameters of the power system.

Index Terms- **Electric power quality, power quality indices, monitoring, MSP430, UART, sensors, C language, ALP, LINUX, GCC**

I. INTRODUCTION

ELECTRIC power quality is an issue that is becoming increasingly important to electric consumers at all levels of usages. The issues are cost, losses, loss of life, metering errors, electromagnetic compatibility, proper services to the load etc.

The increasing application of electronic equipment that can cause electromagnetic disturbances or that can be sensitive to this phenomenon has increased the interest in power quality in recent years. Therefore it is essential to monitor power quality of power supplied and analyze how loads affect power quality of the system. In this paper a microcontroller based low cost low power consuming power quality monitoring system is suggested which can be used by a common man interested in monitoring power quality. This paper highlights the need of power quality monitoring system, causes and impact of power quality and basic design aspect of the system. Also describes the main feature of microcontroller, which makes it suitable for electric power quality monitoring system.

Dinesh G. Badshe, P. G. Scholar, Dept. of Electronics and Telecomm., Prof. Ram Meghe Institute of Technology & Research, Badnera, Amravati, dinesh_badshe@rediffmail.com.

S. V. Pattalwar, Assistant Professor, Dept. of Electronics and Telecomm., Prof. Ram Meghe Institute of Technology & Research, Badnera, Dist. Amravati – 444701, shirishpattalwar@yahoo.com.

II. NEED OF POWER QUALITY MONITORING SYSTEM

There are many reasons to monitor power quality; the main reason is economic. Adverse effect like misoperation, process damage, disruption, equipment damage cost both time and money. Monitoring is important because it is often difficult to determine from the observal effects specified on costumer's equipment which electromagnetic phenomenon caused the electromagnetic disruption. Changes in important characteristics such as voltage imbalance, voltage regulation, harmonics or transients can be an indication of a problem that needs to be addressed and the monitoring system should be set up to alarm important changes in the system power quality.

III. CAUSES OF POWER QUALITY PROBLEMS

Following are the causes of the power quality problems:

A. Voltage Variation of Short Duration

They caused by fault conditions, energization of large loads, which require high starting currents or loose connections in wiring. Voltage sags, voltage swells and interruptions come under this category. Voltage sags are primarily caused by voltage depression due to large fault currents. Voltage swells can be due to temporary voltage rise on unfaulted phases during a single line to ground fault.

B. Voltage variation of Long Duration

They consist of undervoltages, overvoltages and sustained interruption and are normally caused by load variations on the system and switching operations. Overvoltage is the result of load switching off or energizing a capacitor bank. It may also be due to incorrect tap setting on transformers. Undervoltages can be caused due to a load switching on or a capacitor bank switching off [2]. Sustained interruptions may be due to load shedding or system faults.

C. Transients

The term transients normally used to refer to fast changes in the system voltage or current. Transients are broadly of two types: impulsive and oscillatory, depending upon characteristics. Impulsive transients are sudden, non-power frequency phenomenon found in steady state condition of voltage, current or both (unidirectional in polarity), is caused due to lightening. Oscillatory transients are similar to the impulsive type but having its polarity changing rapidly. These are often the result of a local system response to a impulsive transient. Back-to-back capacitor energization and cable switching also result in oscillatory transients [2].

D. Waveform Distortions

1) Harmonics:

Harmonic distortion of the voltage and current results from operation of nonlinear loads and devices on the power system [3]. Typical sources of harmonics in power network are variable speed drives, arc furnaces, rectifiers for direct current power supplies and switching mode power supplies. Interharmonics are caused mainly due to frequency converters, cycloconverters, induction motors and arcing devices [4], [5].

2) Notching:

It is caused by the normal operation of power electronic devices when current is commuted from one phase to another. They are typically present in the waveform during SCR commutation or at the time when one phase SCR is being turned off and the next one turned on [6].

3) Noise:

Power electronic devices, control circuits, arcing equipments and switching mode power supplies mainly cause noise [3].

4) Flickers:

They are caused by loads, which can exhibit continuous rapid variations in the load current magnitude (e.g. in ac arc furnace), which in turns causes voltage variations [4].

5) DC Offset:

This can occur as a result of geomagnetic disturbance or due to effect of half-wave rectification [4].

E. Voltage Imbalance

It is caused by asymmetry in the supply networks and the connection of unbalanced (typically single phase) loads. The primary source of voltage imbalance less than two percent is single-phase loads on a three-phase circuit. They can also be result of blown fuses in one phase of a three-phase capacitor bank [4].

F. Frequency Deviation

If there is change in dynamic balance between load and generation, slight variations in frequency occur. The size of the frequency shift and its duration depends on the load characteristics and the response of the generation control system to load changes. Higher frequency variations can be due to block of load being disconnected or a large source of generation going offline or it maybe due to local generation.

It is commonly reported at power quality conferences that most of all the power quality problems reported by customers are related to wiring and grounding problems within a facility [4]. Simply tightening a loose connection or replacing a corroded conductor solves many power quality problems.

IV. IMPACT OF POOR POWER QUALITY

As long as voltage deviations are within the specified range there is no concern. However, once the limits are surpassed, many undesirable effects occur which pose to be of severe consequences. Machine process / downtime, product quality and repair costs contribute to making these types of problems costly to the end user.

A. Voltage Dips

They are by far the dominant and most costly power quality phenomena around the world. Increased loading on the local network may cause voltage dip, which in turn can cause delaying of the motors to reach their rated speed [2]. A sudden voltage decrease may lead to dropouts of sensitive consumer's equipments [3].

B. Transients

They cause tripping, component failure, hardware reboot, software glitches, poor product quality [5]. It also leads to processing errors, computer lock-up, and degradation of electrical insulation, equipment damage [6].

C. Harmonics

They can cause overloading of rotating equipment, transformers and current carrying conductors that can deteriorate electrical system operation. They also cause audible interference with telephone systems, transformers and neutral conductor heating, leading to reduced equipment life span, video flutter, software glitches and power supply failure [3], [4], [6]. They affect on the energy efficiency of the system also.

D. Undervoltage

They may cause speed changes for induction machinery.

E. Voltage Imbalance

Even a low level of imbalance can cause significant power supply ripple and heating effects on the generation, transmission, and distribution system equipment [4]. In case of unbalanced voltages, the positive sequence component produces the wanted positive torque and the negative sequence component produces the undesired negative torque on a three-phase motor.

F. Frequency Variations

They affect the operation of rotating machines or processes that require their timing from the power frequency (e.g. clocks). Also, slight variations in frequency on an electrical system can cause severe damage to generator and turbine shafts due to subsequent large torques developed [2].

V. POWER QUALITY PARAMETERS AND INDICES

Power Quality parameters and indices provide a means of evaluating the performance of power system. The power quality parameters are the basic elements, which are always calculated for evaluating (in a general manner) the power system. However, power quality indices provide the information of the power system for specific interest.

A. Power Quality Parameters

The important Power Quality parameters for Voltage, Current, and Power are Instantaneous voltage, current; voltage and current spectrum; peak voltage and current; RMS voltage and current; Harmonic RMS voltage and current; Harmonic power spectrum; real, reactive and apparent power; power factor; Total Harmonic Distortion; Even Harmonic Distortion; Odd Harmonic Distortion; Displacement Factor; Supply frequency [8], [9].

B. Power Quality Indices

Important power quality indices for different cases are as follows:

1) RMS Variation Indices:

a) SARFI: System Average RMS Variation Frequency Index.
b) SMARFI: System Momentary Average RMS Variation Frequency Index
c) STARFI: System Temporary Average RMS Variation Frequency Index
d) SAUFI: System Average Under voltage Frequency Index
e) SASIFI: System Average Sustained Interruption Frequency Index and Voltage Distortion Index.

2) Steady State and Harmonic Indices:

a) SATHD*:* System Average Total Harmonic Distortion*.*
b) Unbalance Factor and K- factor.

3) Transient Indices:

a) SATMORIx = System Average Transient Magnitude Occurrence Rate Index peak [8], [9].

VI. HARDWARE DISCEREPTION OF POWER QUALITY MONITORING SYSTEM

To facilitate a common man who is interested in a power quality issues, a low cost power quality monitoring system is proposed in this paper as shown in block diagram of Fig. 1. Mainly it consists of a microcontroller to process the power quality data, sensor circuits to sense the supply voltages & currents and then attenuate them to the level suitable for the Analog to Digital Converter (ADC) resides inside the microcontroller, line driver and receiver to shift the voltage levels, a constant power supply to the chip and a Personal Computer to display results and interact with user.

The processor board having the MSP430F148 microcontroller and the UART interface for programming and communication with the serial port of the computer, the UART interface with the PC serial port for transmitting power quality data [10].

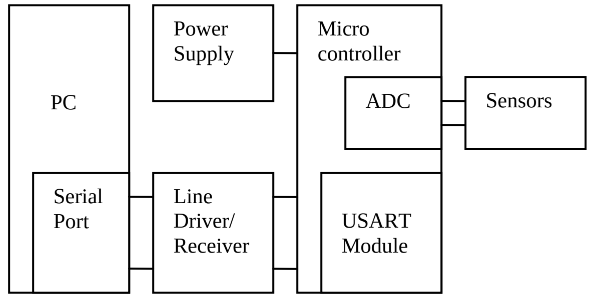

Fig. 1. Block Diagram of Power Quality Monitoring System

A. *A. Microcontroller*

The processor for the system is the ultra-low power Mixed Signal Microcontroller MSP430F148 from Texas Instruments. It has 16- bit RISC architecture, 125 ns instruction cycle, 12 bit Analog to Digital converter (with fast sampling and conversion), on chip comparator, USART, hardware multiplier, 48 KB Flash, 2KB RAM, two timers, 16 CPU registers and many other features including five power saving modes which make it suitable for being the processor for the power quality monitoring system [11], [12].

B. The UART Interface

For transmitting the processed power quality data from the microcontroller to the computer via serial port, the USART module resident in the microcontroller is used in asynchronous mode (i.e. UART mode) as shown in Fig. 2. In UART mode, the USART transmits and receive character at a bit rate asynchronous to another device. Timing of each character is based on the selected baud rate [12].

The serial port understands RS-232C standard, while microcontroller sends and receive low voltage CMOS level signals. So, a line driver/receiver IC MAX 3243 is required in between to convert CMOS levels to RS-232 levels and vice versa.

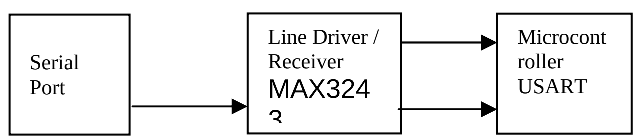

Fig. 2. Transceiver circuit for USART interface.

C. *Sensor Circuits*

There are two types of sensors required viz. voltage and current sensors which are designed for measuring line voltages up to 440V RMS and currents unto 6 Amperes.

1) Voltage Sensor:

These are consists of differential amplifiers and resistances which takes voltage from AC mains, then attenuated and level shifted appropriately to fit within range 0 - 3.3V.

2) Current Sensor:

Hall Effect sensors are used as a current sensor whose measured output is suitably amplified and level shifted and finally 3.3 Zener is provided.

VII. SYSTEM ARCHITECTURE

The prime concern in the system under study is to have enough processing power, should be easy to implement, flexible and cost effective and also should have good interface.

The dual processor architecture can be used which is based on a microcontroller interfaced to a personal computer [13]. The tasks like data acquisition, data processing and data transmission to PC are delegated to run on the optimized hardware of the microcontroller board, while final result calculations, display of result in data format and graphical format are run on personal computer. Attractive features of this architecture are the graphical user interface and storage facilities provided by personal computer.

VIII. CHOOSING A PROCESSOR FOR AN APPLICATION

Before selecting a processor the requirement of the design must be understood thoroughly. In light of these requirements various processors should be evaluated. The selecting criterion involves cost of processor, memory available, availability of software development tools, speed to meet the requirement of the application, easy availability etc.

IX. SOFTWARE DEVELOPMENT

For the purpose of enabling the microcontroller to process the sampled voltages and currents and convert them into power quality information and also for transmitting the data to computer, application software in assembly language (ALP) has been developed. This software is burnt into the flash memory of the microcontroller to enable its functioning as the Power Quality Monitoring System. For the computer to receive the data transmitted by the microcontroller at every fixed interval of time, from the serial port and display it in a user-friendly format, software in C language has been developed for the PC side. Using a HLL like C can cut development effort substantially. The baud rate and data format on both the sides (microcontroller and PC side) must match. The results are displayed in a graphical manner and also written into file format (same as whatever is displayed on screen).

The operating system used for this project is LINUX. The open source MSP430 GNU Cross Complier (GCC) for MSP430 provides the development environment such as drivers, assemblers, linkers, compilers, header files, device description files, debugger and graphical user's interface for seeing, controlling and configuring the microcontroller's functions and registers along with the facility of programming the flash memory with the application program.

X. TEST RESULTS

The Power Quality Monitoring System processes and displays the power quality parameters from the samples of voltage and current (as input) sensed by the ADC. A plot of instantaneous samples of line voltage, sampled by the system for specific samples if shown in Fig. 3.

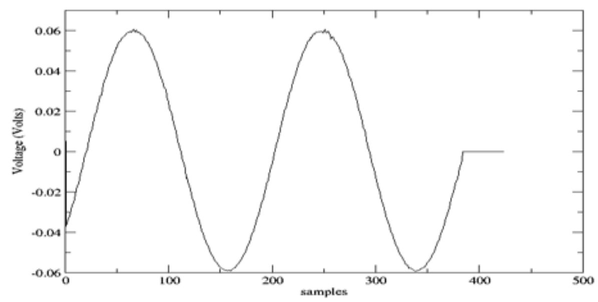

Fig. 3. Plot of the instantaneous voltage sampled by PQPM

The corresponding power quality parameters for the voltage waveform as computed and displayed by the PQMS are given below.

No. of samples – 423
Frequency of the signal – 50.03248
RMS value of the signal – 1.199282
Peak value of the signal – 1.711333
Energy of the Signal – 263.204773

XI. CONCLUSION

The system proposed in [13] is DSP based solution, which involves high cost and considerable high power consumption. Also it is a complex system to design and useful in high-end applications. But by taking into the consideration, the interest of a common man, this paper proposes a low cost system, which a common man can afford. It is also very easy to implement and portable unit.

The proposed system in [14] has been successfully made to measure and display power quality data for single phase low voltage power system The measurements are of appreciable accuracy, which is validated by comparing the results (of measurement) with standard measuring instruments.

In India less attention is paid towards the quality of the power. In this situation if users have such a low cost system, he himself can analyze a power quality and take necessary assistance from the utilities. The results generated by this system can be used to avoid the consequences of the poor power quality, so that process, equipment damages and misoperation can be eliminated.

XII. ACKNOWLEDGEMENT

The authors gratefully acknowledge the contributions of the Dr. V. T. Ingole, Principal, PRMIT, Badnera for his valuable guidance in the research work.

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XIV. BIOGRAPHIES

Dinesh G. Badshe is the P. G. Scholar at the Sant Gadgebaba Amravati University. He graduated from the Govt. Collage of Engineering, Amravati, Amravati University in 1997. He is persuing postgraduate degree in Prof. Ram Meghe Institute of Technology and Research, Badnera at Sant Gadgebaba Amravati University, Amravati, MS, India.

His employment experience includes the teaching at Mumbai University, MS, India and as a engineer in MSEDCL, Mumbai, MS, India.

S. V. Pattalwar has completed his graduation and post graduation from Amravati University, Amravati, MS, India.

His employment experience includes SES College of Engineering, Kopargaon in Pune University, Pune, MS, India and VYWS College of Engineering, Badnera, Amravati in Amravati University, MS, India. He is the member of ISTE, IE and IETE.