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Power Factor Improvement by Engaging Appropriate Number of Shunt Capacitor

Akash Srivastava

Student, Department of E & Tc, Bharti Vidyapeeth College of Engineering, Pune, India

Shubham Saxena

Student, Department of E & Tc, Bharti Vidyapeeth College of Engineering, Pune, India

Mihir Dwiwedi

Student, Department of E & Tc, Bharti Vidyapeeth College of Engineering, Pune, India

Deepak Ray

Assistant Professor, Department of E & Tc, Bharti Vidyapeeth College of Engineering, Pune, India

Abstract:

Poor power factor which results due to wasted energy capacity is often ignored or overlooked. It results in various safety problem and high cost for generation of energy. Low power factor makes your system less economical to operate. The actual which is being dissipated in circuit is called true power. The reactive power is generated through various loads such as capacitors and inductors. Combination of these two powers is called apparent power. Load can be any type such as it can be inductive, resistive and capacitive. Inductive load working in such operation are loads are transformer, reactors and Induction motors. Capacitive loads includes capacitor, variable or fixed capacitor bank, generators and synchronous motors.

1. Introduction

1.1. What Is Power Factor?

Power factor is a measure of how effectively you are using electricity. Mathematically is defined as the ratio of real power flowing to load to the apparent power in circuit. The range of power factor lies in close interval of -1 to 1.

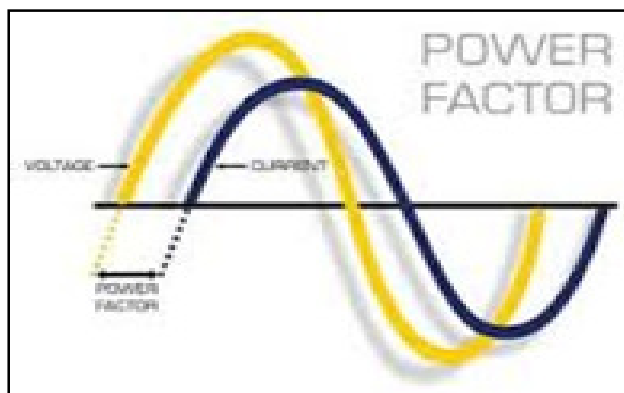


Figure 1

When the power factor becomes less than one which means that both the current and voltage waveform are out of phase which directly reduces the instantaneous product of both waveforms ($V \times I$). Real power is the actual capacity of the circuit which is used for performing work in a particular set of time.

1.2. Problems of Low Power Factor

Low power factor results in inefficient system operation and losses. The major problems results due to low power factor are as follows.

1.2.1. Current Drawn

For a given active power, a low power factor will result in increase in the current drawn from supply. The percentage increase in current drawn at unity power factor is 0% of rated current, the corresponding percentage increase in current drawn at 0.5 power factor will be 100% that is twice the rated current will be drawn.

From this we can conclude that the transformers, switchgear, cables will have to be oversized to carry this increased current in case of low power factor.

1.2.2. Cable Losses

As we know that improved power factor result in reduction in line current. For a given cable losses are proportional to square of this current.

Thus improving power factor from initial to final value of $\cos\Phi_1$ to $\cos\Phi_2$, the reduction in loss is given by the expression:

$$1.2.1.1. \text{Percentage saving in losses} = \{1 - (\cos\Phi_1 / \cos\Phi_2)\}^2 \times 100$$

1.2.3. Transformer Losses

There are two types of losses in transformer:-

1. Losses in core i.e. iron losses
2. Losses in windings i.e. copper losses

The iron losses are equal to the power consumed by transformer under no load conditions. However the copper losses vary with the square of current and thus becoming directly related to power factor of load supplied from transformer.

1.2.4. Voltage Regulation

When transformer operate on load which result in voltage drop in secondary voltage in comparison to the no load secondary voltage. This voltage drop is indicated b percentage regulation of a transformer. Power factor improvement has a positive impact in reducing the voltage drop hence improving its regulation.

2. Block Diagram for Power Factor Improvement

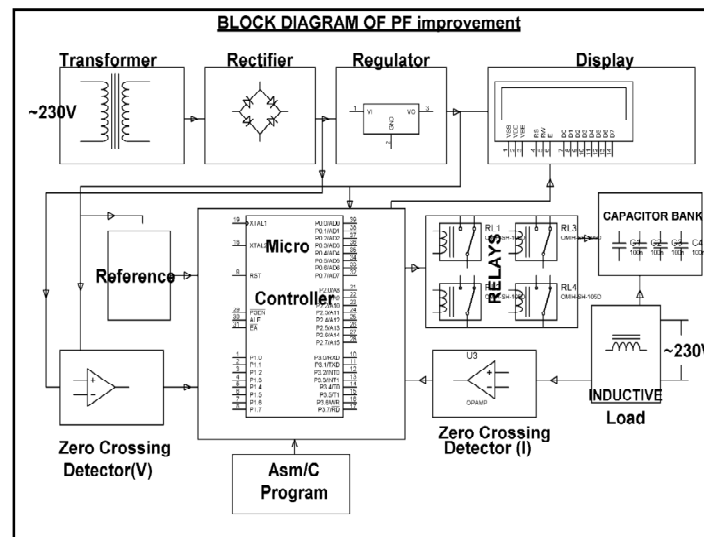


Figure 2

2.1. Hardware Component Used for Power Factor Improvement

- i. Microcontroller
- ii. Relay
- iii. Relay driver
- iv. LCD
- v. Current transformer
- vi. Inductive load
- vii. Shunt capacitor
- viii. Push button
- ix. LED
- x. Resistor
- xi. Capacitor

2.2. Circuit Description

- i. Power supply consist of a step-down transformer which ranges from 230V to 12V and a bridge rectifier which is formed by 4 diodes generates pulsating dc which is filtered by an electrolytic capacitor of about 470 μ F to 1000 μ F.
- ii. The received filtered dc being unregulated, the role of IC LM7805 is used to get constant 5V DC at pin no 3 which doesn't depend upon input DC which varies from 7V to 15V.
- iii. The variation of input dc in the event of input ac at 230volts section varies from 160V to 270V. The ratio of the primary transformer voltage V1 to secondary voltage V2 is known by the formula $V1/V2=N1/N2$. As the ratio remain unchanged the secondary voltage V2 is directly proportional to V1.
- iv. If the transformer generates 12V at 220V input supply it will give 7.69V at 150V at output. Thus the range of dc voltage at the input of the regulator varies from about 9V to 16V the regulator output will remain constant.
- v. The further filter of regulated 5V DC by an electrolytic capacitor of 10 μ F for any noise so generated by the circuit. LED is connected in series with a current limiting resistor of 330 Ω to the ground i.e. 5V power supply available due to generation of negative voltage.

3. Circuit Explanation

- i. The main component of circuit includes DC power supply, Micro-controller, LCD display, zero voltage crossing detectors, Relays, Capacitor bank and Load circuit.
- ii. DC power supply the required DC power for Micro-controller and other peripherals.
- iii. We need digitized voltage and current signals for the calculation of the power factor by the Micro-controller. The voltage is taken from the main and the bridge rectifier converts it into pulsating DC which is given to a comparator which generates the digital voltage signal.
- iv. By calculating the voltage drop of the load current across a resistor of 10 ohms we convert current signal into voltage signal.
- v. The conversion of AC signal into the digital signal as done for the voltage signal which are further sent to the micro-controller.
- vi. The time difference between the zero crossing points of current and voltage is calculated by the microcontroller, which is directly proportional to the power factor. 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.
- vii. As per requirement the shunt capacitor are connected in parallel with the load and thus the power factor is improved.

3.1. Selection of Capacitors

Basically there are broadly two types of electrical installation namely LT installation and HT installation.

In LT installation, electricity board supplies power to installation at 415 volts where in HT installation electricity supplies power at 11kv or higher and consumers are expected to provide their own transformer to step down the voltage to 415 volts.

In two part tariff system in respect of HT installation, the electricity board bill consumes for demand charges and energy charges i.e. KVA and KWH respectively. The electricity board keep records power factor of installation from meter and calculate by the following method:

3.2. STEP 1: By evaluating 'KVAR' Required

Evaluation of KVAR is done with the assistance of various tables which provide data and methods for selecting KVAR for different loads under various parameters such as size, load, rpm, frequency, voltage and constructional characteristics.

3.3. STEP 2: Choose 'MODE' of Compensation

There are three modes of compensation which are:

- a. Central compensation
- b. Group compensation
- c. Individual compensation

3.4. STEP 3: Choose 'TYPE' of Compensation

It involves choosing type of compensation i.e. Fixed compensation or Variable compensation.

Fixed compensation implies that KVAR of capacitor is constant where Variable compensation implies that KVAR of capacitor can be varying depending upon load requirement by either manual or automatic switching.

3.5. What are Advantages of PF Factor Improvement?

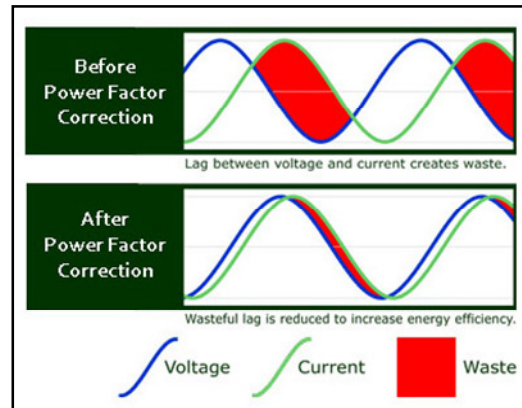


Figure 3

3.5.1. Technical Benefits

By connecting the capacitor in the required circuit we are capable of "correcting" half of the reactive power of a load which finally leads to a reduction in the demand on the supply. This results in the following:

- i. The load on the switches and cables is reduced
- ii. The supply load capacity increases.
- iii. The company charges for electricity is reduced

3.5.2. Commercial Benefits

By maintaining the power factor at or above 0.95 lagging under all load conditions:

- Excess reactive power charges are avoided
- Losses in system are reduced

3.5.3. Environmental Benefits

Every kVAR of Power Factor Correction supplied by Power Capacitors Ltd there is reduction in CO₂ emissions by 146kg per annum. Any responsible company having or seeking ISO14001 approval is wise to take advantage of this.

3.6. What are the Applications of PF Factor?

Every year, with the increase in production of millions of notebook computers, LCD monitors and LCD televisions and other electronic devices using more and more power, actions must be taken to ensure the functionality of the nationwide power grid. In 2001, the European Union put EN61000-3-2 into effect to set the harmonic regulation standard on any power grid supplied application with power consumption over 75 watts. This essentially requires power factor correction (PFC).



Figure 4

3.7. Automatic Power Factor Controller

There are two types of PFCs:

1. Passive PFCs
2. Active PFCs

3.7.1. Passive PFC.

Passive PFC is simplest form of PFC. It uses a filter at the AC input to correct low power factor. The passive PFC circuitry uses only passive components — an inductor and some capacitors.

3.7.2. Active PFC

Active PFC offers better THD and is significantly smaller and lighter than a passive PFC circuit. It generally operate at high frequency than the 50HZ/60Hz line frequency to reduce the size and cost of passive filter elements.

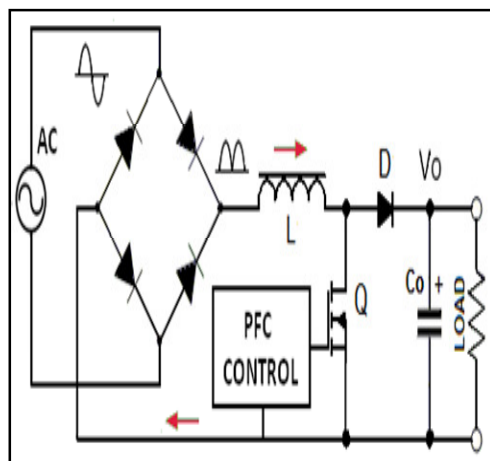


Figure 5

4. Results and Calculations

Delay Time in mS	Delay Angle		PF (angle*PIE/180)
	(90/5)*Time in Ms	COS	
0.5	9		0.987688341
0.6	10.8		0.982287251
0.7	12.6		0.975916762
0.8	14.4		0.968583161
0.9	16.2		0.960293686
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
1.6	28.8		0.87630668
1.7	30.6		0.860742027
1.8	32.4		0.844327926
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
2.5	45		0.707106781
2.6	46.8		0.684547106
2.7	48.6		0.661311865
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
3.4	61.2		0.481753674
3.5	63		0.4539905
3.6	64.8		0.425779292

Table 1

5. Conclusion

We simply calculated the delay time and switch on as many capacitors as required across the inductive load to bring the pf to near unity. For that we have taken 4 capacitors only and have taken 4 sets of time delay range. Thus between 0.5 to 921 u Sec (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.

6. Acknowledgement

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