CHAPTER ONE

INTRODUCTION

1.1 General Concepts

The electrical energy is almost exclusively generated, Transmitted and distributed in the form of alternating current. Therefore, the question of power factor immediately comes into picture. Most of the loads (e.g. induction motors , arc lamps) are inductive in nature and hence have low lagging power factor. The low power factor is highly undesirable as it causes an increase in current, resulting in additional losses of active power in all the elements of power system from power station generator down the utilisation devices[1].

1.2 Problem Statement

In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. The higher currents increase the energy lost in the distribution system, and require larger wires and other equipment. Because of the costs of larger equipment and wasted energy, electrical utilities will usually charge a higher cost to industrial or commercial customers where there is a low power factor.

Linear loads with low power factor (such as induction motors) can be corrected with a passive network of capacitors or inductors. Non-linear loads, such as rectifiers, distort the current drawn from the system. In such cases, active or passive power factor correction may be used to counteract the distortion and raise the power factor. The devices for correction of the power factor may be at a central substation, spread out over a distribution system, or built into power-consuming equipment [1].

1.3 Objectives

The main objective of this project is to design a small automatic compensation unit, summarized as follow:

- Improve the power factor automatically.
- Reducing the voltage drops on installation.
- Increasing overall power.
- Savings on the electricity bill.
- Increase overall efficiency.

1.4 Methodology

By observing a real APFC panel from (Sue Gutter) company the general idea of designing an automatic power factor correction unit has been learned as shown in APPENDIX D. Depending on the same idea a simple model has been designed on a PCB.

1.5 Project Layout

This project is organized as follows:

Chapter One gives an introduction to the research including : general idea, problem statement, objectives, methodology .

Chapter Two describes the reactive energy, introduction to embedded system ,type of compensation and effect of harmonics.

Chapter Three shows the main components of the automatic power factor compensation unit.

Chapter Four explains the operation of the automatic power factor compensator unit.

Chapter Five gives conclusion and recommendations

Chapter two

Reactive Energy

2.1 Introduction

All AC electrical networks consume two types of power, active power and reactive power.

The active power (kW) is the real power transmitted to loads such as motors, lamps, heaters, computers … The electrical active power is transformed into mechanical power, heat or light.

$$P = VI\cos(\Theta) \quad (2.1)$$

The reactive power (kvar) is used only to supply the magnetic circuits of machines, motors and transformers .The apparent power (kVA) is the vector combination of active and reactive power. In this representation, the Power Factor (P/S) is equal to cosφ.

$$Q = VI\sin(\Theta) \quad (2.2)$$

The power factor is defined as the ratio of the active power (P) and volt-amperes (S),.

$$\text{Power Factor} = P/S = P/VI \quad (2.3)$$

For sinusoidal waveforms the power factor is the cosine of the phase angle Θ between voltage and current.

$$\text{Power factor} = \cos(\Theta) \quad (2.4)$$

All these three powers and the phase angle are show in the power triangle as shown in figure 2.1 below.

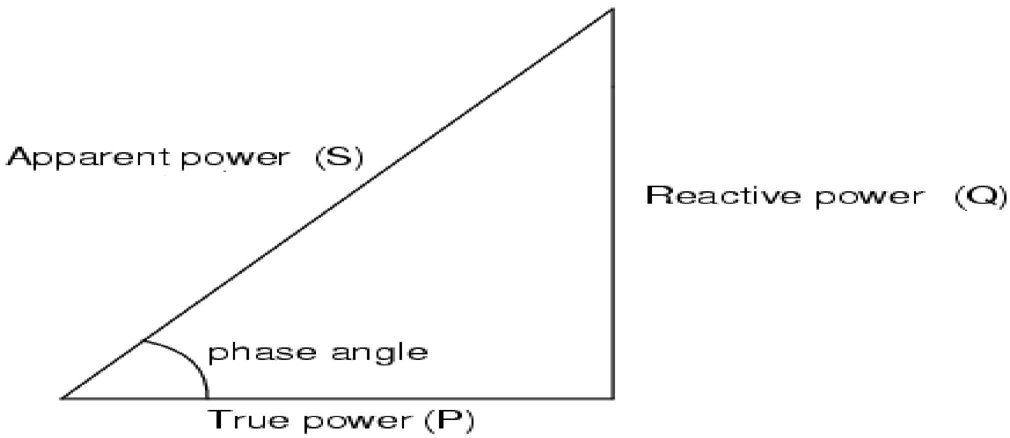


Figure 2.1: Power triangle

The supply voltage remains constant hence for a given P required by the load the current I taken by the load varies inversely as the load power factor cos(Θ). Thus a given load takes more current at a low power factor then it does at a high power factor as shown in equation below:

$$I = P / V \cos(\Theta) \tag{2.4}$$

The circulation of reactive power in the electrical network has major technical and economic consequences. For the same active power, a higher reactive power means a higher apparent power and thus, a higher current must be supplied.

The circulation of active power over time is resulting in active energy (in kWh).The circulation of reactive power over time is resulting in reactive [5].

2.2 Definition of Reactive Power

Reactive power is a concept used by engineers to describe background energy movement in alternating current system arising from the production of electric and magnetic fields.

These fields store energy which store energy by virtue of a magnetic field by flow of current are said to absorb reactive power, those which store energy by virtue of electric fields are said to generate reactive power[5].

2.3 Sources of Reactive Power

There are many sources of reactive power .

2.3.1 Synchronous Generators

Can generate or absorb reactive power depending on the excitation. When over excited they supply reactive power, and When under excited they absorb reactive power. The capability To continuously supply or absorb reactive power is, however, Limited by the field current, armature current and region of Heating limits. Synchronous generators are normally equipped With automatic voltage regulators which continually adjust The excitation so as to control the armature voltage.

2.3.2 Synchronous Compensators

Certain generators once run up to speed and synchronized to the system, can be declutched from their turbine and provide reactive power without producing real power, this mode of operation is called synchronous compensation.

2.3.3 Capacitive and Inductive Compensators

These are devices that can be connected to the system to adjust voltage level. A capacitive compensator produces an electric field there by generating reactive power whilst an inductive compensator produces a magnetic field to absorb reactive power. Compensation device are available as either capacitive or inductive alone or as hybrid to provide both generation and absorption of reactive power.

2.3.4 Over Head Line and Underground Cables

Overhead lines and underground cables, when operation at the normal system voltage, both produce strong electric field and so generation reactive power. When current flows through a line or cable it produces a magnetic field which absorbs reactive power. Lightly loaded overhead line is a net generator of reactive power whilst a heavily loaded line is a net Of reactive power. In the case of cables designed for use at 275 and 400 kva the reactive power generated by the electric field is always greater than the reactive power absorbed by the magnetic field and so cables are always net generators of reactive power.

2.3.5 Transformer

Transformer always absorb reactive power regardless of their loading, at no load the shunt magnetizing reactive effects predominate; and at full load, the series leakage inductance effects predominate.

Some loads such as motors produce a magnetic field and therefore absorb reactive power, but other customer loads such as fluorescent lighting generate reactive power.in addition reactive power may be generated or absorbed by the lines and cables of distribution system[4].

2.4 Introduction to Embedded Systems

An Embedded System is a combination of computer hardware and software, and perhaps additional mechanical or other parts, designed to perform a specific function. An embedded system is a microcontroller-based, software driven, reliable, real-time control system, autonomous, or human or network interactive, operating on diverse physical variables and in diverse environments and sold into a competitive and cost conscious market [1].

Applications

- Military and aerospace embedded software applications
- Communication Applications
- Industrial automation and process control software
- Mastering the complexity of applications.

2.5 Selection of Compensation Type

Different types of compensation shall be adopted depending on the performance requirements and complexity of control. Fixed by connection of a fixed-value capacitor bank. Automatic by connection of different number of steps allowing adjustment of the reactive energy to the requested value. Dynamic for compensation of highly fluctuating loads [3].

2.5.1 Fixed Compensation

This arrangement uses one or more capacitor(s) to provide a constant level of compensation. Control may be Manual by circuit breaker or load break switch.

Semi-automatic by contactor Direct connection to an appliance and switched with it. These capacitors are applied At the terminals of inductive loads (mainly motors). At bus bars supplying numerous small motors and inductive appliances for which individual compensation would be too costly In cases where the load factor is reasonably constant.

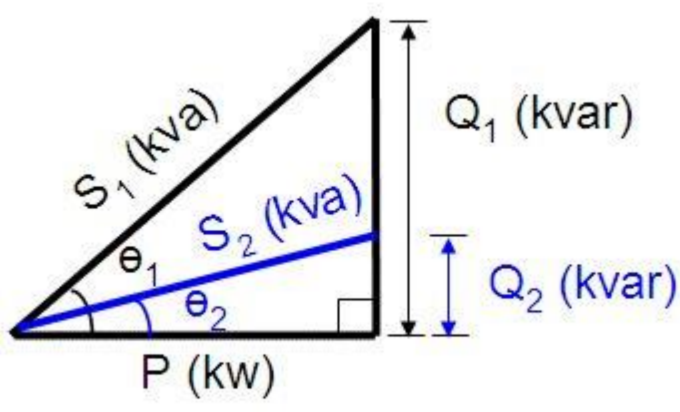


Figure 2.2: Injected reactive power

As we know the real power is constant for a constant load, so to reduce power factor the reactive power should be reduced according to the following equations [2]:

$$S1 = P+JQ1 \qquad (2.5)$$

The inserted capacitor bank add negative reactive power

$$Qc = Q1 - Q2 \qquad (2.6)$$

$$Q1 = V*I1*\sin(\Theta 1) \qquad (2.7)$$

$$Q2 = V*I2*\sin(\Theta 2) \qquad (2.8)$$

$$Qc = P(\tan(\Theta 1) - \tan(\Theta 2)) \qquad (2.9)$$

2.5.2 Automatic Compensation

This kind of compensation provides automatic control and adapts the quantity of reactive power to the variations of the installation in order to maintain the targeted cos φ. The equipment is applied at points in and installation where the active-power and/or reactive power variations are relatively large for example:

- At the bus-bars of a main distribution switch-board,
- At the terminals of a heavily-loaded feeder cable.

Where the kvar rating of the capacitors is less than, or equal to 15% of the supply transformer rating, a fixed value of compensation is appropriate. Above the 15% level, it is advisable to install an automatically-controlled bank of capacitors. Control is usually provided by contactors. For compensation of highly fluctuating loads, fast and highly repetitive connection of capacitors is necessary, and static switches must be used [3].

2.5.3 Dynamic compensation

This kind of compensation is requested when fluctuating loads are present, and voltage fluctuations should be avoided. The principle of dynamic compensation is to associate a fixed capacitor bank and an electronic VAR compensator, providing either leading or lagging reactive currents.

The result is a continuously varying and fast compensation, perfectly suitable for loads such as lifts, crushers, spot welding,etc [3].

2.6 Effects of Harmonics

There are effect of harmonics in electrical installation and capacitors.

2.6.1 Harmonics in Electrical Installations

The presence of harmonics in electrical systems means that current and voltage are distorted and deviate from sinusoidal waveforms. Harmonic currents are currents circulating in the networks and which frequency is an integer multiple of the supply frequency. Harmonic currents are caused by non-linear loads connected to the distribution system. A load is said to be non-linear when the current it draws does not have the same waveform as the supply voltage. The flow of harmonic currents through system impedances in turn creates voltage harmonics, which distort the supply voltage. The most common non-linear loads generating harmonic currents are using power electronics, such as variable speed drives, rectifiers, inverters, etc…. Loads such as saturable reactors, welding equipment, arc furnaces ,also generate harmonics. Other loads such as inductors, resistors and capacitors are linear loads and do not generate harmonics [3].

2.6.2 Influence of Harmonics in Capacitors

Capacitors are particularly sensitive to harmonic currents since their impedance decreases proportionally to the order of the harmonics present. This can result in a capacitor overload, shortening steadily its operating life. In some extreme situations, resonance can occur, resulting in an amplification of harmonic currents and a very high voltage distortion.

Amplification of Harmonic currents is very high when the natural resonance frequency of the capacitor and the network combined happens to be close to any of the harmonic frequencies present. This situation could result in severe over voltages and overloads which will lead to premature failure of capacitors

To ensure a good and proper operation of the electrical installation, the harmonic level must be taken into account in the selection of the power factor correction equipment. A significant parameter is the cumulated power of the non-linear loads generating harmonic currents [3].

CHAPTER THREE

CIRCUIT EQUIPMENT

This chapter mention the main components of this project and explains their main function which described as follow:

3.1 Transformer

Transformers convert AC electricity from one voltage to another with a little loss of power. Step-up transformers increase voltage, step-down transformers reduce voltage. Most power supplies use a step-down transformer to reduce the dangerously high voltage to a safer low voltage. Figure 3.1 shows a typical transformer.

Figure 3.1: A Typical Transformer

The input coil is called the primary and the output coil is called the secondary. There is no electrical connection between the two coils; instead they are linked by an alternating magnetic field created in the soft-iron core of the transformer. The two lines in the middle of the circuit symbol represent the core. Transformers waste very little power so the power out is (almost) equal to the power in. Note that as voltage is stepped down and current is stepped up [4].

The ratio of the number of turns on each coil, called the turn's ratio, determines the ratio of the voltages. A step-down transformer has a large number of turns on its primary (input) coil which is connected to the high voltage mains supply, and a small number of turns on its secondary (output) coil to give a low output voltage. The turns ratio can be calculated using equation (3.1)

TURNS RATIO = (Vp/Vs) = (Np / Ns) (3.1)

3.2 Voltage Regulator

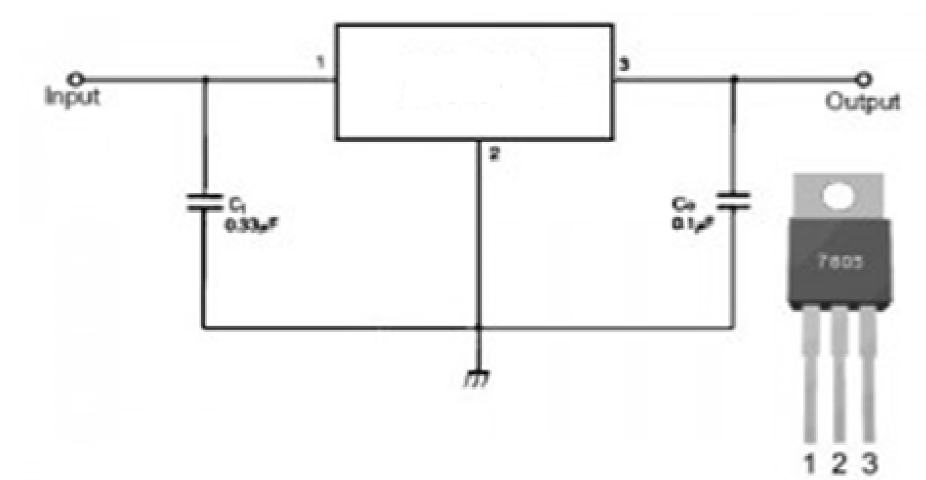


Figure 3.2 : Voltage Regulator

The LM78XX/LM78XXA series of three-terminal positive regulators are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a Wide range of applications. Each type employs internal current limiting, thermal shutdown and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output Current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents [1].

3.3 Rectifier

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), current that flows in only one direction, a process known as rectification. Rectifiers have many uses including as components of power supplies and as detectors of radio signals. Rectifiers may be made of solid state diodes, vacuum tube diodes, mercury arc valves, and other components. The output from the transformer is fed to the rectifier. It converts A.C. into pulsating D.C. The rectifier may be a half wave or a full wave rectifier. In this project, a bridge rectifier is used because of its merits like good stability and full wave rectification. In positive half cycle only two diodes (1 set of parallel diodes) will conduct, in negative half cycle remaining two diodes will conduct and they will conduct only in forward bias only [4]. As shown in figure (3.3).

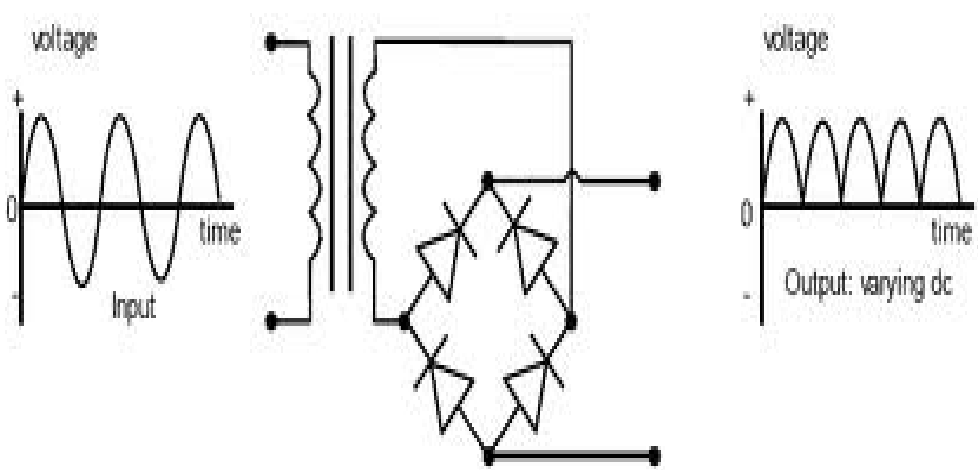


Figure 3.3: Bridge Rectifier

3.4 Filter

Capacitive filter is used in this project. It removes the ripples from the output of rectifier and smoothens the D.C. Output received from this filter is constant until the mains voltage and load is maintained constant. However, if either of the two is varied, D.C. voltage received at this point changes. Therefore a regulator is applied at the output stage.

The simple capacitor filter is the most basic type of power supply filter. The use of this filter is very limited. It is sometimes used on extremely high-voltage, low-current power supplies for cathode-ray and similar electron tubes that require very little load current from the supply. This filter is also used in circuits where the power-supply ripple frequency is not critical and can be relatively high. Below figure (3.4) can show how the capacitor charges and discharges [4].

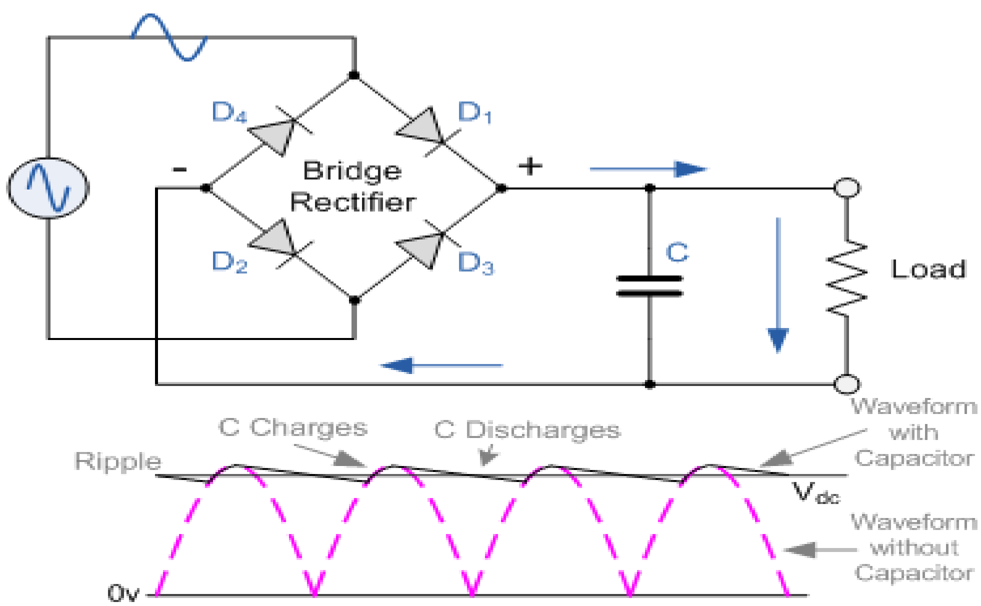


Figure 3.4: Waveform after Bridge Rectifier and A Filter

3.5 Microcontroller (AT89S52)

The "AT89S52" is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device is manufactured using Atmel's high-density non volatile memory technology and is compatible with the industry standard 80C51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non volatile memory programmer. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S52 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications. The AT89S52 provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry. In addition, the AT89S52 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM contents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset. The figure below shows the pin diagram of AT89S52 model [2].

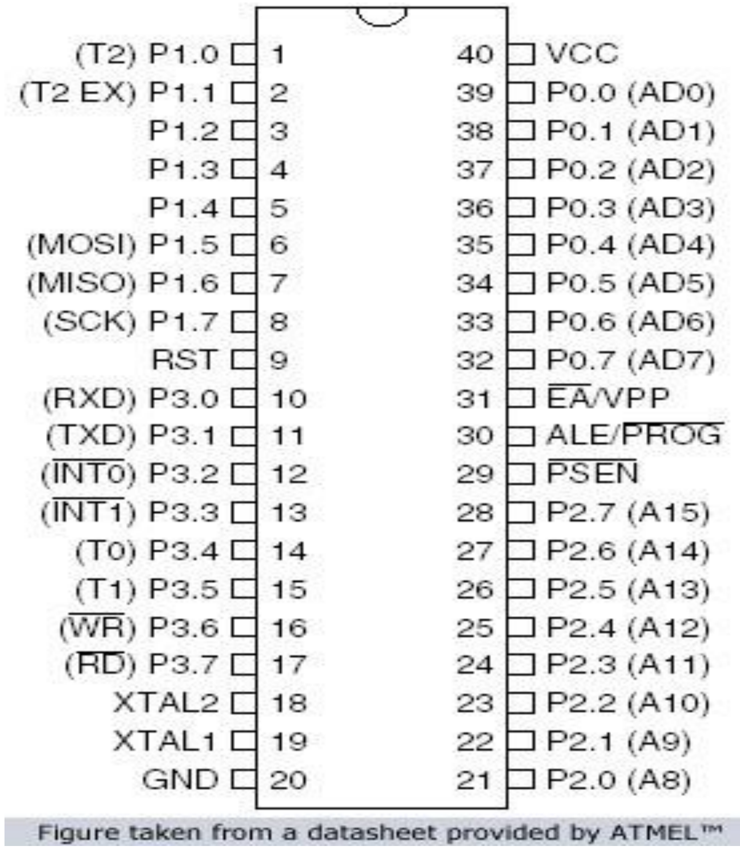


Figure 3.5: Pin diagram of (AT89S52)

3.6 Relay

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and most have double throw (changeover) switch contacts as shown in the diagram.

Relays allow one circuit to switch a second circuit which can be 0completely separate from the first. For example a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits; the link is magnetic and mechanical [4].

3.7 Relay Driver (ULN2003)

The ULN2003 is a monolithic high voltage and high current Darlington transistor arrays. It consists of seven NPN Darlington pairs that feature high-voltage outputs with common-cathode Clamp diode for switching inductive loads. The collector-current rating of a single Darlington pair is 500mA. The Darlington pairs may be paralleled for higher current capability. Applications include relay drivers, hammer drivers, lamp drivers, display drivers (LED gas discharge), line drivers, and logic buffers.

The ULN2003 has a 2.7kW series base resistor for each Darlington pair for operation directly with TTL or 5V CMOS devices. As shown in figure (3.6) [4].

Figure 3.6: Relay driver (ULN2003**)**

3.8 Push Buttons

A push button (also spelled push button) or simply button is a simple switch mechanism for controlling some aspect of a machine or a process. Buttons are typically made out of hard material, usually plastic or metal. The surface is usually flat or shaped to accommodate the human finger or hand, so as to be easily depressed or pushed. Buttons are most often biased switches, though even many un-biased buttons (due to their physical nature) require a spring to return to their un-pushed state. Different people use different terms for the "pushing" of the button, such as press, depress, mash, and punch [4]. Different examples of push buttons are show in figure (3.7) below:

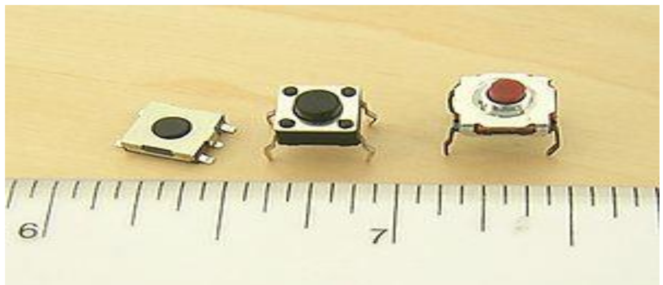


Figure 3.7: Push buttons

3.9 Liquid Crystal Display

This is the first interfacing example for the Parallel Port. We will start with something simple. This example doesn't use the Bi-directional feature found on newer ports, thus it should work with most, if not all Parallel Ports. It however doesn't show the use of the Status Port as an input for a 16 Character x 2 Line LCD Module to the Parallel Port. These LCD Modules are very common these days, and are quite simple to work with, as all the logic required running them is on board [2].

3.9.1 LCD BACKGROUND (44780)

The 44780 standard requires 3 control lines as well as either 4 or 8 I/O lines for the data bus as shown in figure (3.8). The user may select whether the LCD is to operate with a 4-bit data bus or an 8-bit data bus. If a 4-bit data bus is used the LCD will require a total of 7 data lines (3 control lines plus the 4 lines for the data bus). If an 8-bit data bus is used the LCD will require a total of 11 data lines (3 control lines plus the 8 lines for the data bus).

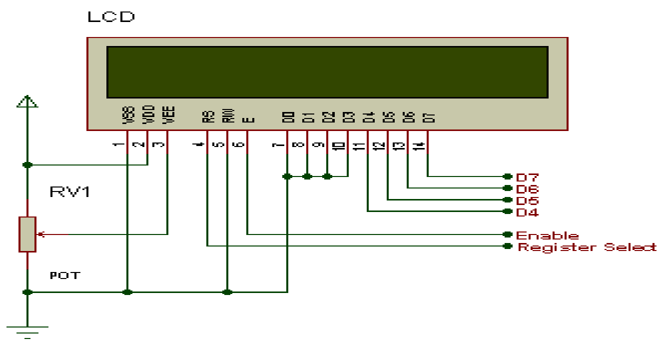


Figure 3.8 : LCD Background (44780)

The three control lines are referred to as **EN**, **RS**, and **RW**.The **EN** line is called "Enable." This control line is used to tell the LCD that you are sending it data. To send data to the LCD, your program should make sure this line is low (0) and then set the other two control lines and/or put data on the data bus. When the other lines are completely ready, bring **EN** high (1) and wait for the minimum amount of time required by the LCD datasheet (this varies from LCD to LCD), and end by bringing it low (0) again.The **RS** line is the "Register Select" line. When RS is low (0), the data is to be treated as a command or special instruction (such as clear screen, position cursor, etc.). When RS is high (1), the data being sent is text data which should be displayed on the screen. For example, to display the letter "T" on the screen you would set RS high. The **RW** line is the "Read/Write" control line. When RW is low (0), the information on the data bus is being written to the LCD. When RW is high (1), the program is effectively querying (or reading) the LCD. Only one instruction ("Get LCD status") is a read command. All others are write commands--so RW will almost always be low .Finally, the data bus consists of 4 or 8 lines (depending on the mode of operation selected by the user). In the case of an 8-bit data bus, the lines are referred to as DB0, DB1, DB2, DB3, DB4, DB5, DB6, and DB7 [2].

3.10 Quad Voltage Comparator (LM339)

The LM339 consists of four independent precision voltage comparators, with an offset voltage specification as low as 20㎷ max for each comparator, which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

These comparators also have a unique characteristic in that the input common-mode voltage range includes ground, even though they are operated from a single power supply voltage. The LM339 series was designed to directly interface with TTL and CMOS. When operated from both plus and minus power supplies, the LM339 series will directly interface with MOS logic where their low power drain is a distinct advantage over standard comparators [1]. The (LM339N) quad voltage comparator is shown in figure (3.9) below:

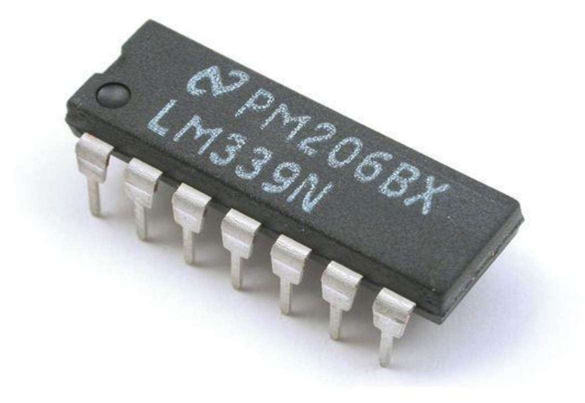


Figure 3.9:Quad Voltage Comparator (LM339N)

3.11 Current Transformer

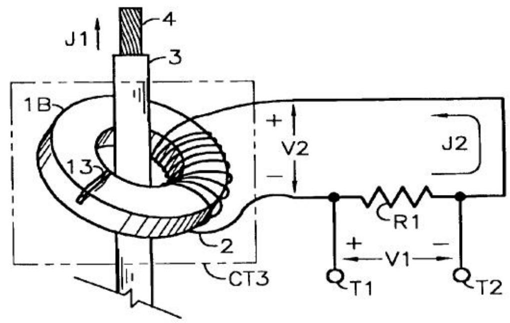


Figure 3.10: Current Transformer

In electrical engineering, a current transformer (CT) is used for measurement of electric currents. Current transformers, together with voltage transformers (VT) (potential transformers (PT)), are known as instrument transformers. When current in a circuit is too high to directly apply to measuring instruments, a current transformer produces a reduced current accurately proportional to the current in the circuit, which can be conveniently connected to measuring and recording instruments. A current transformer also isolates the measuring instruments from what may be very high voltage in the monitored circuit. Current transformers are commonly used in metering and protective relays in the electrical power industry [4]. Figure (3.10) above shows a simple type of current transformer.

3.12 Inductive Load

Figure 3.11: Inductive load

A load that is predominantly inductive, so that the alternating load current lags behind the alternating voltage of the load. Also known as lagging load. Any devices that have coils of wire in there manufacture can be classed as inductive loads. E.g. motors, solenoids and contactor coils are a few. Example of resistive loads can be baseboard heaters, filament light bulbs, toasters and stove top elements [4]. An inductive load is shown above in figure (3.11).

3.13 Shunt Capacitors

Figure 3.12: Shunt capacitors

Shunt capacitor banks are used to improve the quality of the electrical supply and the efficient operation of the power system. Studies show that a flat voltage profile on the system can significantly reduce line losses. Shunt capacitor banks are relatively inexpensive and can be easily installed anywhere on the network [4]. Different types of shunt capacitors are shown in figure (3.12) above.

3.14 LED

LEDs are semiconductor devices. Like transistors, and other diodes, LEDs are made out of silicon. What makes an LED give off light are the small amounts of chemical impurities that are added to the silicon, such as gallium, arsenide, indium, and nitride. When current passes through the LED, it emits photons as a byproduct. Normal light bulbs produce light by heating a metal filament until it is white hot. LEDs produce photons directly and not via heat, they are far more efficient than incandescent bulbs [5]. Figure (3.13) shows typical LED (a) & circuit symbol (b).

Figure 3.13: LED

3.15 Diodes

Different diodes are used in this project.

3.15.1 Rectifier Diode (1N4007)

Diodes are used to convert AC into DC these are used as half wave rectifier or full wave rectifier. Three points must he kept in mind while using any type of diode [5].

- Maximum forward current capacity
- Maximum reverse voltage capacity
- Maximum forward voltage capacity

Figures 3.14 shows a PN diode (a), electrical symbol (b|) and voltage – current curve of silicon diode (c).

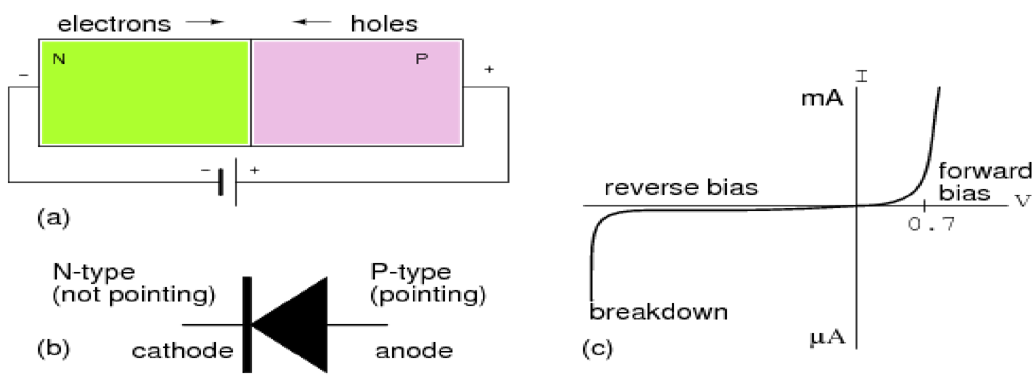


Figure 3.14: Rectifier Diode (1N4007)

3.15.2 Signal Silicon Diode (1N4148)

The 1N4148 is a standard small signal silicon diode used in signal processing. Its name follows the JEDEC nomenclature. The 1N4148 is generally available in a DO-35 glass package and is very useful at high frequencies with a reverse recovery time of no more than 4ns. This permits rectification and detection of radio frequency signals very effectively, as long as their amplitude is above the forward conduction threshold of silicon (around 0.7V) or the diode is biased. Figure (3.15) shows a signal silicon diode [5].

Figure 3.15: Signal silicon diode (1N4148)

3.16 Resistors

A resistor is a two-terminal electronic component designed to oppose an electric current by producing a voltage drop between its terminals in proportion to the current, that is, in accordance with Ohm's law:

$$V = IR \qquad (3.2)$$

Resistors are used as part of electrical networks and electronic circuits. They are extremely commonplace in most electronic equipment. Practical resistors can be made of various compounds and films, as well as resistance wire (wire made of a high-resistivity alloy, such as nickel/chrome).

Two types of resistors are used:

3.16.1 Adjustable Resistors

A resistor may have one or more fixed tapping points so that the resistance can be changed by moving the connecting wires to different terminals. Some wire wound power resistors have a tapping point that can slide along the resistance element, allowing a larger or smaller part of the resistance to be used.

Where continuous adjustment of the resistance value during operation of equipment is required, the sliding resistance tap can be connected to a knob accessible to an operator. Such a device is called a rheostat and has two terminals.

3.16.2 Potentiometers

A common element in electronic devices is a three-terminal resistor with a continuously adjustable tapping point controlled by rotation of a shaft or knob. These variable resistors are known as potentiometers when all three terminals are present, since they act as a continuously adjustable voltage divider. A common example is a volume control for a radio receiver.

Accurate, high-resolution panel-mounted potentiometers (or "pots") have resistance elements typically wire wound on a helical mandrel, although some include a conductive-plastic resistance coating over the wire to improve resolution. These typically offer ten turns of their shafts to cover their full range. They are usually set with dials that include a simple turns counter and a graduated dial. Electronic analog computers used them in quantity for setting coefficients, and delayed-sweep oscilloscopes of recent decades included one on their panels [5].

3.17 Capacitors

A capacitor (formerly known as condenser) is a device for storing electric charge. The forms of practical capacitors vary widely, but all contain at least two conductors separated by a non-conductor. Capacitors used as parts of electrical systems, for example, consist of metal foils separated by a layer of insulating film.

Capacitors are widely used in electronic circuits for blocking direct current while allowing alternating current to pass, in filter networks, for smoothing the output of power supplies, in the resonant circuits that tune radios to particular frequencies and for many other purposes [5]. Different sizes of capacitors are shown in figure (3.16).

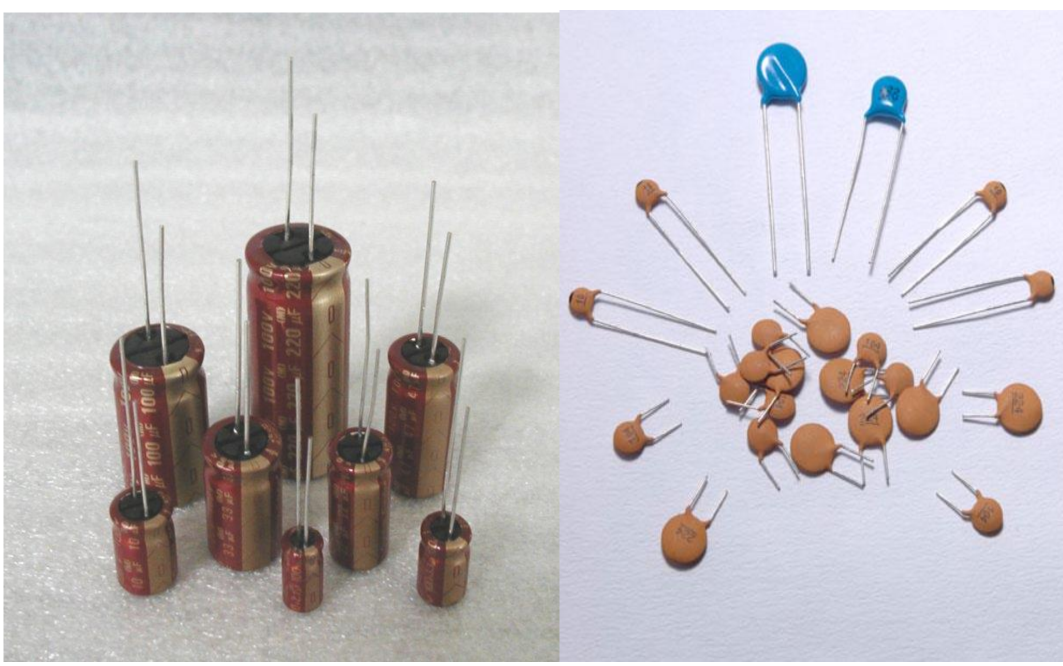


Figure 3.16: Capacitors

CHAPTER FOUR

CIRCUIT OPERATION

4.1 Flow Chart

The control algorithm for automatic power factor correction is represented using flow chart shown in figure (4.1) below:

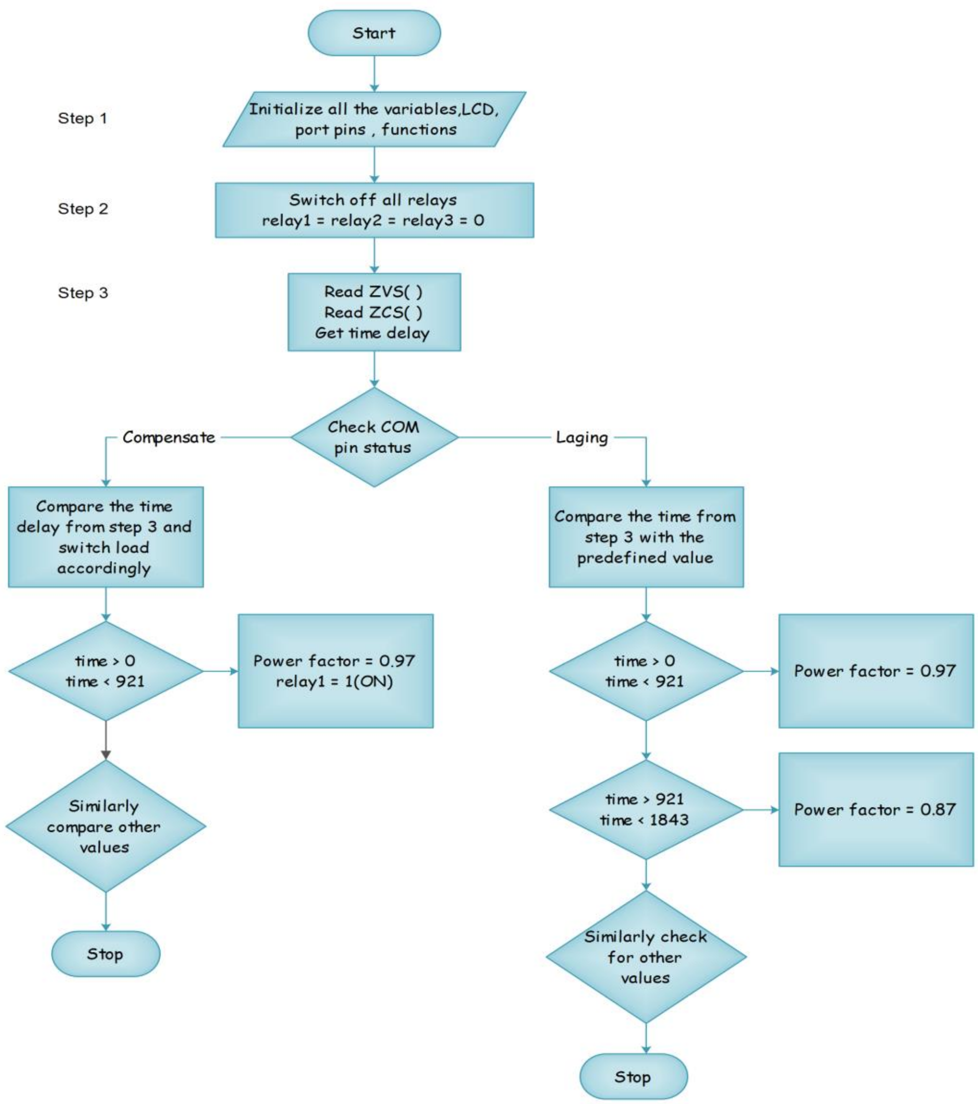


Figure 4.1: Flow Chart

The control circuit was designed on a PCB shown in figure (4.2) below:

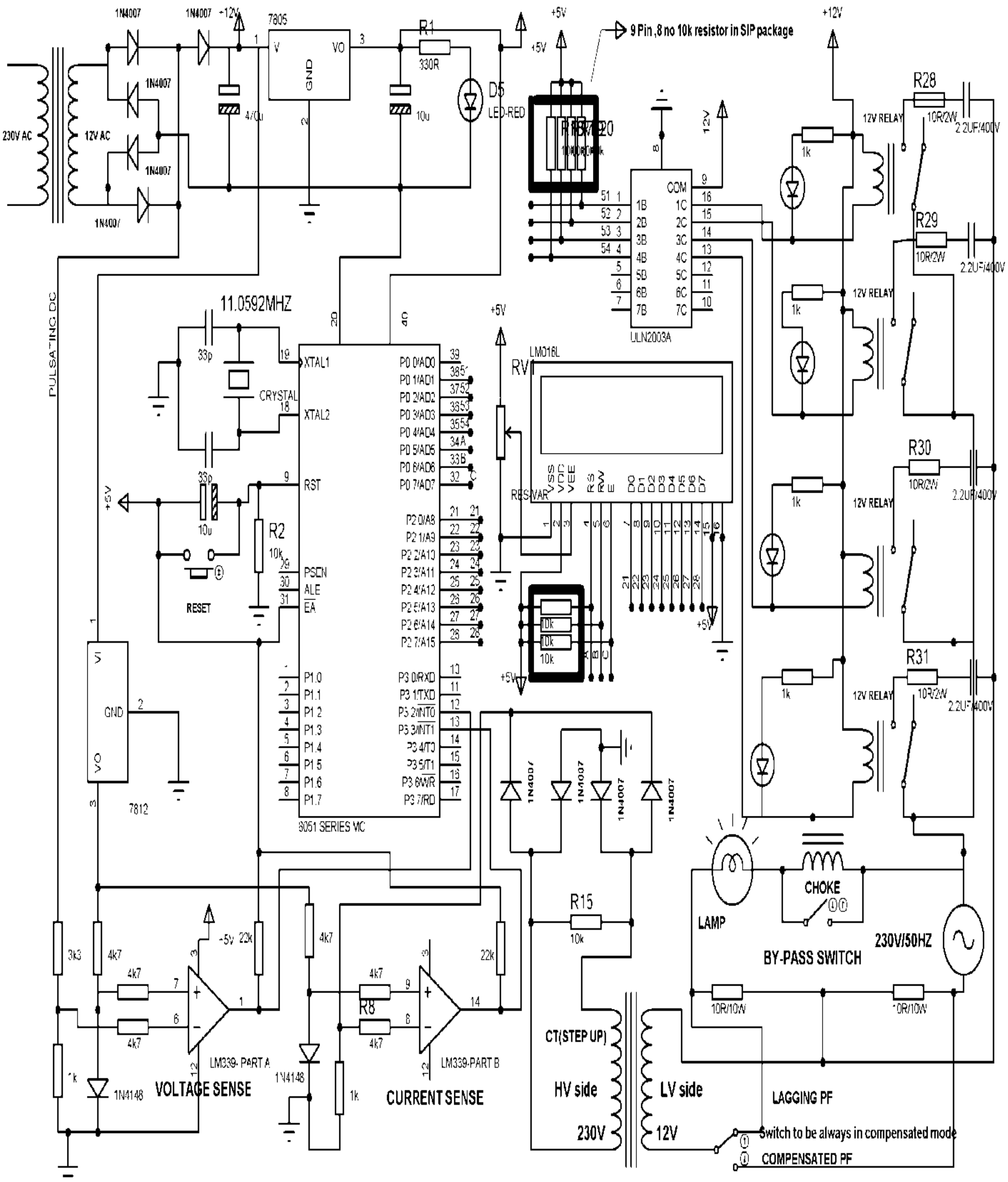


Figure 4.2 : Diagram of Project

4.2 Power Supply

The circuit uses standard power supply comprising of a step-down transformer from 230Vto 12V and 4 diodes forming a bridge rectifier that delivers pulsating dc which is then filtered by an electrolytic capacitor of about 470µF to 1000µF. The filtered dc being unregulated, IC LM7805 is used to get 5V DC constant at its pin no 3 irrespective of input DC varying from 7V to 15V. The input dc shall be varying in the event of input ac at 230volts section varies from 160V to 270V in the ratio of the transformer primary voltage V1 to secondary voltage V2 governed by the formula V1/V2=N1/N2. As N1/N2 i.e. no. of turns in the primary to the no. of turns in the secondary remains unchanged V2 is directly proportional to V1.Thus if the transformer delivers 12V at 220V input it will give 8.72V at 160V.Similarly at 270V it will give 14.72V.Thus the dc voltage at the input of the regulator changes from about 8V to 15V because of AC voltage variation from 160V to 270V the regulator output will remain constant at 5V.

The regulated 5V DC is further filtered by a small electrolytic capacitor of 10µF for any noise so generated by the circuit. One LED is connected of this 5V point in series with a current limiting resistor of 330Ω to the ground i.e., negative voltage to indicate 5V power supply availability. The unregulated 12V point is used for other applications as and when required [1].

4.3 Operation Explanation

The connection, working and the circuit explanation of the automatic power factor correction unit is explained below:

4.3.1 Connections

The output of power supply which is 5v is connected to the 40^{th} pin of microcontroller and GND to the 20^{th} pin or pin 20 of microcontroller. Port 0.1

to 0.4 of microcontroller is connected to Pin 1to 4 of relay driver IC ULN2003. Port 0.5 to 0.7 of microcontroller is connected to Pin 4,5 and 6 of LCD display. Port 2.0 to 2.7 of microcontroller is connected to Pin 7 to 14 of data pins of LCD display. Port 3.1 of microcontroller is connected to output of the OP-Amp (A) LM339. Port 3.3 of microcontroller is connected to output of OP-Amp (B) LM339.

4.3.2 WORKING

The output of the regulator 7805 is given to the Microcontroller 40^{th} pin. The pulsating dc is fed to R_{11} and R_{24} Resistor's. The unregulated voltage is fed to 7812. 7805 output which is 5v is fed to 40^{th} pin of Microcontroller. The output of the 7812 regulator is 12v and is fed to op-Amp. In this circuit we have another bridge rectifier it gives an output as pulsating dc corresponding to the current flowing across the load. The LCD display is connected to corresponding pins. Relay driver drive's relay's and the contacts of relays switch ON the shunt capacitors.

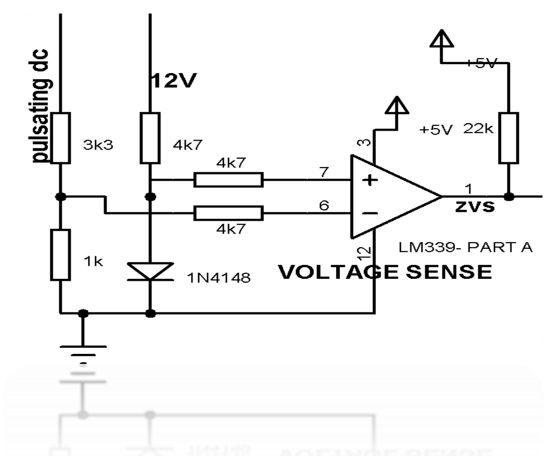


Figure 4.3 : Zero Voltage Sense

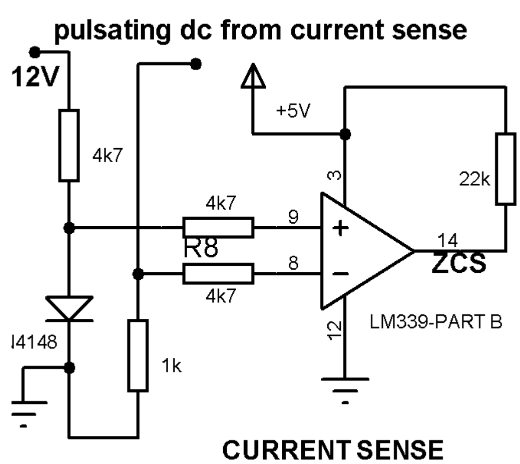


Figure 4.4 : Zero Current Sense

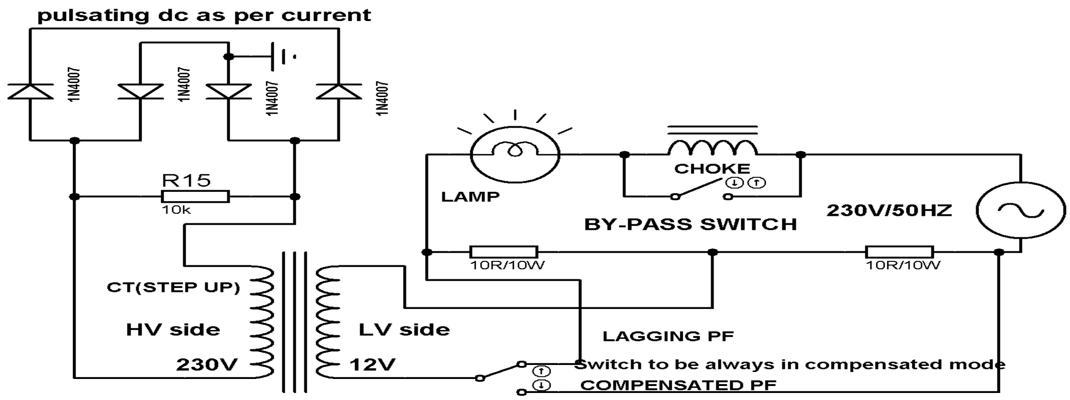


Figure 4.5 : Connection Circuit

In order to generate ZVS (Zero Voltage Sensing) pulses first we need to step down the supply voltage to 12 V and then it is converted into pulsating D.C. Then with the help of potential divider the voltage of 3 V is taken, which is given to a comparator LM339 part A. The comparator generates the zero crossing pulses by comparing this pulsating D.C with a constant D.C of 0.6 V forward voltage drop across a silicon diode.

Similarly for ZCS (Zero Current Sense) the voltage drop proportional to the load current across a resistor of 10R/10W is taken and is stepped up by a CT to feed to a bridge rectifier to generate pulsating dc for the comparator to develop ZCS as explained above like ZVS. The zero crossing pulses from a pulsating D.C [1]. Figures (4.3) and (4.4) shows the circuit diagram of ZVS and ZCS.

4.3.3 Circuit Explanation

This circuit consists of DC power supply unit, zero voltage crossing detectors, Micro-controller, LCD display, Relays and Capacitor bank and Load circuit. Let us see how it operates. The required DC power supply for Micro-controller and other peripherals is supplied by the DC power supply.

For the calculation of the power factor by the Micro-controller we need digitized voltage and current signals. The voltage signal from the mains is taken and it is converted into pulsating DC by bridge rectifier and is given to a comparator which generates the digital voltage signal. Similarly the current signal is converted into the voltage signal by taking the voltage drop of the load current across a resistor of 10 ohms. This A.C signal is again converted into the digital signal as done for the voltage signal. Then these digitized voltage and current signals are sent to the micro-controller. The micro-controller calculates the time difference between the zero crossing points of current and voltage, which is directly proportional to the power factor and it determines the range in which the power factor is. Micro-controller sends information regarding time difference between current and voltage and power factor to the LCD display to display them, Depending on the range it sends the signals to the relays through the relay driver. Then the required numbers of capacitors are connected in parallel to the load. By this the power factor will be improved [1].

Table 4.1 : Relation Between Delay Time, Delay Angle & Power Factor.

Delay Time in msec	Delay Angle (90/5)*Time in msec	Power Factor Cos(angle*pi/180)
0.5	9	0.987688341
0.6	10.8	0.982287251
0.7	12.6	0.975916762 Average PF
0.8	14.4	0.968583161
0.9	16.2	0.960293686 1st relay
1.1	19.8	0.940880769
1.2	21.6	0.929776486
1.3	23.4	0.917754626
1.4	25.2	0.904827052
1.5	27	0.891006524 Average PF
1.6	28.8	0.87630668
1.7	30.6	0.860742027
1.8	32.4	0.844327926 2nd relay

1.9	34.2	0.827080574
2	36	0.809016994
2.1	37.8	0.790155012
2.2	39.6	0.770513243
2.3	41.4	0.75011107
2.4	43.2	0.728968627 Average PF
2.5	45	0.707106781
2.6	46.8	0.684547106
2.7	48.6	0.661311865 3rd relay
2.8	50.4	0.63742399
2.9	52.2	0.612907054
3	54	0.587785252
3.1	55.8	0.562083378
3.2	57.6	0.535826795
3.3	59.4	0.509041416 Average PF
3.4	61.2	0.481753674
3.5	63	0.4539905
3.6	64.8	0.425779292 4th relay

Note: For a 50 Hz supply half cycle is 10 msec = 180degree or 90deg=5msec .

Note:

The objective behind the project is to understand the very concept & the technology adopted. It is a student level project work and not a commercial product which are too expensive for a student level work. The capacitor value required and the extent of PF improvement taking place are not the aim of the project. Such parameters are to be taken into consideration once it is developed to a commercial product. Load current magnitude and KVR requirement of capacitors are of paramount importance then. Our project does not measure the load current magnitude nor the KVR requirement of the capacitors but simply considers the time difference between the voltage and the current. We simply follow the following table to read the delay time and switch on as many capacitors as required across the inductive load to bring the pf to near unity as decided by the program .In order to simplify we have taken 4 capacitors only and have taken 4 sets of time delay range. Thus between 0.5 to 921 uSec (0.9ms) delay for average pf display of (0.975916762) pf by switching 1st relay. Then from 921 to 1843 u Sec (1.8ms) delay for average pf of (0.891006524) pf by switching 2nd relay. And so on for 3rd and 4th relay.

4.4 Discussion

Figure 4.6 shows the system before inserting the inductive load . We notice that the LCD screen shows the unity power factor due pure resistance. No correction is needed in this case.

Figure 4.7 shows the system after inserting the inductive load. The LCD screen show that the power factor decreases to 0.71,so the micro-controller gives order to insert capacitor banks.to raise the power factor to setting value (0.95).

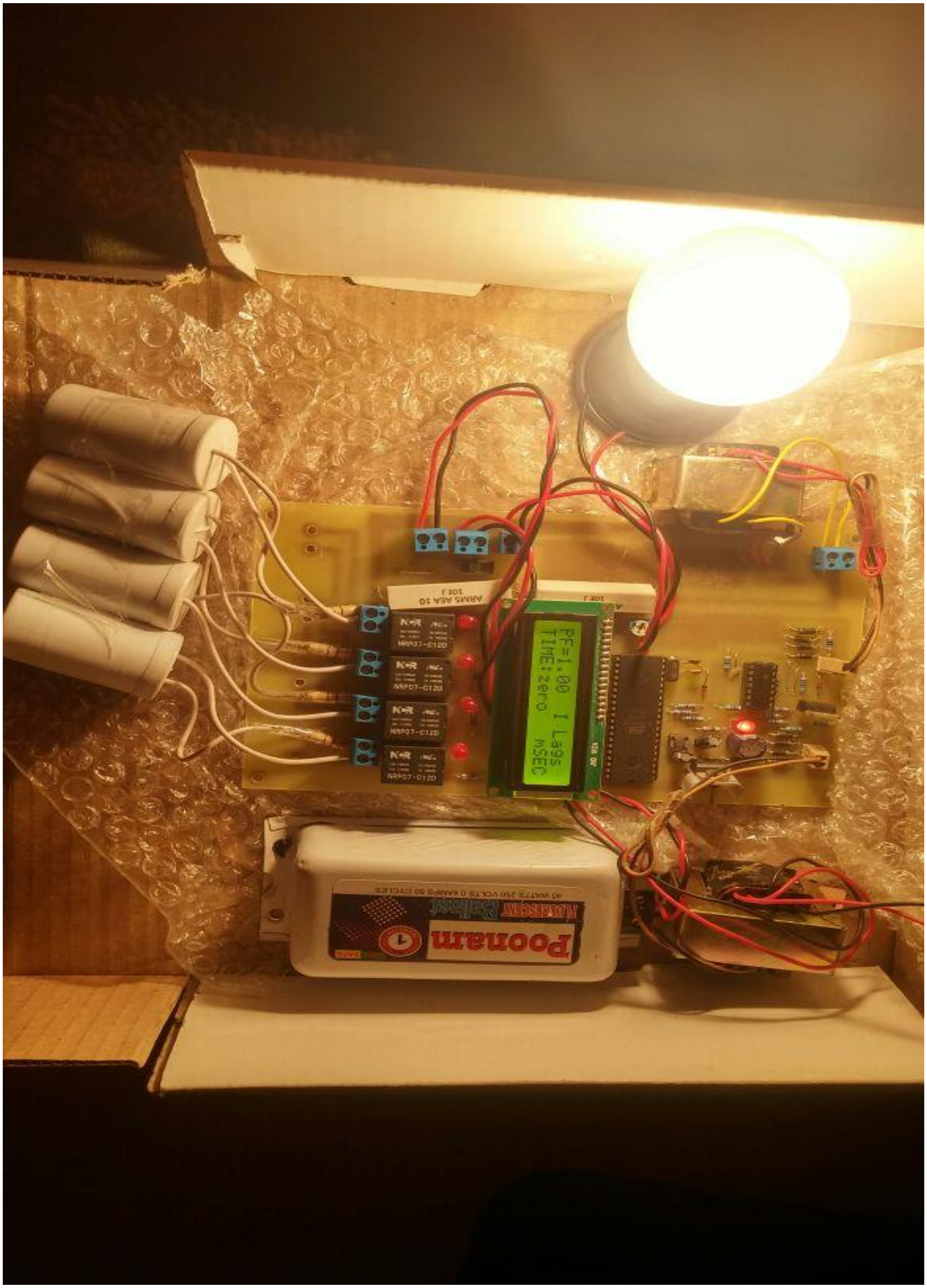


Figure 4.6: Circuit before correction

Figure 4.7 : Circuit after correction

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Power Factor is considered as a basic factor in the AC power system due to the most of recent studies concentrate in power factor controlled by designing circuit of control system so as to conserve the level of it. The microcontroller is used to automatically correct the power factor by giving the order to relay drivers to insert shunt capacitors as reaction to inductive load inserted to raise the power factor to the required value. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S52 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications.

5.2 Recommendations

- To use an advanced relay to control the current entering the capacitors to protect the capacitors from saturation.
- To use special capacitors with additional protection system that has a valve that expands when the pressure increases inside the capacitors to remove the capacitors from the circuit when the heat reaches a high value.
- Using thyristor control switch instead of relay control to avoid contact pitting often encountered by switching of capacitor due to high in rush current.

References

[1] Ashfag Husain "Electrical Power Systems", CBS PUBLISHERS & DISTIBUTORS PVT. LTD, 2014.

[2] Muhammad Ali Mazidi and Janice Gillispie Mazidi “The 8051 Microcontroller and Embedded systems” , Pearson Education.

[3] Schneider electric “Guide for design and production of LV power factor correction, cubicles” by,2011.

[4] Dale R. Patrick,”Electrical Power System Technology”, Fairmont Press,2008.

[5] B.L.Theraja and A.K.Theraja,”Electrical Technology”, S.CHAND & COMPANY LTD,2005.

APPENDIX A

```
#include<reg52.h>
#include<intrins.h>
#include<string.h>
#include<stdio.h>

#define LCD_DATA P2

sbit relay1=P0^1;
sbit relay2=P0^2;
sbit relay3=P0^3;
sbit relay4=P0^4;
sbit zero_ref =P3^2;
sbit current =P3^3;

sbit busy_f  =P2^7;
sbit RS =P0^5;
sbit RW =P0^6;
sbit EN =P0^7;
unsigned int i,j,m,one,k,t2value,total,value;
unsigned int m _at_ 0x30;
unsigned int k _at_ 0x40;
unsigned char byte1,byte2;
float last,last1;
unsigned int previous;
unsigned char test1,test2,test3,test4,test5,test6,test7;
```

```
unsigned char bit1,bit2,bit3,bit4,bit5,bit6 _at_ 0x45;
unsigned char upper,lower,upper1,lower1,upper2,lower2;
void initlcd(void);

typedef unsigned char UCH;
typedef unsigned int UIT;

void ponstr1(unsigned char*,unsigned char);
void ponstr2(unsigned char*,unsigned char);
void ponstr3(unsigned char*,unsigned char);

void ponstr4(unsigned char*,unsigned char);
void ponstr5(unsigned char*,unsigned char);
void ponstr6(unsigned char*,unsigned char);


void lcdcmd(unsigned char);
void lcddata(unsigned char);
void lcdbusy_check(void);
void addr(unsigned char);
void disp(unsigned char);
void delay(unsigned int);
float  bcd_con(unsigned int);
void convascii(unsigned int);
void evalbits(float );
```

```
void dispascii();

void ascii(void);

extern void asm_function();

unsigned char code data1[] = "PF=";

unsigned char code data2[] = "TIME:";

unsigned char code data3[] = "mSEC";


unsigned char code data4[] = "I Lags";

unsigned char code data6[] = "V Lags"; //    modified 1


unsigned char code *data5;




void Initialize(void)

{

        EA=1;                   // ENABLE ALL INTERRUPT

                EX0=1;                  // ENABLE EXTERNAL INT0 INTERRUPT

                IT0=0;                  // MAKE FALLING EDGE TRIGGERED

                EX1=1;                  // ENABLE EXTERNAL INT1 INTERRUPT

                IT1=0;                  // MAKE FALLING EDGE TRIGGERED

}

void INT1_ISR (void) interrupt 0 using 1     //zvs interrupt service routine

{

        TH0 =0x00;                      // LOAD TH0 VALUE

        TL0 =0x00;                      // LOAD TL0 VALUE
```

```
        TH1 =0X00;                      // LOAD TH1 VALUE
        TL1 =0X00;                      // LOAD TL1 VALUE
        while(zero_ref==0);     // WAIT FOR ZVS
        TR0 =1;                         // START THE TIMER0
   upper=TH0;                   //copy data from timer0 high register
        lower=TL0;                      //copy data from timer0 low register

}
void INT0_ISR (void) interrupt 2 using 1    //zcs interrupt service routine
{
        TH0=upper;                              // LOAD TH0 VALUE
        TL0=lower;                      // LOAD TL0 VALUE
        while(current==0);              // WAIT FOR ZCS
        TR1 = 1;                        //start the timer1
        TR0 =0;                                 //stop the timer0
        upper1=TH1;                             //get the value from timer1 high register
        lower1=TL1;                             //get the value from timer1 low register
        upper =TH0;                             //get the value from timer0 high register
        lower =TL0;                             //get the value from timer0 low register
        TH0 =0x00;                              //clear the timer0 high register
        TL0 =0x00;                              //clear the timer0 low register
        TH1 =0X00;                              //clear the timer1 high register
        TL1 =0X00;                              //clear the timer1 low register
        TF1=0;                                  //clear the timer1 overflow flag
   TF0=0;                                       //clear the timer0 over flow flag
```

```
}

void main()
{
 unsigned char status = 0;
unsigned int value=0,value1=0;
 SP=0x60;
 LCD_DATA=0;
 zero_ref = 1;
 current = 1;
 relay1 = 0;                    //relay1 off
 relay2=0;                              //relay2 off
 relay3=0;                              //relay3 off
 relay4=0;                              //relay4 off
 initlcd();                     //Initialise the lcd
 ponstr1(data1,0x80);   //dispaly string on lcd 1st line
 ponstr2(data2,0x0c0); //dispaly string on lcd 2nd line
        Initialize();           ///Initialise the interrupts
        TMOD=0X11;                      //select the timer0 in mode1 and timer1 in mode1
        while(1)
        {  float stdby;
                unsigned char rare;

                 m=0,k=0;
                _nop_();                        //delay function
```

```
                _nop_();

                _nop_();

                _nop_();

                _nop_();

     k=k|upper;

                k=k<<8;

                k=k|lower;

                m=m|upper1;

                m=m<<8;

                m=m|lower1;

                m=m/2;

                k=k-m;

          stdby=bcd_con(k);

                stdby = stdby*1.085f;    //calculate the time difference between voltage and
current wave forms

                rare = stdby;

                if(previous!=rare)

                {

                  if(rare>=0 && rare<=921)        //Time difference b/w voltage and curent is
bwetween 0 to 1msec

                        {

                              ponstr4(data4,0x089); //dispaly string on lcd 1st line


                              status = 0;

                              data5 = "0.97  ";           //powerfacter is 0.97

                              rare = 0;
```

```
        dispascii();
  relay1=1;                         //relay1 on
  relay2=0;                         //relay2 off
  relay3=0;                         //relay3 off
        relay4=0;                          //relay4 off



}
else if(rare>921 && rare<=1843) //Time difference b/w voltage and
curent is  bwetween 1 to 2msec
{
        ponstr4(data4,0x089);  //dispaly string on lcd 1st line

        data5 = "0.87  ";           //powerfacter is 0.87
        status = 0;
 dispascii();
relay1=1;                           //relay1 on
  relay2=1;                         //relay2 on
  relay3=0;                         //relay3 off
        relay4=0;                          //relay4 off



}
else if(rare>1843 && rare<=2764)//Time difference b/w voltage and
curent is  bwetween 2 to 3msec
{
```

```
ponstr4(data4,0x089); //dispaly string on lcd 1st line


data5 = "0.79 ";          //powerfacter is 0.79

status = 0;

dispascii();

 relay1=1;                           //relay1 on

relay2=1;                            //relay2 on

relay3=1;                            //relay3 on

relay4=0;                            //relay4 off


}

else if(rare>2764 && rare<=3686)//Time difference b/w voltage and
curent is  bwetween 3 to 4msec

{

ponstr4(data4,0x089); //dispaly string on lcd 1st line

data5 = "0.51 "; //powerfacter is 0.51

status = 0;

 dispascii();

 relay1=1;                    //relay1 on

relay2=1;                     //relay2 on

relay3=1;                     //relay3 on

relay4=1;                     //relay1 on


}

else if(rare>3686 || rare<=4608)// COMPARE TIME BETWEEN VOLTAGE
AND CURRENT WAVEFORMS
```

```
{
        ponstr4(data4,0x089); //dispaly string on lcd 1st line

        data5 = "0.16  ";          //powerfacter is 0.16
        status = 0;
         dispascii();
         relay1=1;                       //relay1 on
  relay2=1;                       //relay2 on
  relay3=1;                       //relay3 on
        relay4=1;                       //relay1 on
}

else if((rare>4608)||(rare<5530)) //capacitive load 0 to 1msec
{

        ponstr4(data4,0x089); //dispaly string on lcd 1st line



        data5 = "0.82 "; //powerfacter is 0.82

        status = 1;
                dispascii();
         relay1=0;                       //relay1 off
  relay2=0;                       //relay2 off
```

```
relay3=0;                        //relay3 off
        relay4=0;                        //relay3 off
        continue;
    }
    else if((rare>5530)||(rare<6451))        //capacitive load 1 to 2msec
    {
        ponstr6(data6,0x089); //dispaly string on lcd 1st line

        data5 = "0.71 ";           //powerfacter is 0.82



        status = 1;
         dispascii();
         relay1=0;                        //relay1 off
  relay2=0;                        //relay2 off
  relay3=0;                        //relay3 off
        relay4=0;                        //relay3 off
        continue;
    }
 }                    previous = rare;
}

        if( status == 1 )
        {
              rare = rare - 4608;
        }
```

```
void dispascii()

{


 ponstr3(data3,0xcc);

 ponstr5(data5,0x83);


}

 void initlcd(void)

 {

  lcdcmd(0x38);                          // SET LCD IN 2 LINE & 5X7 MATRIX MODE

  lcdcmd(0x01);                          // CLAER THE LCD

  lcdcmd(0x06);                          // SHIFT THE CURSER TO RIGHT

  lcdcmd(0x0c);                          // DISPLAY ON & CURSER BLINKING

 }

 void lcdcmd(unsigned char my_data1)

 {

  lcdbusy_check();

  LCD_DATA = my_data1;

  RS =1;                                 // RS =1 FOR DATA

  RW =0;                                         // RW = 0 FOR WRITING

  EN =0;                                 // ENABLE IS LOW

  EN =1;                                 // ENABLE IS HIGH

  }

  void lcddata(unsigned char ddata)

  {
```

```
 lcdbusy_check();
 LCD_DATA =ddata;
 RS=0;                              // RS = 0 FOR COMMAND
 RW =0;                                     // RW = 0 FOR WRITING
 EN =0;                                     // ENABLE IS LOW
 EN =1;                                     // ENABLE IS HIGH
 }
void lcdbusy_check()
{
busy_f=1;
RS = 0;                       // RS = 0 FOR COMMAND
RW =1;                              // RW =1 FOR READING
  while(busy_f==1)
        {
         EN=0;                      // ENABLE IS LOW
  _nop_();
         EN=1;                      // ENABLE IS HIGH
        }
}
void ponstr1(unsigned char *STR,unsigned char position) //function for display string on lcd
{
 STR = data1;
 while(*STR!='\0')
 {
  addr(position++);
```

```
 disp(*STR++);

 }


}
void ponstr2(unsigned char *strg,unsigned char pogisition) //function for display string on
lcd
{
 strg = data2;
 while(*strg!='\0')
 {
  addr(pogisition++);
         disp(*strg++);
  }


 }
void ponstr3(unsigned char *streg,unsigned char post)//function for display string on lcd
{
streg = data3;
while(*streg!='\0')
{
 addr(post++);
 disp(*streg++);
 }


}
void ponstr4(unsigned char *STR,unsigned char position) //function for display string on lcd
```

```
{
 STR = data4;
 while(*STR!='\0')
 {
  addr(position++);
  disp(*STR++);
 }

}
void ponstr5(unsigned char *streg,unsigned char post)//function for display string on lcd
{
streg = data5;
while(*streg!='\0')
{
 addr(post++);
 disp(*streg++);
 }

}
void ponstr6(unsigned char *STR,unsigned char position) //function for display string on lcd
{
 STR = data6;
 while(*STR!='\0')
 {
  addr(position++);
```

```
  disp(*STR++);
 }

}

void addr(unsigned char letter)
{
 lcdcmd(letter);
}
void disp(unsigned char pos)
{
 lcdbusy_check();
 lcddata(pos);
 lcdcmd(0x06);
}

float bcd_con(unsigned int vale)          //convert from binary to decimal
{
 float my_data;
 unsigned int  hexnum,temp,temp1,temp2;
 unsigned char d1,d2,d3,d4,d5;
 hexnum = vale;
 temp = hexnum/10;
 d1 = hexnum % 10;
 d2 = temp % 10;
```

```
temp1 =temp / 10;
 d3  = temp1 % 10;
 temp2 = temp1 /10;
 d4  = temp2 % 10;
 d5  = temp2 / 10;
 my_data = d1+ 10 *d2 +100 *d3 + 1000 * d4 + 10000 * d5;
 return(my_data);
 }
```

APPENDIX B

List of Parts

Component Name	Quantity
Resistors	
330R	1
10K	2
3.3K	1
4.7K	6
22K	2
1K	6
10R/10W	2
10K PRESET	1
10K SIP RESISTOR	1
Capacitors	
470uF /1000uF (PREFERABLE) /35V	1
10uF/63V	2
33pF Ceramic	2
0.1uf(104) Ceramic	1
2uF/400V (FAN CAPACITOR)	4
Integrated Circuits	
7805	1
7812	1
AT89S52	1
LM339	1
ULN2003	1
IC Bases	
40-PIN BASE	1
16-PIN BASE	1
14-PIN BASE	1
DIODE	
1N4007	9
1N4148	2
Miscellaneous	
CRYSTAL 11.0592MHz	1
LED-RED	5
2-PIN PUSH BUTTON	1
BULB 100W	1
BULB HOLDER	1
CHOKE	1
TRANSFORMER (0-12V 500mA) (Used as Current Transformer)	1
12V RELAY	4
LCD 16X2	1
PCB CONNECTOR 2-PIN	8

SLIDE SWITCHES	2
POWER CORD	1
AC CONNECTOR 2-PIN	1
TRANSFORMER 12V, 1 AMPERE MUST	1
MALE BURGE 2-PIN	2
FEMALE BURGE 2-PIN	2
FEMALE BURGE 16-PIN	1
MALE BURGE 16-PIN (INCLUDED WITH LCD)	1
HEAT SINK	1
SCREW NUT FOR HEAT-SINK	1
COPPER WIRE FOR LOAD	
PLAIN PCB	1
SOLDERING LED (50 gm)	
CONNECTING WIRE	

APPENDIX C

Pin Configurations of Micro-Controller (AT89S52)

Pin Description:

VCC:

Supply voltage.

GND:

Ground.

Port 0:

Port 0 is an 8-bit open drain bidirectional I/O port. As an output port, each pin can sink eight TTL inputs. When 1s are written to port 0 pins, the pins can be used as high-impedance inputs. Port 0 can also be configured to be the multiplexed low-order address/data bus during accesses to external program and data memory. In this mode, P0 has internal pull-ups. Port 0 also receives the code bytes during Flash programming and outputs the code bytes during program verification. External pull-ups are required during program verification.

Port 1:

Port 1 is an 8-bit bidirectional I/O port with internal pull-ups. The Port 1 output buffers can sink/source four TTL inputs. When 1s are written to Port 1 pins, they are pulled high by the internal pull-ups and can be used as inputs. As inputs, Port 1 pins that are externally being pulled low will source current (IIL) because of the internal pull-ups. In addition, P1.0 and P1.1 can be configured to be the timer/counter 2 external count input (P1.0/T2) and the timer/counter 2 trigger input (P1.1/T2EX).

Port 2:

Port 2 is an 8-bit bidirectional I/O port with internal pull-ups. The Port 2 output buffers can sink/source four TTL inputs. When 1s are written to Port 2 pins, they are pulled high by the internal pull-ups and can be used as inputs. As inputs, Port 2 pins that are externally being pulled low will source current (IIL) because of the internal pull-ups. Port 2 emits the high-order address byte during fetches from external program memory and during accesses to external data memory that use 16-bit addresses (MOVX @ DPTR). In this application, Port 2 uses strong internal pull-ups when emitting 1s. During accesses to external data memory that use 8-bit addresses (MOVX @ RI), Port 2 emits the contents of the P2 Special Function Register.

Port 3:

Port 3 is an 8-bit bidirectional I/O port with internal pull-ups. The Port 3 output buffers can sink/source four TTL inputs. When 1s are written to Port 3 pins, they are pulled high by the internal pull-ups and can be used as inputs. As inputs, Port 3 pins that are externally being pulled low will source current (IIL) because of the pull-ups.

RST:

Reset input. A high on this pin for two machine cycles while the oscillator is running resets the device. This pin drives high for 98 oscillator periods after the Watchdog times out. The DISRTO bit in SFR AUXR (address 8EH) can be used to disable this feature. In the default state of bit DISRTO, the RESET HIGH out feature is enabled.

ALE/PROG:

Address Latch Enable (ALE) is an output pulse for latching the low byte of the address during accesses to external memory. This pin is also the program pulse input (PROG) during Flash programming.

In normal operation, ALE is emitted at a constant rate of 1/6 the oscillator frequency and may be used for external timing or clocking purposes. Note, however, that one ALE pulse is skipped during each access to external data memory.

PSEN:

Program Store Enable (PSEN) is the read strobe to external program memory. When the AT89S52 is executing code from external program memory, PSEN is activated twice each machine cycle, except that two PSEN activations are skipped during each access to external data memory.

EA/VPP:

External Access Enable. EA must be strapped to GND in order to enable the device to fetch code from external program memory locations starting at 0000H up to FFFFH. Note, however, that if lock bit 1 is programmed, EA will be internally latched on reset. EA should be strapped to VCC for internal program executions. This pin also receives the 12-volt programming enable voltage (VPP) during Flash programming.

XTAL1:

Input to the inverting oscillator amplifier and input to the internal clock operating circuit.

XTAL2:

Output from the inverting oscillator amplifier.

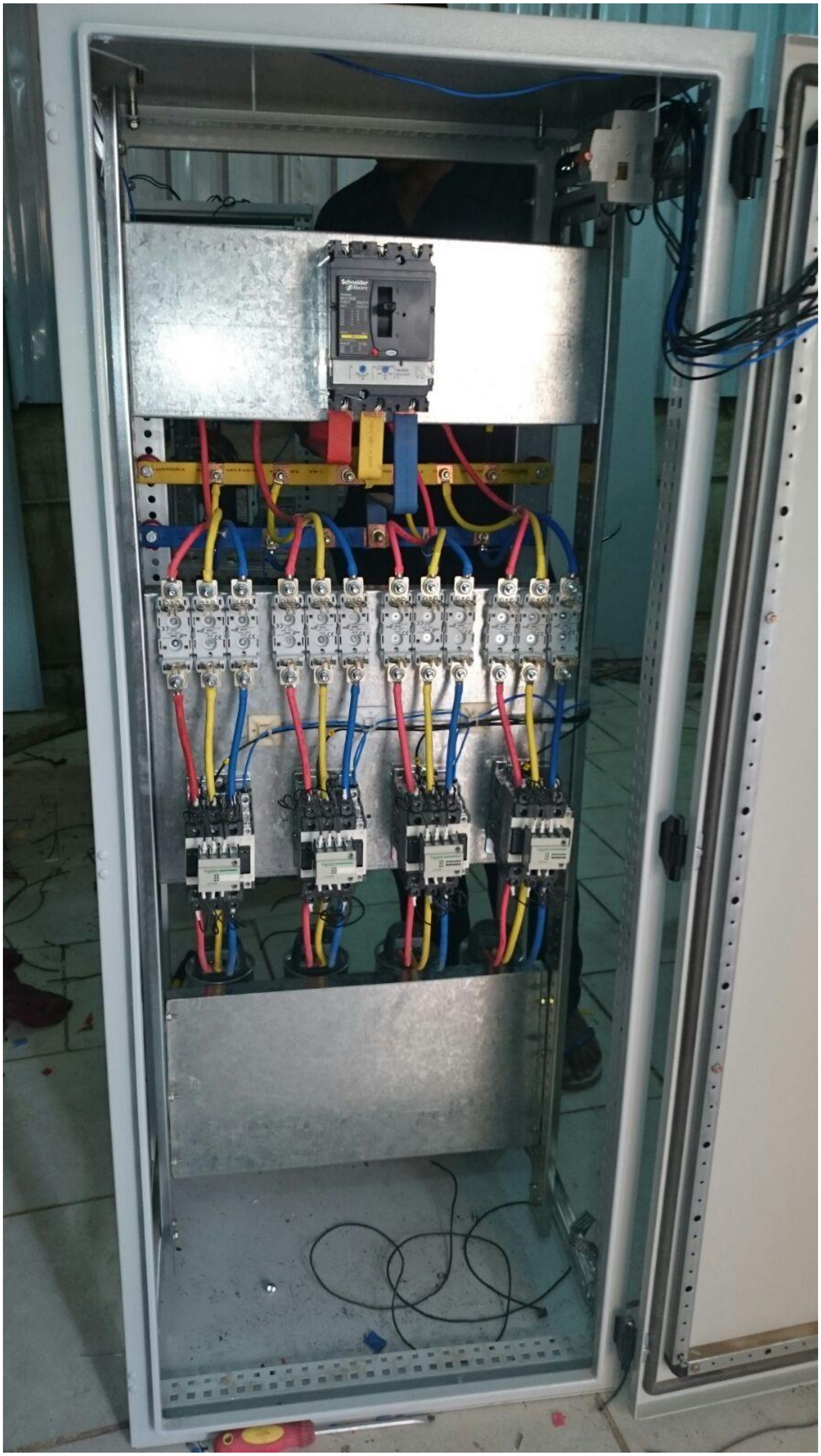
Idle Mode

In idle mode, the CPU puts itself to sleep while all the on chip peripherals remain active. The mode is invoked by software. The content of the on-chip RAM and all the special functions registers remain unchanged during this mode. The idle mode can be terminated by any enabled interrupt or by a hardware reset.

Power down Mode

In the power down mode the oscillator is stopped, and the instruction that invokes power down is the last instruction executed. The on-chip RAM and Special Function Registers retain their values until the power down mode is terminated. The only exit from power down is a hardware reset. Reset redefines the SFRs but does not change the on-chip RAM. The reset should not be activated before VCC is restored to its normal operating level and must be held active long enough to allow the oscillator to restart and stabilize.

APPENDIX D




Schneider Electric
EasyCan
Three Phase
Low Voltage Capacitor