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AUTOMATIC POWER FACTOR CONTROL USING ARDUINO UNO

Ravi Dhameliya[1], Kaushik Domadiya[2], Pratik Miyani[3], Hiren Savaliya[4], Pratik Jariwala[5]

[1,2,3,4,5]Department of Electrical Engineering, Mahavir Swami College of Engineering & Technology, Surat, India

Abstract — *The power quality of the AC system has become a great concern due to the rapidly increased use of inductive loads, electronic equipment. We are wasting a part of the electrical energy everyday due to the lagging power factor in the inductive loads we use. hence, there is an urgent need to avoid this wastage of energy, lower power factor result in poor reliability, safety problems and high energy cost. The power factor of the power system is continuously changing due to differences in the size and number of the equipment being used at a time. This makes it challenging to balance the inductive and capacitive loads continuously. Many control methods for the Power Factor Correction (PFC) were proposed. This paper presents a computationally accurate technique to design and development of a single-phase power factor correction using Arduino Uno micro-controlling chip, The hardware implementation was developed by using Arduino Uno board, which uses the ATmega328 as the Microcontroller, the proposed design has the skill to sense power factor efficiently and by using proper procedure enough capacitors are switched on in order to compensate the reactive power, thus withdraw PF near to unity as a result acquires higher efficiency and better quality AC output.*

Keywords — *Power Factor Correction; Reactive Components; Automatic Switching; Capacitor Bank; ATmega328P; Arduino Uno*

I. INTRODUCTION

In the present scenario of technological revolution, from the whole over observation it can be said that the power is very precious and becoming more and more complex with passing days. The increase in usage of inductive loads in industry will give impact to the power factor value of the system and thus due to that the efficiency of the power system decreases. Nonlinear loads will lead to a poor power factor which can disrupts the AC voltage and give poor performance to other equipment connected to the same source. The main objective of this project is an improvement of the existing AC power factor output by adding capacitance. The ideal power factor controller should produce unity power factor output. This project mainly aims the attention on the arrangement and development of power factor correction using Arduino Uno in which ATmega328 as microcontroller. The power factor controller method and device is useful in improvement of the efficient transmission of active power. This PFC are popular because of their advantages such as high power factor, fast dynamic response, and low cost. Digital PFC converters are more desirable because digital controllers have many advantages over the analog controllers due to their programmability, flexibility, no temperature and aging effect, and more resistance to the input voltage distortion. Power factor correction using capacitor banks reduces reactive power consumption which will lead to minimization of losses and at the same time increases the electrical system's efficiency. Power saving issues and reactive power management has led to the development of single phase capacitor banks for domestic and industrial applications. The development of this project is to enhance and upgrade the operation of single phase capacitor banks by developing a micro-processor based control system. The output of this device which obtains from the simulation result and hardware implementation will be analyzed to see the effect of controlling and correcting activity. This paper proposed the controlling and correction of power factor automatically.

II. POWER TRIANGLE

The power factor of an AC electrical power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit. A power factor of less than one means that the voltage and current waveforms are not in phase, reducing the instantaneous product of the two waveforms (V × I). Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit.

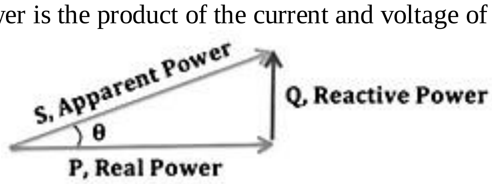

Fig. 1 Power Triangle

We can relate the various components of AC power by using the power triangle. Real power extends horizontally in the î direction as it represents a purely real component of AC power. True power (real power) is symbolized by the letter P and is measured in the unit of Watts (W). Reactive power extends in the direction of ĵ as it represents a purely imaginary component of AC power. Power simply absorbed and returned in load due to its reactive properties is stated to as reactive power. Reactive power is represented by the letter Q and is measured in the unit of Volt-Amps-Reactive, Entire power in an AC circuit, both dissipated and absorbed/returned is mentioned as apparent power. Apparent power is represented by the letter S and is measured in the unit of Volt-Amps (VA), therefore can be calculated by using the vector sum of these two components. We can conclude that the mathematical relationship between these components is,

$$(\text{apparent power})^2 = (real\ power)^2 + (\text{reactive power})^2$$

$$(real\ power) = (apparent\ power) \times \cos(\varnothing)$$

$$(reactive\ power) = (apparent\ power) \times \sin(\varnothing)$$

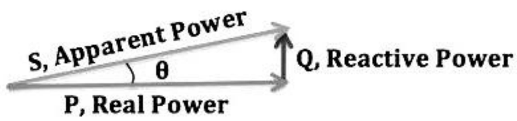

Fig. 2 Increasing Power Factor

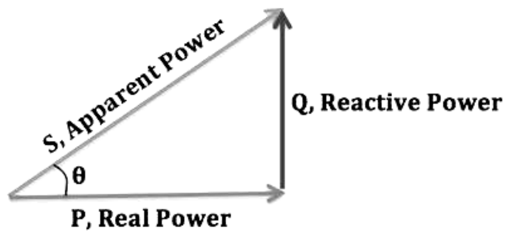

Fig. 3 Decreasing Power Factor

See Fig.2. As the power factor ($\cos\Theta$) increases, the ratio of real power to apparent power (which is = $\cos\Theta$), increases and approaches unity (1), while the angle θ decreases and the reactive power decreases. [$\cos\Theta\rightarrow$, its maximum possible value, $\theta\rightarrow 0$ and so $Q\rightarrow 0$, as the load becomes less reactive and more purely resistive]. Now, See Fig.3. As the power factor decreases, the ratio of real power to apparent power also decreases, as the angle θ increases and reactive power increases.

III. POWER EQUATIONS

When RMS values of voltage and current are taken into account, the power equation is given as,

$$P = |V|\,|I|\,\cos(\Theta) \quad (1)$$

The parameter P, commonly called the average power, is also known as real or active power. Watt is the fundamental unit of both instantaneous and average power but due to the minuteness of watt in relation to power system quantities. P is usually measured in kilowatts or megawatts. The cosine of the phase angle θ between the voltage and the current is called the power factor. The term similar to mentioned above but having sine, alternates positive and negative and gives an average value of zero. This component of the instantaneous power P is called the instantaneous reactive power which expresses the flow of energy towards the load and away from the load, alternately. The maximum value of this pulsating power designated Q, is called reactive power or reactive volt-amperes and is very useful in describing the operation of a power system. Therefore reactive power is given by,

$$Q = |V|\,|I|\,\sin(\Theta) \quad (2)$$

In a simple series circuit where Z is equal to $R + j\,X$ we can substitute $|I||Z|$ for $|V|$ in equations (1) and (2) to obtain,

$$P = |\mathbf{I}|^2|Z|\cos(\Theta) \quad (3)$$

$$Q = |I|^2|Z|\sin(\Theta) \quad (4)$$

Keeping in view,

$$R = |Z|\cos\Theta,\ X = |Z|\sin\Theta$$

Above equations offer another method of calculating power factor since we witness that ***Q/P = tan θ***. The power factor is therefore,

$$\cos(\Theta) = \cos(\tan^{-1} Q/P) \quad (5)$$

Or

$$\cos(\Theta) = P/\sqrt{P^2 + Q^2} \quad (6)$$

An inductive circuit has a lagging power factor and a capacitive circuit is said to have a leading power factor. The terms lagging and leading power factor indicate, respectively, whether the current is lagging or leading to the applied voltage.

IV. BASIC THEORY OF VOLTAGE DIVIDER CIRCUIT

The principle of voltage divider is used for the voltage sensor and Ohm's law for the current sensor. Ohm's law is used to convert the current value to a voltage value. Signals obtained from both measurement systems are conditioned to be read by the Arduino. Digitizing analog signals is carried out by the Arduino. Then, the digital signal is sent to a computer for further processing into the desired information, such as a graph of voltage, current, power consumption, and used energy and also the RMS and the average values.

Voltage divider is a linear circuit which divides input voltage into an output voltage with a specific ratio. It can be arranged by connecting two impedances in a circuit. The impedances can be made by combining resistors, inductors and capacitors. In this research, voltage divider is arranged by combining resistor,

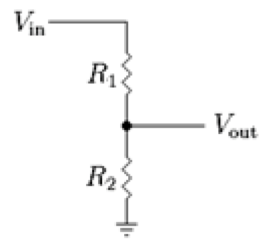

Fig. 4 Voltage Divider Circuit

$$V_{out} = \frac{R_2}{R_1+R_2} V_{in} \quad (7)$$

Ohm's law is also used for calculating the value of the load current which is as below,

$$V = IR \quad (8)$$

Microcontroller used in this research has a power supply which produces a stable output voltage 5 V. This power supply is then utilized to shift the sensor output voltage until the output can be read properly by the Arduino, the source of electricity voltage is scaled and then shifted by 2.5V, the voltage sensor change ±340V to a voltage around ±2.5V. At the current sensor circuit, voltage is obtained by multiplying the current by 0.5 ohms resistance. Then the voltage signal from the current sensor is shifted by 2.5V. At the current sensor circuit, it can be seen that the current sensor is capable to read up to 5 Ampere current. Thus, the current will produce ±2.5V. Shifting voltage is needed because microcontroller used only capable to receive an analog voltage signal from 0 to 5V. Then, the resistors are connected to the 5V power supply from the microcontroller so that the final output signal has a value from 0 to 5V. Voltage value of 2.5V indicates a value of zero for the current and voltage sensors, while the 5V and 0V indicate the maximum and minimum values of the related sensors. These are used in order to make analog signal to digital data conversion can be processed by the microcontroller.

V. ARDUINO UNO HARDWARE AND IDE

The Arduino Uno is based on the popular Atmel ATmega 328P. Older Arduino Uno Boards utilized the ATmega8 or ATmega168, however, boards featuring those microcontrollers are no longer available. The ATmega 328P is a low power 8-bit AVR RISC-based microcontroller. The ATmega supports operating frequencies up to 20 MHz, however it is clocked at 16 MHz on Arduino Uno boards. The 328P features a variety of useful peripherals to interact with its environment. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. Another important feature of the ATmega 328P is its three hardware timers (0,1 and 2). Timer 0 and 2 are 8-bit timers, while Timer 1 is a 16-bit timer. The timers can be used to generate the PWM signal required to control the power converter. At 100 kHz, the PWM resolution is approximately 7.3 bits. In the standard Arduino programming environment, the PWM frequency is set to 490 Hz, which is far too low to be useful in any power electronics application. Methods to access the fast PWM will be elaborated on in later sections. The timer can also be useful to generate timed interrupts. All Arduino Uno boards are supported by the Arduino Integrated development environment (IDE). The Arduino IDE can be used to both program and communicate with the Arduino boards. The Arduino IDE utilizes its own programming language, which is based on C. The main advantage of the Arduino programming language is its ease of use. A variety of functions used to interact with the peripherals are predefined in the IDE. Some of these peripherals include: External Interrupts, Timer with PWM, ADC, and Serial Communication.

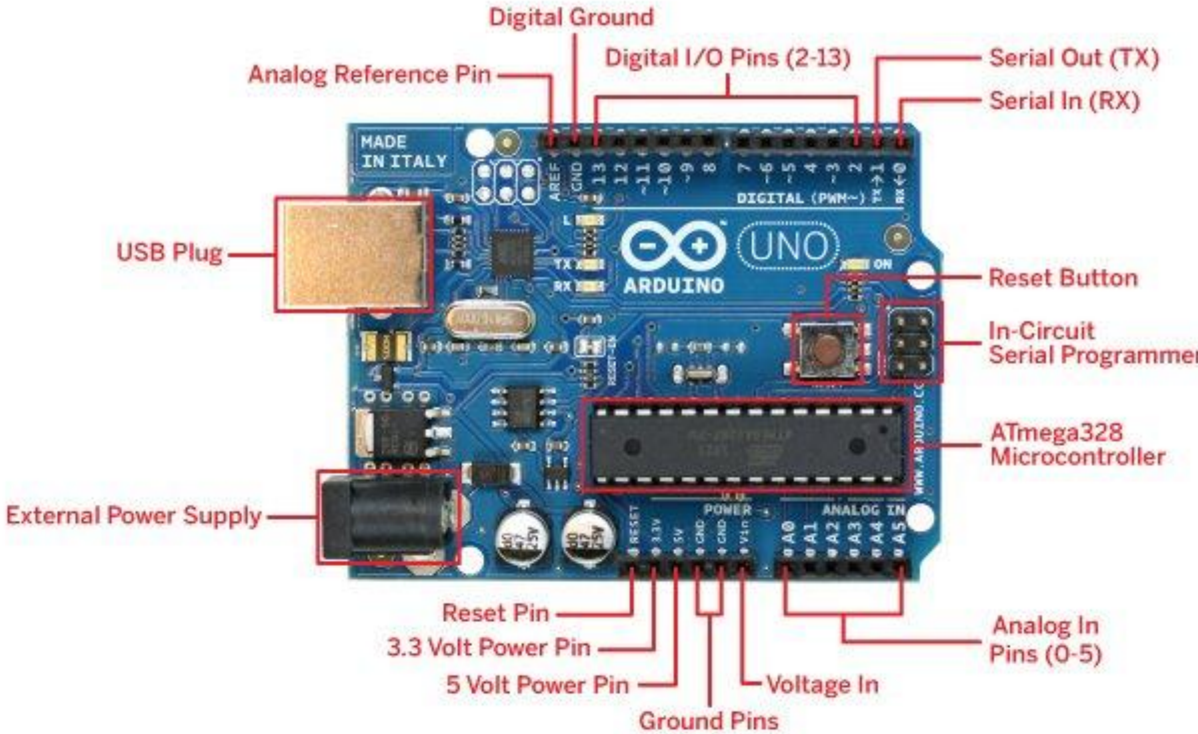

Fig. 5 Arduino Uno Microcontroller

VI. RELATIONSHIP OF CAPACITOR WITH POWER FACTOR

Capacitor is the main component that supplies capacitive reactance, which is negative reactive power. Since, the power factor is the ratio of real power and apparent power, where apparent power has the relation with reactive power and real power as shown in the power triangle in fig.1. As majority power system has inductive loads thus normally only lagging power factor occurs hence capacitors are used to compensate by producing leading current to the load to reduce the lagging current, thereby shrink the phase angle distance between the real power and apparent power. In general, power capacitors shall be Y-connected on the three-phase distribution feeder. Grounding the neutral is essential for the fuses to operate in case of any event of capacitor fault. For a small ungrounded Y-connected capacitor bank, faulty capacitor would not blow the fuse to isolate faulty capacitor. Any event of this could lead to an explosion to the capacitor bank. However, isolating the neutral of the Y-connected of a capacitor bank has the advantage of reducing harmonics. The method can only be an alternative when grounding the neutral would cause operating difficulty for a particular installation. In case of insulation failure inside the unit, phase-to-ground fault can still occurs to an ungrounded Y-connected capacitor bank even with its enclosure properly grounded. The most effective solution is to insert reactors in series with each capacitor group connected between the phase wire and the neutral of a 3-phase bank. Frequency is standardized at constant 50 Hz, or 60 Hz; power factor correction is valid as a solution to such fixed network frequency, the only key solution is by addition of capacitor in shunt to the load. Capacitors are commonly used within a lot of power system, especially electronic constructed circuitry. Though common it is consequently least understood by majority as one most beneficial component for power system.

- Release of system capacity
- Reduction of KVAR generation requirements
- Reduction of system loss
- Regulation or improvement in voltage

Connects capacitor in parallel (shunt) rather connecting in series. The function of shunt power capacitor is to provide leading (capacitive) KVARs to an electrical system when and where needed. Lagging (inductive) KVARs appear when there are inductors (coils) exist within electrical (e.g. motor) or electronic (personal computer) equipment, as the amount grows, the increment of inductive KVARs will increase as well, thus the demand of capacitive KVARs to compensate is pretty much required in order to reduce unnecessary lost. The actual capacitor in farads of a capacitor bank can be calculated using the following equation,

$$C=\frac{VAR}{2\pi f \times V_R^2} \qquad (9)$$

Where, VAR = capacitor unit VAR rating
C = capacitor (farads)
f = frequency (cycles/second)
V_R = capacitor unit rated voltage

VII. POWER FACTOR IMPROVEMENT

7.1 Need for improvement

Power factor correction is desirable because the source of electrical energy must be capable of supplying real power as well as any reactive power demanded by the load. This can require large, more expensive power plant equipment, transmission lines, transformers, switches, etc. than would be necessary for only real power delivered. Also, resistive losses in the transmission lines mean that some of the generated power is wasted because the extra current needed to supply reactive power only serves to heat up the power lines. The electric utilities therefore put a limit on the power factor of the loads that they will supply. The ideal figure for load power factor is unity (1), that's a pure resistive load, because it requires the smallest current to transmit a given amount of real power. Real loads deviate from this ideal condition. Electric motor loads are phase lagging (inductive), therefore requiring capacitor banks to counter their inductance. Sometimes, when the power factor is leading due to capacitive loading, inductors are used to correct the power factor. In the electric industry, inductors are said to consume reactive power and capacitors are said to supply it, even though the reactive power is actually just moving back and forth between each AC cycle.

7.2 Procedure

7.2.1 Design

Power factor can be improved by installing especially designed PFC capacitors or reactive power generators into the electrical distribution system. These devices supplement the demand of reactive power for the operation of all inductive loads and reduce the amount of KVA drawn from the main transformer, registered on the meter as "peak demand". The capacitor draws a leading current and partly or completely neutralizes the lagging reactive component of load current. This raises the power factor of the load connected. A high power factor output is the main goal of this paper which focuses on the design and implementation of power factor correction using Arduino Uno microcontroller, measures the power factor of loaded power system, performs proper action to feed sufficient capacitance to recover appropriate power loss using program and finally simulates the design with Arduino Uno controller chip. Program code has been written in C language.

7.2.2 Calculations

Capacitors are connected in parallel. The function of shunt power capacitor is to provide leading (capacitive) KVARs to the electrical system. Lagging (inductive) KVARs appear when there are inductors (coils) within electrical (e.g. motor) or electronic equipment. As the amount grows, the increment of inductive KVARs will increase as well, consequently there is a need of capacitive KVARs to compensate it in order to reduce unnecessary power loss. The actual capacitor in farads of the capacitor bank is calculated using equation 9. Capacitors of standard ratings like 240uF, 300uF and so are available that are sufficient to provide enough KVARs for the desired power factor improvement on the load side. They are connected in parallel with the equipment in the form of a capacitor bank. Their demand is ensured by first determining the value of power factor from the code.

7.2.3 Flow chart

Flow chart in Fig.6 show the design,

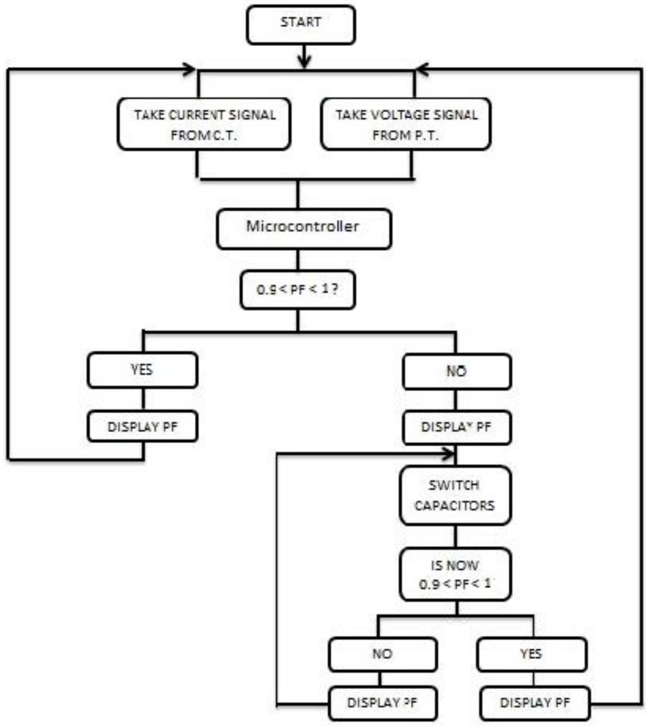

Fig. 6 Flow Chart of Design Scheme

7.2.4 Simulation

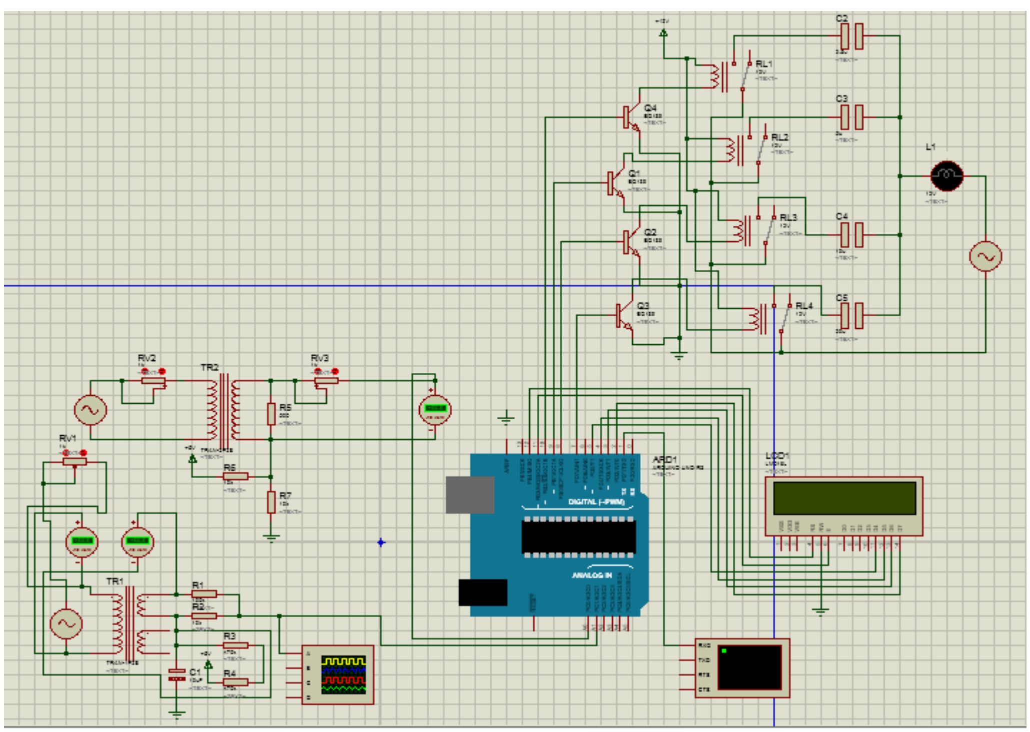

Fig. 7 PFC Schematic in Proteus

Proteus ISIS Design Suite has been used for making the simulation. The schematic can be seen from Fig.7. Code helps to display various state vectors related to power. Voltages and currents of single phases are sensed using transducers; potential transformer (PT) and current transformer (CT) respectively. These signals are applied to controller to measure the values of currents and voltages, to measure the angle between voltage and current and to measure the values of sine and cosine in order to determine the active and reactive powers. Using these values we calculate the ratings of capacitors. Magnetic relay is used to couple 5V DC signal from microcontroller to 220V AC to determine which particular capacitors are to be turned ON or OFF for optimum power factor. Potential Transformer turns ratio is selected to be 230:5 to make voltage at secondary side compatible with analog input of microcontroller. Similarly current transformer rating is such that we get 5V on the secondary.

VIII. CONCLUSION

The Automatic Power Factor Detection and Correction provides an efficient technique to improve the power factor of a power system by an economical way. By using the Automatic Power Factor Improvement module we can raise power factor is a proven way of increasing the efficient use of electricity by utilities & end users. Economic benefits for end users may include reduced energy bills, lower cable, transformer losses & improved voltage conditions, while utilities benefit from released system capacity.

IX. ACKNOWLEDGMENT

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REFERENCES

[1] Fransiska R.W., Septia E.M.P., Vessabhu W.K., Frans W., Abednego W., Hendro, "Electrical Power Measurement Using Arduino Uno Microcontroller and LabVIEW", 3rd International Conference on Instrumentation, Communications, Information Technology, and Biomedical Engineering (ICICI-BME), pp. 226-229, November 7-8, 2013.

[2] Nurul Huda Ishak, Muhammad Naim Zainodin, Nur Ashida Salim, Faizal Muhamad Twon Tawi, Aini Hafizah Mohd Saod. "A design of an Automatic Single Phase Power Factor Controller by using Arduino Uno Rev-3", Applied Mechanics and Materials Vol. 785, pp 419-423, 2015.

[3] Ahsan Shahid, Anwar Shabir, "Microchip Based Embedded System Design for Achievement of High Power Factor in Electrical Power Systems", Power and Energy Engineering Conference (APPEEC), December 2013.

[4] Richard Tingge, Yi Hu, Le Tang, Harry Mathews, Rick Tyner, "Power Factor Controller - An Integrated Power Quality Device Auto Parts", Institute of Electrical and Electronics Engineers (IEEE), 1999.

[5] Lukas Muller, Masihuddin Mohammed, Jonathan W. Kimball, "Using the Arduino Uno to Teach Digital Control of Power Electronics", Institute of Electrical and Electronics Engineers (IEEE), 2015.

[6] Nader Barsoum, "Programming of Pic Micro-controller for Power Factor Correction", Proceedings of the First Asia International Conference on Modelling & Simulation (AMS'07), (IEEE), 2007.

