Arduino Based Smart Power Factor corrector with Cloud Computing

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Abstract: This paper present an approach for the development of smart power factor by integrating any appliances with Cloud Computing. Smart Power Factor is a technique of counterbalance the abominable effects of electric load that make the power factor which is less than one. It may be adapted either by an electric power transmission utility to enhance the stability and efficiency of transmission network or it may be installed by individual electric consumer to minimize the costs penalty charged to them by their electricity supplier. The approach targets on: (1) embedding agility into sensors using Arduino platform (2) networking smart things (3) aiding communication with smart things using cloud services; Also we implement three main cases to determine feasibility and efficiency, i.e. measuring device data, monitoring, controlling data and access data from anywhere in the world. By showing the electricity consumption to the customers help them to increase their awareness about the power usage, hence encourage them to reduce the energy consumption in their daily life.

Keywords : Power factor, Arduino, Coolterm, Cloud Computing, Tonido.

1. INTRODUCTION

Electrical energy is in always substantialdemand for society. Any RL load which operate on alternating current needs apparent power whose unit is KVA which is vectorial sum of real power and reactive power, measured in KW and KVAR respectively. Real power performs the useful work whereas reactive power is that which is required by magnetic equipment (transformer, motor, relay etc.)to produce the magnetizing flux and flow back and forth in to the system. Therefore Power Factor is the ratio between the real (true or useful) to the apparent (total) power. In simple way it measure how much power is consumed by load and how much power is returned to the source. The ideal power factor is one or unity. If it is less than unity which means that it requires excess power to perform or achieve the actual work and thus efficiency of the system decreases [1][2][3].

1.1. Advantages of Power Factor Improvement

Technical and Economic advantages are:

1. Better utilization of electric machines by delivering small reactive power for same active power.
2. Better utilization of electric lines by reduction in current which allow thechoosing of conductors with less cross sectional area.

3. Reduction in the power losses of an electric conductor.
4. Reduction of voltage drop for the same level of transmitted active power.
5. Reduction in electricity bills.
6. Efficiency increases.

1.2. Idea to Improve Power Factor

Static type compensation is one of the traditional method for power factor correction in which static type capacitors are used. These capacitors bank having star or delta connection are connected in parallel with the inductive load which provide KVAR requirement. During star/delta type control it should be kept in mind that these capacitors bank should not be subjected to rapid On-Off conditionsotherwise this could lead to dangerous situations for both plant and personnel [6].

1.3. Working and Sizing of Capacitors Banks

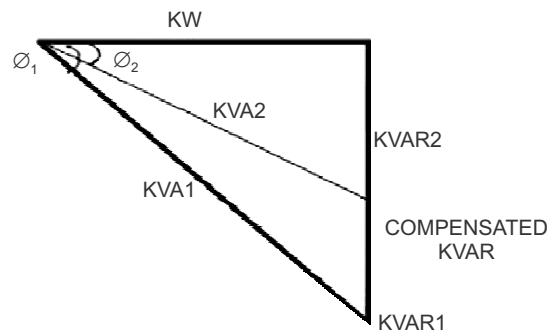The working of capacitors can be explained with the help of power triangle.

Figure 1: Power triangle

Power factor is given by $\cos \varnothing = kW / KVA$ (1)

Whereas $KVA = KW + kVAR$ (2)

Before and after providing compensation the amount of kVAR required is $kVAR1$ and $kVAR2$ respectively. The source is now relaxed of transferringamount of $kVAR$.Thus by decreasing the amount of kVARrequired from the system will result in less current consumption from the source which decrease the KVA value.

COMPENSATED $kVAR = kVAR1 - kVAR2$

$$= kW \tan \varnothing 1 - \tan \varnothing 2$$

$$= kW [\tan \varnothing 1 - \tan \varnothing 2] \qquad (3)$$

Which is required rating of capacitors bank to be connected. Where:

$$\cos \varnothing 1 = \text{Original power factor}$$

$$\cos \varnothing 2 = \text{Target power factor}$$

2. METHODS OF POWER FACTOR CORRECTION

2.1. Static Compensation

In static compensation method static capacitors are used which are connected in parallel with the load which works on low power factor. It provide leading current which will oppose the lagging part of load current and thus improve power factor.

2.2. Synchronous Condenser

A synchronous motor running under no load condition and at over excited mode is called synchronous condenser. When it is over excited it works like a capacitor by providing leading current which eliminate the reactive component kVAR and thus improve power factor. These are mainly used in power and sub transmission network not in power distribution networks because of higher installation and maintenance costs.

2.3. Static VAR Compensator

It is a power electronics based compensator in which control is carried out by couples of antiparallel thyristors. Static VAR compensator consist of both TSC (thyristor switched capacitors) and TCR (thyristor controlled reactors). TSC produce a step by step control of the reactive power dispatched by groups of capacitors, whereas TCR provide a continuous control of the reactive power drawn by the inductors. These compensators are used in very high voltage networks.

2.4. Automatic Power Factor Correction Scheme

In my project I am going to use this scheme. This scheme is based on technique of continuous monitoring of devices such as voltage sensor and current sensor with a power factor regulator. It allow the automatic switching of various capacitors banks which are connected in parallel with the load through relays, thus allow the deviation of the absorbed reactive power and maintain constant power factor near unity. This type of scheme is formed by:

1. Some sensors detecting current and voltage signals. In my project I use Hall Effect sensor as a current sensor and voltage divider circuit as a voltage sensor.
2. An intelligent unit which match the measured power factor with the reference one and thus allow the connection and disconnection of the capacitors banks with the required reactive power. In my project I use Arduino Mega as a microcontroller unit.
3. An electric power board consist of switching and protection devices such as relay board, MCB etc.
4. Some capacitor banks. As there is no rotating part in capacitor it has less switching losses as compare to that of static compensation. Since there is no extra motor is used for power factor correction therefore cost is very less as compare to that of synchronous condenser technique [9].

3. COMPONENTS, FUNCTIONAL BLOCKDIAGRAM AND SCHEMATIC DIAGRAM

3.1. Main Components

Main components used in smart power factor are:
1. Arduino Mega microcontroller(AT-mega2560)
2. MCB , USB Cable for Arduino
3. LCD Display
4. Hall Effect Current sensor
5. Transformer, diodes,small capacitor and Variac for Voltage Sensor
6. Relay Board
7. Capacitor Banks
8. Total RL Load of 320W which include three Choke coil of 40W each and two Incandescent lamp of 100W each.
9. Data storage device.
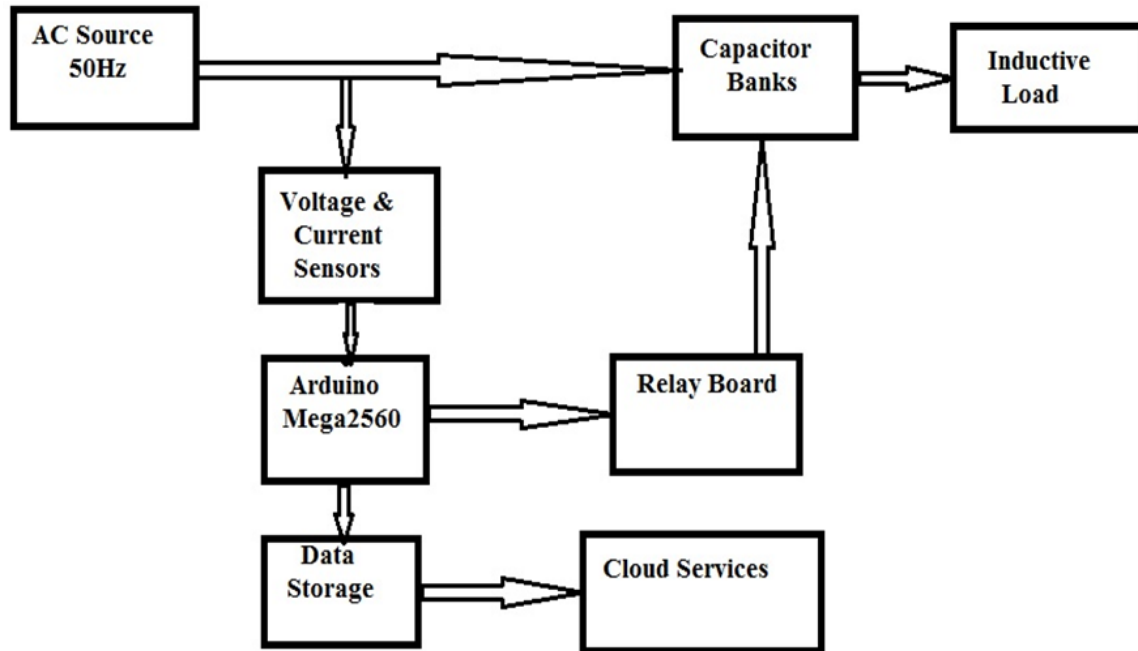10. Tonido as Cloud service

3.2. Block Diagram

Figure 2: Block Diagram of System

The line voltage and current waveform are detected by zero crossing detector from voltage sensor and Hall Effect current sensor which are connected to the analog input of Arduino. Depending upon the phase difference between voltage and current waveform Arduino sends out the signal to switch on/off capacitor banks through relay and thus improves power factor. Database/Data store stores data from Arduino microcontroller enabled sensors and cloud services for data visualization and analysis. In this we use Tonido which is a web application serving as cloud services.

3.3. Microcontroller Description: Arduino Mega

Figure 3: Arduino Mega2560

The Arduino Mega 2560 is a microcontroller board based on the Atmega2560. It has 54 digital input/output pins of which 15 can be used as PWM outputs, 16 analog inputs, 4 UARTs hardware serial ports, a 16 MHz crystal oscillator, a USB connection, a powerjack, an ICSP header and a reset button. Fig3 show the basic structure of Arduino Mega.

Arduinoprovides programming environment which aid the developer to conduct, compile, upload, and simulate programs. By connecting an USB cable from computer to Arduino we can see serial data in real time and store it in text or in excel file [6].

Table 1
Features of Arduino Mega

Microcontroller	At mega 2560
Operating Voltage	5 V
Recommended Output Voltage	7-12 V
Input Voltage	6-20 V
Digital I/O Pins	54
Analog I/P Pins	16
DC Current per I/O Pin	40 mA
Dc Current for 3.3 V Pin	50 mA
Flash Memory	256 KB out of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 Hz

4. METHODOLOGY

The methodology on which my paper is based consist

4.1. Voltage Measurement Design
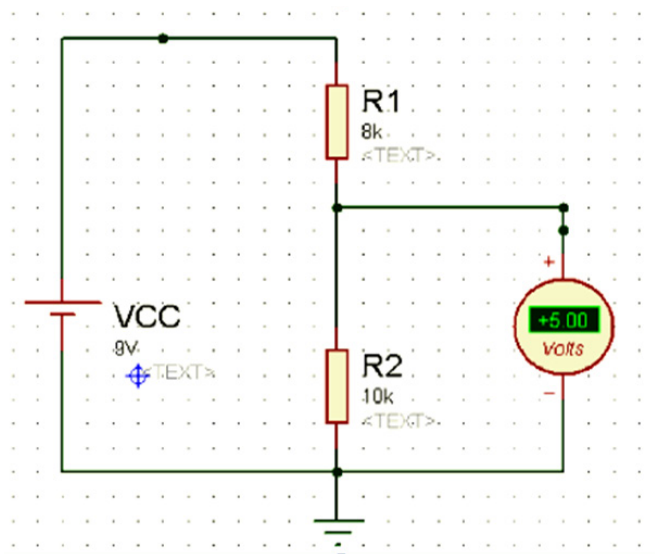
Figure 4: Voltage divider

Voltage step down is a method that used for the purpose of stepping down the system voltage to a certain safe point to be fed into the system. In my project, to step down the voltage method used is voltage divider. A voltage divider is very simple circuit consists of two resistor which will turn a large voltage into a smaller voltage. For smaller voltage this method is very easiest and economical. The relationship between Vout and Vin in voltage divider is given by

$$V_{out} = V_{in} \frac{R1}{R1 + R2}$$

(4)

4.2. Zero Cross Detector (ZCD)

To detect the transition of voltage and current signal waveforms from positive and negative precisely when it hit the zero point, zero crossing detectors are used. The main concept of zero crossing detector operation is operational amplifier. In this thesis work, the operational amplifier is used as a voltage comparator. LM358 is selected because it has dual amplifiers inside it and only need one supply voltage which can be used for both the amplifiers. It also has wide power supply range which is 3V to 32V foe single supply and 1.5V to 16V for dual supplies.
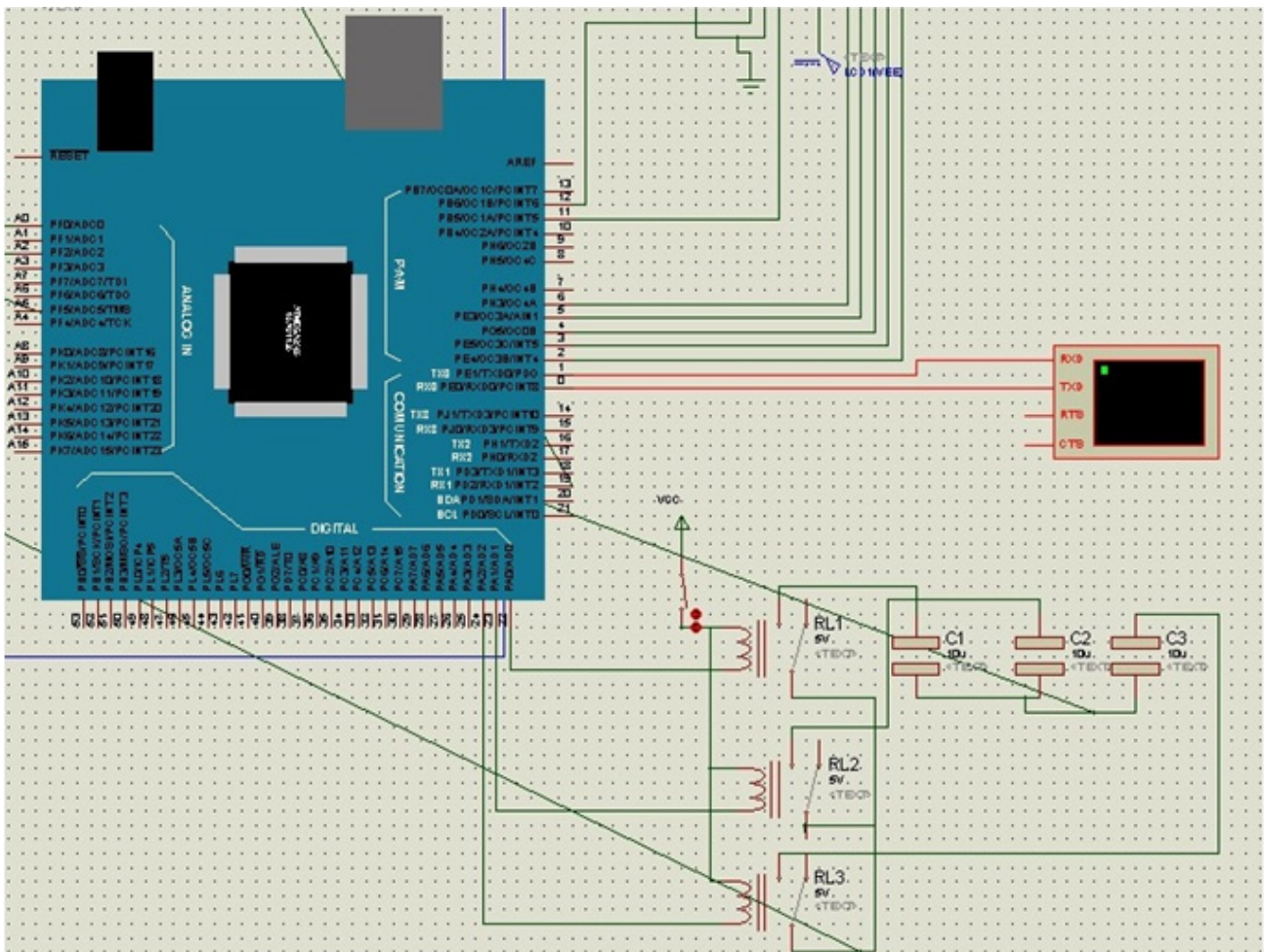
4.3. Capacitor and relay board

Figure 5: Capacitor with relay board

The simplest method of correcting power factor is by installing capacitors bank between the connection of source and load. The application of capacitors bank will be optimal if the load and the power factor are measured correctly, so the value of capacitors needed can be calculated precisely. By calculating the power factor before correction and the power factor desired, it is easier to find the correct value of capacitors needed. In this project, bulk compensation is used. This method allows the microcontroller to maintain the power factor value close to the desired one. This method uses several numbers of capacitors which connected to relays station. The relays connect or disconnect the capacitors to reduce the reactive power that produced by the load the relays are maintained directly from microcontroller. The connection of capacitor banks with relay board is shown in Figure5 [7].

Flowchart :
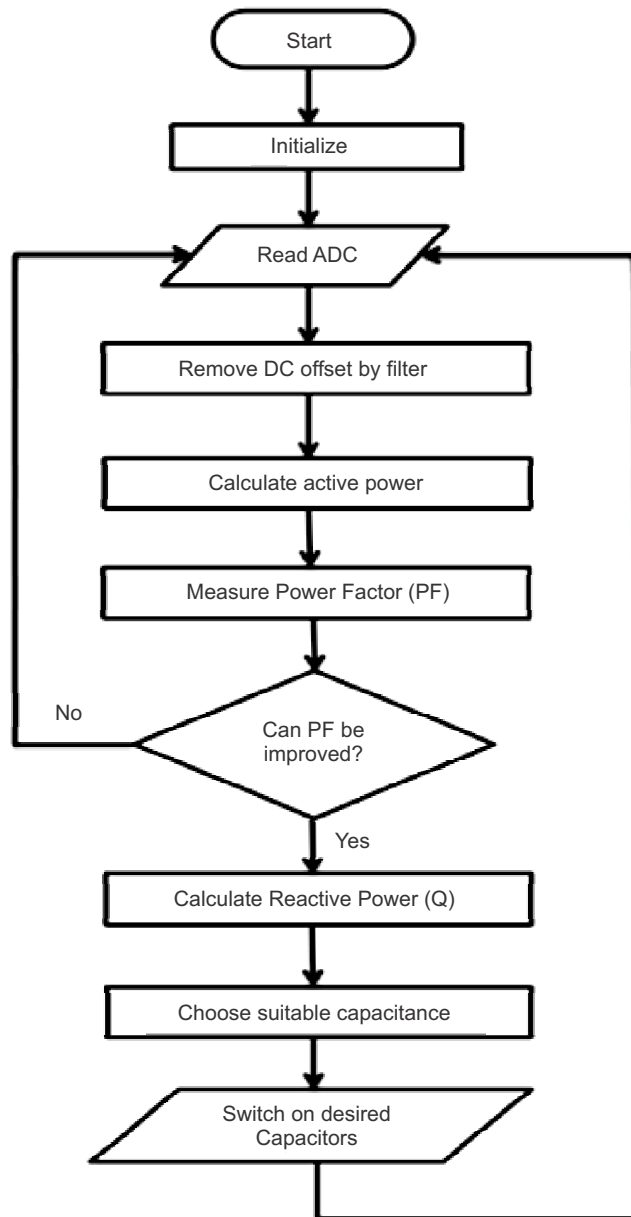
Figure 6: Flowchart of smart power factor

4.4. Cloud Computingusing Tonido

Smart power factor is based on cloud computing which provides storage and computing resources to implement web applications. The main advantage of cloud services is that it can be accessed from anywhere and anytime in the world which is very useful. The main responsibility of web application is to read sensors value, store readings and monitoring household and commercial appliances over the internet. Further we use Coolterm software for serial data communication which stores sensor value on computer in text or excel file. For cloud computing we use Tonido which is remote access and home server software for network attached storage. Once it is installed on a computer this software makes the computer files available remotely through internet by using web browser or through mobile apps.It is public cloud software for establishing, expanding and maintaining our web applications because Tonido is very simple to use, extensible to service requests and have anadjustableinterface [4].

5. RESULTS AND DISCUSSION

5.1. Zero Crossing Detector Waveforms

Proteus software is usedto see the current, voltage phase shift waveforms and output of zero crossing detector before and after power factor correction. Yellow waveform represent voltage, blue waveform represent current and pink represent output of zero crossing detector.
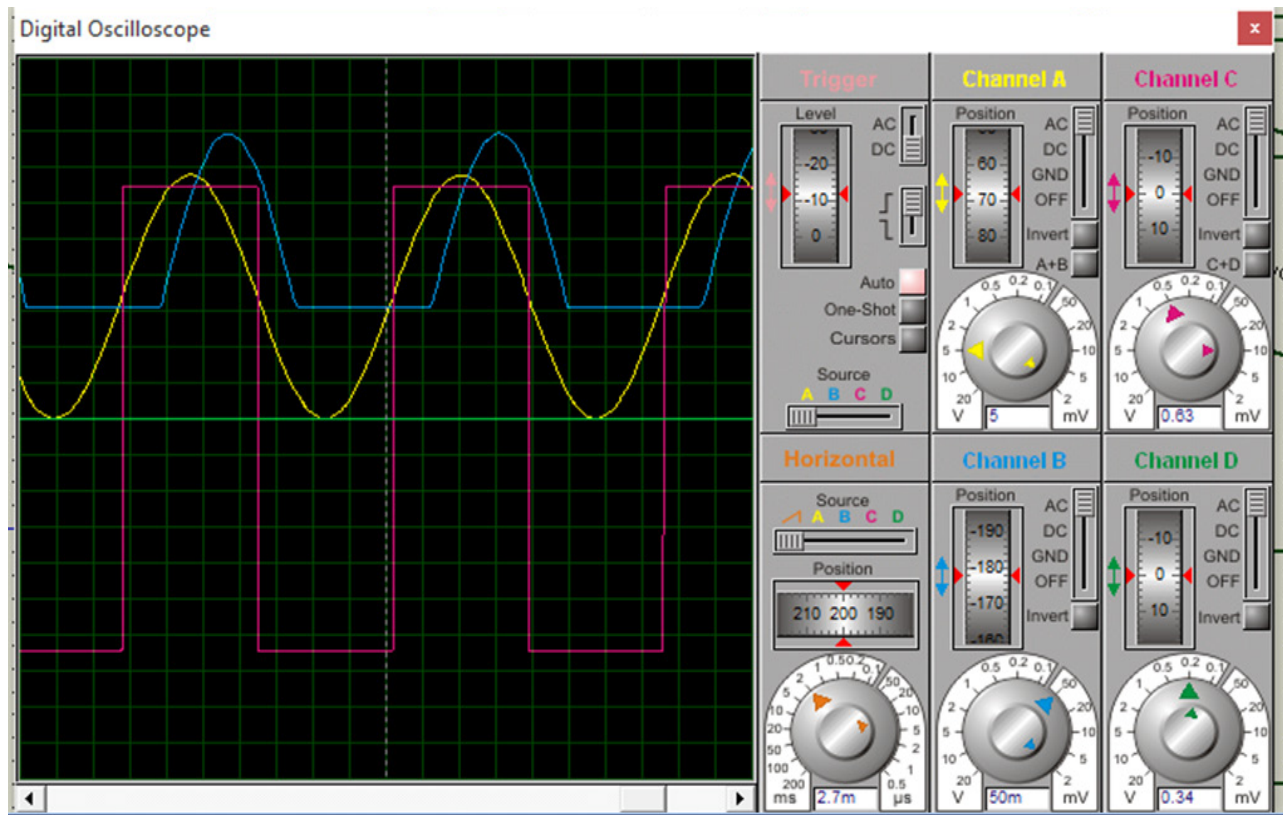

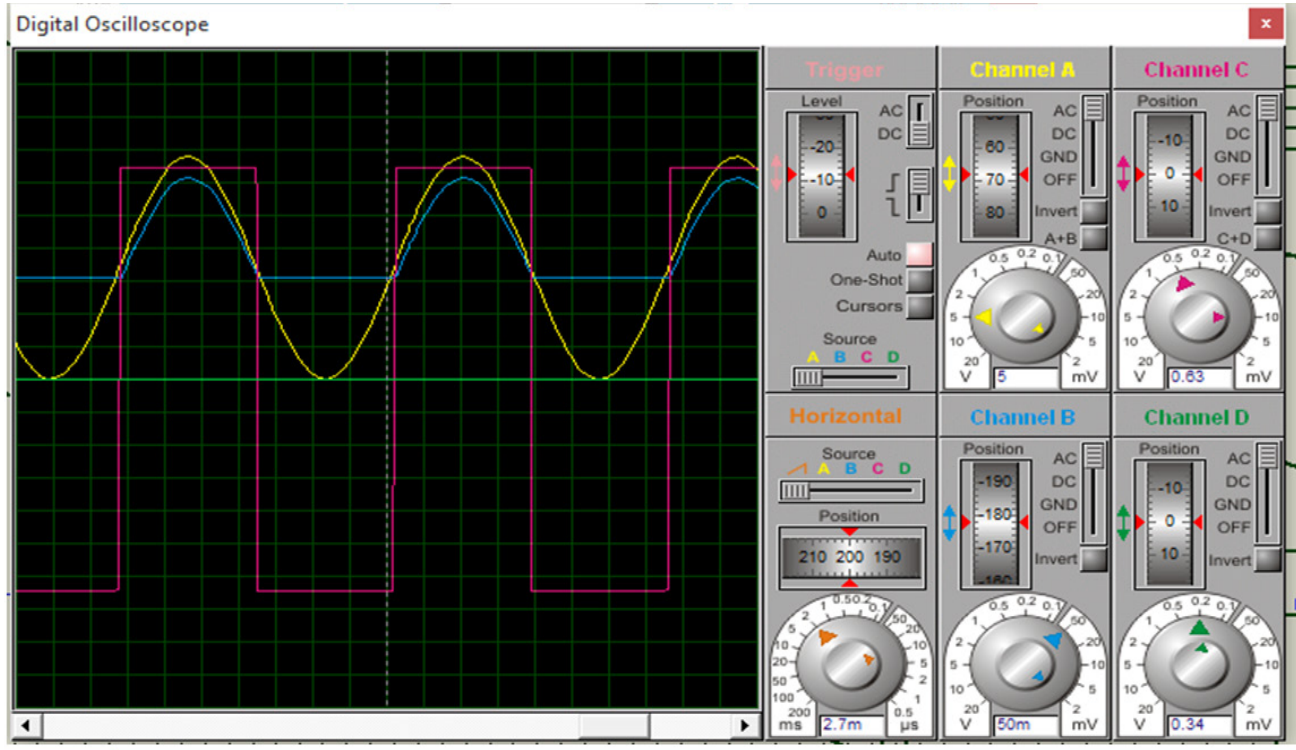**Figure 7: Before power factor correction**

Figure 8: After Power factor Correction
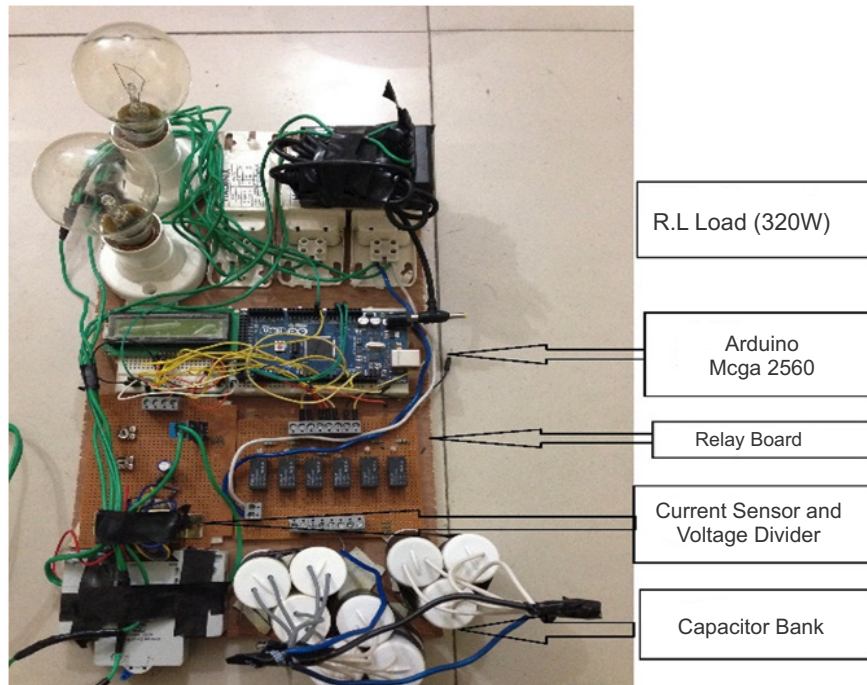
5.2. Electrical Circuit Hardware Design

Figure 9: Arya: Pictorial view of System

Comparative observation of Power factor of 320W RL load before and afterSmart power factor circuit insertion is shown below:

Table 2
Before power factor correction

Voltage(V)	Current(A)	W(watts)	PF
230	2.2	500	0.5

Table 3
After power factor correction

Voltage(V)	Current(A)	W(watts)	PF
230	1.4	322	0.9

The current and Power Factor of 320W RL load before applying capacitors bank are 2.2 A & 0.5. After apply capacitor banks of 20 Microfarad (uF) the current and Power Factor are 1.4A and 0.9 respectively.

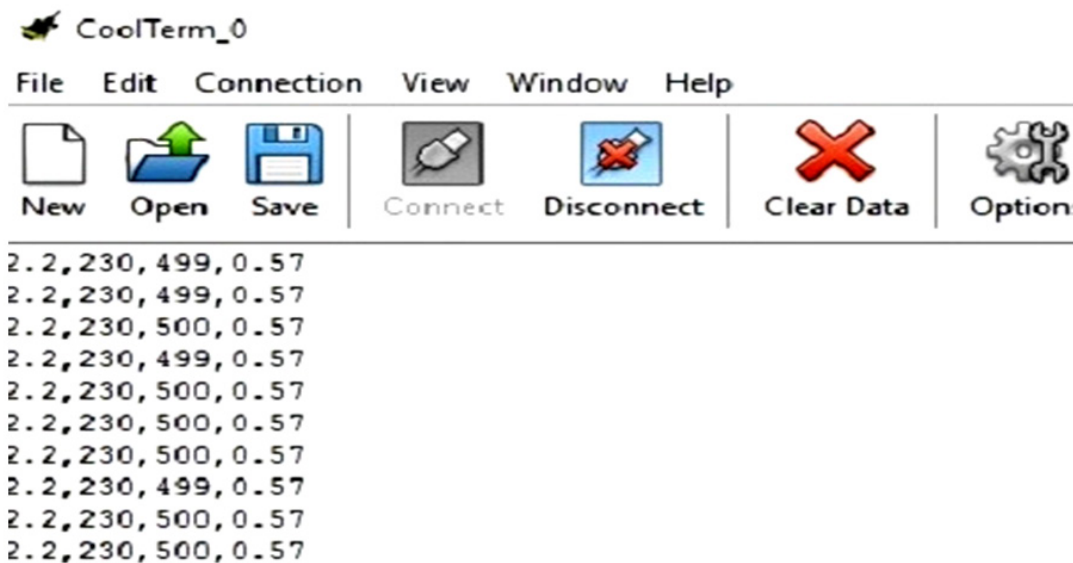### 5.3. Serial Data Communication through Coolterm

Figure 10: Serial data communication

6. CONCLUSION

This project work is an effort to design and implement the smart power factor Controller using Arduino microcontroller. There is also provision to define the own current minimum range and power factor minimum and maximum range. Arduino monitors both ranges continuously and then takes the control action according to the lagging and leading power factor. Therefore it provide more reliable and easily operated power factor controller. From the project we can see that maintaining the power factor of a system is one way to save power usage and prevent power losses during the operation and also increase the efficiency of the system. Also Installation of capacitors banks in power factor correctionsystem will bring benefit for consumer and electrical agency. This thesis makes possibleto store the real time action taken by the Arduino and this stored data can be accessed from anywhere in the world using internetthrough cloud computing by which reliabilityand efficiency of the system can be increased.

7.   FUTURE SCOPE

Future scope In future, the smart power factor correction system can be expands to improve the power factor of multi loads. There are so many ways for correcting the power factor of a system and one of it by using capacitors bank. This work is not tested on static var compensator or synchronous condenser because of huge amount of expense is required. The usage of another microcontroller beside Arduino can be done to see the effectiveness. Cloud computing technology can provide future power system more computation power which can be addressed by utilizing all the available computer resources. In future certain new accurate and reliable method of connecting Arduino with cloud computing technology can be implemented.

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