AC Over Voltage and Under Voltage Protection Using Arduino

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***Abstract* — In this paper, an experimental system based on Arduino Uno microcontroller board was developed for measuring electrical quantities and protecting overvoltage and undervoltage conditions in a single-phase power supply. The main components are described in detail, including the hardware and software to build the system in which an Arduino Uno platform is implemented as a vital microcontroller to read voltage and current measurement from a voltage sensor (ZMPT101B) and a current sensor (ACS712) respectively. In addition, the Arduino is also used to send all measurement to a PC through a serial port for monitoring the measured data graphically. The proposed method for designing the software uses the root mean square (RMS) method for measuring electrical quantities and then the RMS voltage measurement is compared with the minimum voltage and the maximum voltage to switch on or switch off the load. The monitoring GUI is designed with the use of the free and open-source Telemetry Viewer v0.5 software to monitor RMS voltage, RMS current, active power, and trip signal of the experimental system. The experimental results in this paper demonstrate that the system operated correctly.**

Keywords-experiment system; overvoltage; undervoltage; realtime measurement; voltage relay

I.INTRODUCTION

In modern power systems, voltage quality is becoming increasingly important with their growth in power electronics and their high sensitivity of electronic equipment. Voltage quality covers a wide range of voltage disturbances and deviations in voltage magnitude or waveform from the optimum values.

The main target of this project is to design and develop an Arduino Based Smart Overvoltage and Under voltage Protection System to protect the appliance from damage. Nowadays fluctuation in AC mains voltage is frequent in domestic houses and industries. The abnormal over and under voltages may be caused due to some reasons such as sudden interruption of heavy load, thunder lightning, switching impulses etc. It can easily damage sensitive electronic parts in these conditions. It is so preferable to have a tripping system such as MCB, or MCCB to protect the appliances. But we build here an advanced system that can smartly control your whole house’s electric supply using the user’s choice. Yes, we can set our desired maximum and minimum voltage for our needs.

In today’s market, various types of smart Overvoltage and Under voltage protection systems have come out. But these are a little bit costly. Our project aims at protecting the electrical equipment from over and under voltages using just an Arduino and voltage sensor at a low cost. Here we use the ZMPT101B voltage sensor which is more accurate than others also it is cost-effective. It detects any voltage greater than 230V AC and below 190V AC (predefined value). If the voltage is across the limits than the predefined values, it sends a signal to the Arduino. Then it immediately trips the circuit breaker (here the relay module). Then the circuit breaker isolates the load from the main source.

In today’s power system, voltage quality is an important factor with the growth in power electronics and the high sensitivity of electronic components. Voltage quality covers a wide range of voltage disturbances and fluctuations in voltage magnitude or waveform from the maximum values. Daily operation of the power grid may result in disruption of voltage quality. Also, voltage irregularities are the major issues in the industries and domestic users are facing and often damage sensitive electronic equipment. Here voltage is increase above the limit or decrease above the limit then supply of load is automatically cut to prevent load from damage.

II. LITERATURE REVIEW

Disturbances related to voltage quality could occur as a consequence of the operation of the power grid and/or of units connected to the grid. On the other hand, voltage irregularities are the major issues the industry and home users are facing and are often responsible for damages in sensitive equipment [1-2]. Overvoltage or undervoltage often result in damaging equipment. Electronic loads increase day by day and they are very sensitive to voltage variations [3]. In [4], authors proposed a method for monitoring voltage disturbances based on discrete wavelet transform and adaptive linear network.

The types of voltage disturbances studied included voltage sag, voltage swell and voltage interruption. After applying the method, the voltage disturbances were classified according to IEEE Std. 1159-2009.

Authors in [5] proposed an algorithm based on a deep belief network for online voltage sags recognition. The causes and waveform characters of voltage sags were analyzed. Then according to the characters of different sag waveforms, ten voltage sag characteristic parameters were proposed and proven to be effective, and finally a deep belief network model was built using the parameters to complete automatic recognition of the sag event types.

An adaptive approach for voltage sag automatic segmentation was presented in [6]. An adaptive threshold for different waveforms was addressed, in which sag depth, mean square error, and entropy of the sag waveform were considered. Because of the effects of voltage sags on power system operation, the dynamic voltage restorer, one of the most effective solutions for mitigating voltage sag in power system, was proposed in [7-8].

Authors in [7] presented a configuration and control strategy for dynamic voltage restorer which used a closed-loop PI control law in the d-q reference frame and a linear Kalman filter was employed to estimate three-phase voltage sag. In [8], a new control method of multifunctional dynamic voltage restorer for voltage quality correction was presented. The control method was designed in the stationary frame by combining proportional resonant controllers and sequence-decouple resonant controllers. The method can mitigate many different conditions such as voltage swell, voltage sag due to symmetrical and unsymmetrical short circuit, starting of motors, and voltage distortion. The aim of this work was to design and implement an experimental system based on an Arduino Uno microcontroller board that can monitor electrical quantities and protect over/under voltage in a power supply. The voltage sensor (ZMPT101B) and the current sensor (ACS712) are embedded as the sensors which transmit continuously real-time data of a single-phase power supply to the Arduino Uno board, and then the data are processed to measure all necessary measurements.

The protection of electrical equipment and control of various parameters in power systems can be traced to have begun toward the end of the 19th century with the use of lead, tin, and silver fuses for the protection of generators, cables, and motors from overheating [14] . Over the centuries, protection technology evolved from the use of fuses through relays to the emergence of electronic protection devices in the 1950s. Digital protection technology emerged in the 1970s with the use of microcomputers for the control of various processes in the power industry [15] , which eventually extended to the use of microcontrollers as known today.

Application-oriented research on voltage variation protection has employed technology based on the use of operational amplifiers and voltage regulator integrated circuits (IC) and various microcontrollers.

Thentral et al. [16] designed and implemented an overvoltage and undervoltage protection system using operational amplifiers based on the LM424 IC and IC7812 voltage regulator. For an input voltage of 230 V, the system considers a safe voltage supply between 195 V and 215 V, triggering off for voltages out of this range.

The system proposed by Bhosale et al. [13] also uses the LM424 and IC7812 but its input and safe voltage range are not specified. Overvoltage and undervoltage protection systems developed on the basis of microcontrollers include those that use the PIC16F877 and ATmega328 family of microcontrollers.

Based on the use of PIC16F877 family, Ponnle and Omojoyegbe [17] developed a system using the PIC16F877A microcontroller and incorporated the LM7806 voltage regulator. For an input voltage of 220 V, the system considers a safe voltage supply of 200 -

240 V, triggering off for voltages outside this range. Based on the use of the ATmega328 family, overvoltage and undervoltage systems have been designed and implemented using the ATmega328 in standalone mode or via the Arduino Uno and Arduino Nano boards that incorporate the ATmega328 as the controller.

For example, Savita et al. [18] designed and implemented a system using ATmega328 alongside with an LM324N IC voltage amplifier and a SIM900A GSM module. The system considers 6 - 10.5 V as a safe voltage range, triggering off the system when the input voltage is out of this range. Furthermore, the system uses the SIM900A GSM module to send alerts about the system to the user. Another system has been designed and implemented by Simatupang et al. [19] . These authors used the Arduino Uno board alongside with the LT1083 IC voltage regulator. The system offers two safe voltage ranges: 3 - 5 V; and 10 - 15 V. Tung and Khoa [20] developed a system using the Arduino Uno board, a voltage sensor (ZMPT101B), and a current sensor (ACS712). The system was used to measure electrical system parameters during induced conditions of overvoltage and undervoltage.

III. PROPOSED SYSTEM

In ML-based approaches, the big data that is acquired by the monitoring system must be timely processed in order to correctly detect abnormal operation and faults. Fault detection and diagnosis mainly involves three steps, that is, data collection, data processing for feature extraction and finally, fault classification. Relevant solutions for fault detection are mainly based on supervised, unsupervised and deep learning methods.

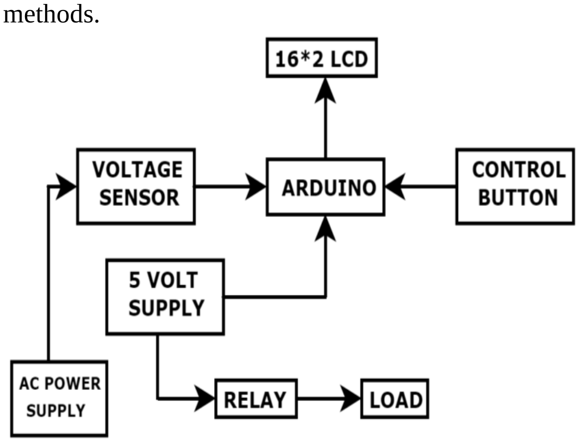

Fig. 1 Block diagram of the Proposed system

IV .EXPERIMENTAL DETAILS

In the area of supervised learning, several studies have employed ML methods to tackle issues of industrial fault detection and diagnosis. In Reference, the authors targeted the development of an automated diagnosis tool for circuit-boards, in order to reduce human effort and improve the diagnostic accuracy. The intelligent detection and diagnosis solution relied on three ML classification methods, that is, ANNs, SVMs and weighted-majority voting (WMV), where the latter combined the benefits of ANNs and SVMs.

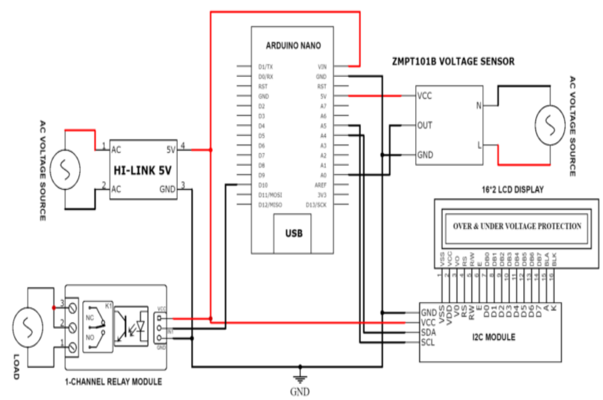

Fig. 2 Circuit diagram of the Proposed system

The hardware of the experimental system is designed to measure electrical quantities and then to protect overvoltage and undervoltage conditions in single-phase power supply as shown in Figure 1. It includes the following main components: The voltage sensor ZMPT101B used in this work is a voltage transformer ideal to measure the single-phase AC voltage. It has high accuracy, good consistency for voltage and power measurement and it can measure up to 250V AC. It is simple to use and comes with a multi turn trim potentiometer for adjusting the analog-digital converter output. Its features consist of measurement within 250V AC, onboard microprecision voltage transformer, analog output corresponding quantity can be adjusted, good consistency, for voltage and power measurement and high efficiency and accuracy. The current sensor ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, automotive, commercial, and communications systems. The device package allows easy implementation by the customer. Its typical applications include motor control, load detection and management, switched-mode power supplies, and overcurrent fault protection. In this paper it is used to measure the AC current of the single-phase power supply. The Arduino Uno is a microcontroller board based on the ATmega328. It has 20 digital input/output pins (of which 6 can be used as PWM outputs and 6 can be used as analog inputs), a 16MHz resonator, a USB connection, a power jack, an in-circuit system programming (ICSP) header, and a reset button. It contains everything needed to support the microcontroller, it just simply needs to be connected to a computer (or appropriate wall power adapter) with a USB cable or with a AC-to-DC adapter or battery to get started. In addition, other components are used to build the experimental system such as an LCD to display all data measurements, a relay to switch the circuit when overvoltage or undervoltage occurs, push buttons for automatic/manual mode, trip and close command of the system. The completed experimental system for protecting overvoltage and undervoltage in this work built from the aforementioned components is shown in Figure 2.

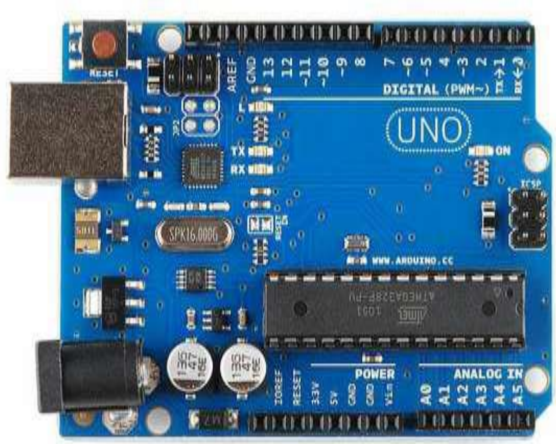

Fig. 3 AVR Controller (ATMega328)

The Atmel 8-bit AVR RISC-based microcontroller combines 32 KB ISP flash memory with read-while-write capabilities, 1 KB EEPROM, 2 KB SRAM, 23 general-purpose I/O lines, 32 general-purpose working registers, 3 flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8 channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and 5 software-selectable power-saving modes. The device operates between 1.8 and 5.5 volts. The device achieves throughput approaching 1 MIPS/MHz.

IV. RESULTS AND DISCUSSION

To test the overvoltage and undervoltage protection function of the experimental system, an experimental setup was established as shown in Figure 4. In Figure 4, three additional parts, namely a variable transformer, a PC monitoring, and a voltmeter are added to the setup. The key task of the variable transformer is to generate a variable voltage source. Therefore, various voltage conditions including normal voltage, overvoltage, and undervoltage can be created by tuning the knob on the front of the variable transformer. Then, its output voltage is used to supply the experimental system. All electrical quantities are measured and displayed locally on the LCD on the front of the system. Moreover, the status of the electrical circuit which is closed or open is also monitored and displayed on the LCD. In order to validate the voltage measurement of the experimental system, the voltmeter is added and connected to the output of the variable transformer. The measurement results from the experimental system and the voltmeter can be compared. Moreover, the monitoring software on a PC connected to the experimental system through a USB cable is designed to monitor all electrical quantities remotely. All measurements are continuously transmitted from the Arduino Uno board to the PC and are displayed on the PC's monitor graphically. From the monitoring software, we can observe and save all measurement data to a csv file, therefore, we can use the data for any further analysis.

In order to measure RMS voltage and current of a circuit, the voltage and current signals from the voltage sensor and current sensor are sampled in the Arduino Uno. With the processing speed of the Arduino Uno, the sampling time for both voltage and current signals equals to 4ms. This means there are 5 samples of voltage or current per cycle. The AC power supply generated by a variable transformer is nominally 230V AC 50Hz. Using the variable transformer to generate different voltage conditions, in this paper, one voltage condition is established by reducing the voltage magnitude in a period of about 10s. The voltage waveform is recorded in the csv format file by the monitoring software and then it is plotted in Matlab as shown in Figure. Moreover, we can obviously see the voltage waveform using its magnification from 5.2s to 5.6s as shown in Figure. When the load changes, the current waveform through the circuit recorded by the monitoring software also changes.

ADVANTAGES OF THE PROPOSED SYSTEM

1) We use Arduino circuit will reduce, compact and more flexible.
2) We use current, voltage, temperature, light of industries then No one parameter is missing to detect.
3) System is compact and consumes low power
4) Due to relay in system when fault is occurs our system is trip the supply
5) System cost is very less.

APPLICATIONS

1) In power generation, transmission and distribution station for maintaining big transformer
2) In farm for transformer protection
3) In chemical and textile industries for protection of fire due to transformer
4) In city where main transformer is use to divide electricity area wise
5) In government sectors for transformer protection

V. CONCLUSION

In this research work, an experimental system based on the Arduino Uno microcontroller board was developed for measuring electrical quantities and protecting onvervoltage and undervoltage of a single-phase power supply. The hardware and software of the system were designed and tested in a laboratory at our University. In order to evaluate the effectiveness of the system, we generated many different scenarios including automatic and manual mode to demonstrate and test the operation of the system. The real-time measurement results are locally monitored at an LCD on the front of the experimental system. Moreover, they can be graphically monitored through the monitoring GUI software on a PC and they can be also saved in a csv file for further analysis. The main contribution of this work is the propose of an experimental method to build a system based on an Arduino Uno microcontroller board for protecting overvoltage and undervoltage in single-phase power supplies and to implement a simple method which is uploaded to the board for measuring electrical quantities.

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