MICROCONTROLLER BASED POWER FACTOR IMPROVEMENT

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Project Advisor:

MR. MOAZZAM SHAHZAD

Submitted By:

Mohsin Raza	060820-016
Jawad Anwar	060820-017
Tasawwar Abbas	060820-036

Department of Electrical Engineering
University of Management and Technology
Lahore

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Bachelor of Science

In

Electrical Engineering

By

Mohsin Raza 060820-016

Jawad Anwar 060820-017

Tasawwar Abbas 060820-036

University of Management and Technology Lahore


بسم الله الرحمن الرحيم
In the Name of Allah,
the Beneficent, the Merciful.

MESSAGE FROM QURAN

"O ye who believe! When it is said unto ou, Make room! In assemblies, then make room; Allah will make way for you (here after), And when it is said, Come up higher! Go up higher; Allah will exalt those who believe among you, and those who have knowledge, to high rinks. Allah is informed of what ye do. "

(Surah Al-Mujadila)

PROPHET MUHAMMAD (S.A.W)

"Let there be no envy, except in two things:

1. A man whom Allah gave a wealth and guided him to spend it in righteous way.

2. Or a man whom Allah gave wisdom and he acts wisely and teaches to the others"

(Al-Bukhari and Muslim)

CERTIFICATE OF APPROVAL

It is certified that the work contained in this project report, entitled

“Microcontroller Based Power Factor Improvement”

Was carried out by

Mohsin Raza	**060820016**
Jawad Anwar	**060820017**
Tasawwar Abbas	**060820036**

Under the supervision of Mr. Moazzam Shahzad for the partial fulfillment of the degree requirement of Bachelor in Electrical Engineering.

Approved By

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Mr. Moazzam Shahzad

Advisor

ACKNOWLEDGEMENT

We express our sincere thanks and deep sense of gratitude towards **MR. MOAZZAM SHAHZAD** under whose able guidance we were able to implement this thought of ours into a reality.

His timely and incisive review, comments and suggestions throughout the project enabled us to modify the project before things went out of our hand. We thank him for everything, from conception of getting things done practically and a lot of steps along the way, which helped us in overcoming our difficulties and making the project a successful.

Mohsin Raza	060820016	
Jawad Anwar	060820017	
Tasawwar Abbas	060820036	

ABSTRACT

Power factor correction (PFC) is a technique of counteracting the undesirable effects of electric loads that create a power factor (p.f.) less than 1.power factor correction may be applied either by an electrical transmission utility to improve the stability and efficiency of the transmission network or correction may be installed by individual electrical customers to reduce the costs charged to them by their electricity supplier. The most practical and economical power factor correction device is the capacitor. Incorporation of a micro-controller into a static capacitor device facilitates a sort of an automatic control action where by the power factor is always kept a fixed value, irrespective of the load power factor conditions. It improves the power factor because the effects of capacitance are exactly opposite those of inductance. The micro-controller determines the power factor of the system at any instant of time and determines the reactive power to be supplied and the value of capacitance to be switched in to make the power factor unity. The capacitor is switched in parallel to the load through a relay controlled by the processor. The circuit is capable of correcting the power factor for any inductive load within the rating of the system.

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Introduction

1.1 Introduction

The amount and complexity of household electrical equipment has increased tremendously over the last few years. Electronic ballast lighting, computer monitors and air conditioners are welcome additions to our homes but come with additional burdens. The change in the end consumer profile is a disadvantage for energy distributors which bill energy based only on active power. With the application of non-linear loads to power lines the active power no longer represents the total energy delivered. As a response the measurement of reactive power is gaining interest. This growing interest in measuring reactive power leads to different methods that should be implemented to accurately measure the reactive power. Although today's electronic devices enable reactive power measurement to be closer to the theoretical value, there is no consensus in the field of energy metering on the methods of measurement.

Active, reactive and apparent powers are the most important quantities in power system that influences its operation. The presence of a microcontroller in the system increases the functionality of the instruments, increases accuracy, resolution, readability and ability to provide automatic measurement in system application.

1.2 Aim of project

This project aims at incorporating a sort of an automatic control of power factor of the load. This makes the device capable of sensing the power factor and the changes in power factor of the load and apply correction as and when needed in the correct amount. Thus the power factor can always be kept at a fixed value or even unity. Thus effort is made to make an ordinary capacitor bank an automatic and controllable power factor correcting device. Thus the static capacitors can revert some of the most serious inherent drawbacks, thus increasing its popularity in power factor correction in electrical equipments and distribution and transmission networks.

1.3 Power Factor

The cosine of angle between voltage and current in an a.c. circuit is known as power factor.

1.4 Apparent Power (S)

The product of *VI* is called apparent power and is indicated by the symbol S. The units of S are volt-ampere (VA) and Kilovolt-ampere (kVA).

$$\mathbf{S} = \text{apparent power} \qquad S = I^2Z \qquad S = \frac{E^2}{Z} \qquad S = IE$$

Measured in units of ***Volt-Amps (VA)***

1.5 Reactive power (Q)

The product of *VI sin ф* is called reactive power and is indicated by the symbol Q. The units of Q are volt-ampere-reactive (VAR) and kilovolt-ampere-reactive (kVAR).

$$\mathbf{Q} = \text{reactive power} \qquad Q = I^2X \qquad Q = \frac{E^2}{X}$$

Measured in units of ***Volt-Amps-Reactive (VAR)***

1.6 Average Power (P)

The product of *VI cos ф* is called average power and is indicated by the symbol P. The units of P are Watts and kilowatts.

$$\mathbf{P} = \text{true power} \qquad P = I^2R \qquad P = \frac{E^2}{R}$$

Measured in units of ***Watts***

CHAPTER

2

POWER FACTOR IMPROVEMENT

2.1 Power Factor

The cosine of angle between voltage and current in an a.c. circuit is known as **power factor.**

In an a.c. circuit, there is generally a phase difference ϕ between voltage and current. The term cosϕ is called the power factor of the circuit. If the circuit is inductive, the current lags behind the voltage and the power factor is referred to as lagging. However, in a capacitive circuit, current leads the voltage and power factor is said to be leading.

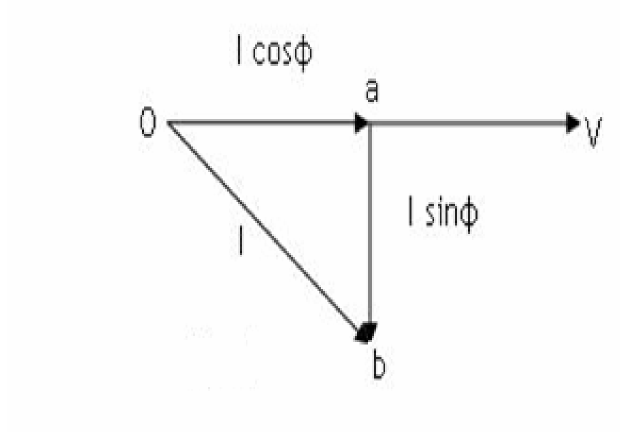


Fig2.1

Consider an inductive circuit taking a lagging current *I* from supply voltage *V* the angle of lag being ϕ. The phasor diagram of the circuit is shown in Fig 2.1. The circuit current *I* can be resolved into two perpendicular components, namely

a) *I* cos ϕ in phase with *V*

b) *I* sin ϕ out of phase with *V*

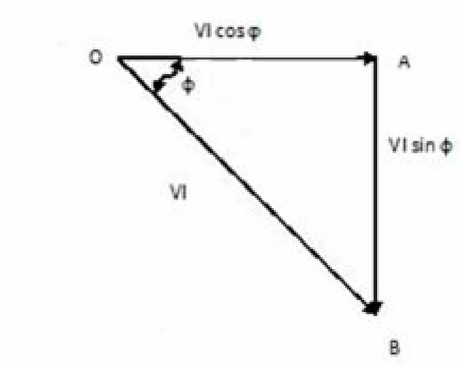
The component *I* cos ϕ is known as active or wattful component, where as component *I* sin ϕ is called the reactive or wattles component. The active component is the measure of power factor. If the active component is small, the phase angle ϕ is small and hence power factor cos ϕ will be high. Therefore, a circuit having small reactive current (i.e., *I* sin ϕ) will have high power factor and vice- versa. It may be noted that value of power factor can never be more than unity.

i) It is a usual practice to attach the word 'lagging' or 'leading' with the numerical value of power factor to signify whether the current lags or leads the voltage. Thus is the current has a p.f of 0.5 and the current lags the voltage, we generally write p.f as 0.5 lagging.

ii) Sometime power factor is expressed as a percentage. Thus 0.8 lagging power factor may be expressed as 80 % lagging.

2.2 Power triangle

The angle of power factor can also be made in terms of power drawn by an a.c. circuit. If each side of the current triangle *oab* of is multiplied by voltage V, then we get the power triangle OAB



OA = VI cos ϕ and represents the *active power* in watts or kW

AB = VI sinϕ and represents the *reactive power* in VAR or kVAR

OB = VI and represents the *apparent power* in VA or kVA

Fig. 2.2

The following points may be noted from the power triangle:

(i) The apparent power in an a.c. circuit has two components *viz.,* active and reactive power at right angles to each other.

$$OB^2 = OA^2 + AB^2$$

Or (apparent power)^2 = (active power)^2 + (reactive power)^2

Or $(kVA)^2 = (kW)^2 + (kVAR)^2$

(ii) Power factor cos ϕ = OA / OB = active power / apparent power = kW/ kVA

Thus the power factor of a circuit may also be defined as the ratio of active power to the apparent power. This is a perfectly general definition and can be applied to all cases, whatever the waveform.

(iii) The lagging reactive power is responsible for the low power factor. It is clear from the power triangle that smaller the reactive power component, the higher is the power factor of the circuit.

$$kVAR = kVA \sin \phi = (kW / \cos \phi) \sin \phi$$

$$kVAR = kW \tan \phi$$

(iv) For leading current, the power triangle becomes reversed. This fact provides a key to the power factor improvement. If a device taking leading reactive power (e.g. capacitor) is connected in parallel with the load, then the lagging reactive power of the load will be partly neutralized, thus improving the power factor of the load.

(v) The power factor of a circuit can be defined in one of the following three ways:

(a) Power Factor = cos ϕ = cosine of angle between *V* and *I*

(b) Power Factor = *R/Z* = Resistance / Impedance

(c) Power Factor = *VI* cos ϕ / *VI* = Active power/ Apparent Power

(vi) The reactive power is neither consumed in the circuit nor does it do any useful work. It merely flows back and forth in both direction in the circuit. A wattmeter does not measure reactive power.

2.3 Disadvantages of Low Power Factor

The power factor plays an important role in a.c. circuits since power consumed depend upon this factor.

$P = V_L I_L \cos\phi$ (For Single Phase Supply)

$I_L = P/ V_L \cos\phi$

$P = \sqrt{3} V_L I_L \cos\phi$ (For 3 Phase Supply)

$I_L = P/ \sqrt{3} V_L \cos\phi$

It is clear from above that for fixed power and voltage, load current is inversely proportional to the power factor. Lower the power factor, higher is the load current and *vice-versa.* A power factor less then unity results in the following disadvantages.

(i) Large KVA rating of equipment

The electrical machinery (e.g. alternators, transformers, switchgear) is always rated in kVA.

Now, $kVA = kW/\cos\phi$

kVA rating of the equation is inversely proportional to power factor. The smaller power factor, the larger is the kVA rating. Therefore, at low power factor, the kVA rating of the equipment has to be made more, making the equipment larger and expensive.

(ii) Grater Conductor Size

To transmit or distribute a fixed amount of power at constant voltage, the conductor will have to carry more current at low power factor. This necessitates large conductor size. For example, take the case of a single phase a.c. motor having an input of 10 kW on full load, the terminal voltage being 250 V. at unity p.f., the input full load current would be 10,000/250 = 40 A. At 0.8 p.f., the kVA input would be10/0.8 = 12.5 and the current input 12,500/250 = 50 A. If the motor is worked at low power factor of 0.8, the cross-sectional area of the supply cables and motor conductor would have to be based upon a current of 50 A instead of 40 A which would be required at unity power factor.

(iii) Large Copper Losses

The large current at low power factor causes more I^2R losses in all the elements of the supply system. This result is poor efficiency.

(iv) Poor Voltage Regulation

The large current at low lagging power factor causes greater voltage drops in alternator, transformer, transmission lines and distributors. These results in the decreased voltage available at the supply end, thus impairing the performance of utilization devices. In order to keep the receiving end voltage within permissible limits, extra equipment (i.e., voltage regulator) is required.

(v) Reduced Handling Capacity of System

The lower power factor reduces the handling capacity of all the elements of the system. It is because the reactive component of current prevents the full utilization of installed capacity.

2.4 Causes of Low Power Factor

Low power factor is undesirable from economic point of view. Normally, the power factor of the whole load on the supply system in lower than 0.8. The following are the causes of low power factor.

(i) Most of the a.c. motors are of inductive type (1ϕ and 3 ϕ induction motor) which have low lagging power factor. These motors work at a power factor which is extremely small on light load (0.2 to 0.3) and rises to 0.8 to 0.9 at full load.

Fig. 2.3

(ii) Arc lamps, electric discharge lamps and industrial heating furnaces operate at low lagging power factor.

(iii) The load on the power system is varying; being high during morning and evening and low at other times. During low load period, supply voltage is increased which increases the magnetization current. This results in the decreased power factor.

2.5 Power Factor Improvement

The low power factor is mainly due to the fact that most of the power loads are inductive and, therefore, take lagging current. In order to improve the power factor, some device taking leading power should be connected in parallel with the load. One of such devices can be a capacitive. 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.

Illustration: To illustration the power factor improvement by a capacitor, consider a single phase load taking lagging current *I* at a power factor cos ф

The capacitor *C* is connected in parallel with the load. The capacitor draws current *I* c which leads the supply voltage by 90˚. The resulting line current *I'* is the phasor sum of I and *Ic* and its angle of lag is ф2. It is clear that ф2 is less then ф1, so that cos ф2 is greater than cos ф1. Hence, the power factor of load is improved. The following points are worth noting:

(i) The circuit current *I'* after p.f. correction is less than the original circuit current *I.*

(ii) The active or wattful component remains the same before and after p.f. correction because only the lagging reactive component is reduced by the capacitor.

$$I \cos \phi 1 = I' \cos \phi 2$$

(iii)The lagging reactive component is reduced after p.f. improvement and is equal to the difference between lagging reactive component of load (I sin ф1) and capacitor current(Ic) i.e.,

$$I' \sin \phi 2 = I \sin \phi 1 - Ic$$

(iv) As $I \cos \phi 1 = I' \cos \phi 2$

$$VI \cos \phi 1 = VI' \cos \phi 2 \qquad \text{[Multiplying by V]}$$

Therefore, active power (kW) remaining Unchanged due to power factor improvement

(v)

$$I' \sin \phi 2 = I \sin \phi 1 - Ic$$

$$VI' \sin \phi 2 = VI \sin \phi 1 - Vic \quad \text{[Multiplying by V]}$$

i.e. Net kVAR after p.f., correction = Lagging kVAR before p.f., correction – leading kVAR of equipment.

2.6 Power Factor Improvement Equipment

Normally, the power factor of the whole load on a large generation station is in region of 0.8 to 0.9. However, sometime it is lower and in such cases it is generally desirable to take special steps to improve the power factor. This can be achieved by the following equipment.

1. Static Capacitors
2. Synchronous Condenser
3. Phase Advancers

2.6.1Static Capacitors

The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor. The capacitor (generally known as static 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. For three-phase loads, the capacitors can be connected in delta or star. Static

capacitors are invariably used for power factor improvement in factories.

Fig. 2.4

2.6.1.1 Advantages

(i) They have low losses

(ii) They required little maintenance as there are no rotating parts

(iii)They can be easily installed as they are light and require no foundation.

(iv)They can work under ordinary atmospheric condition.