Power Factor Correction Using PIC Microcontroller

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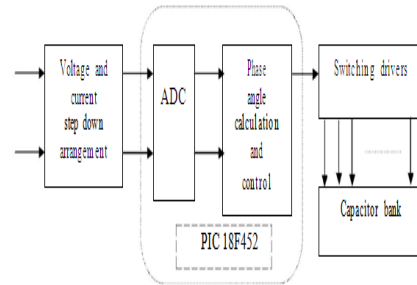
Abstract;- In recent years, the power quality of the ac system has become great concern due to the rapidly increased numbers of electronic equipment, power electronics and high voltage power system. Most of the commercial and industrial installation in the contry has large electrical loads which are severally inductive in nature causing lagging power factor which gives heavy penalties to consumer by electricity board. This situation is taken care by PFC. Power factor correction is the capacity of absorbing the reactive power produced by a load. In case of fixed loads, this can be done manually by switching of capacitors, however in case of rapidly varying and scattered loads it becomes difficult to maintain a high power factor by manually switching on/off the capacitors in proportion to variation of load within an installation. This drawback is overcome by using an APFC panel. In this paper measuring of power factor from load is done by using PIC microcontroller and trigger required capacitors in order to compensate reactive power and bring power factor near to unity.

*Index Terms:-***power factor, PIC, Hardware**

I. INTRODUCTION

Power factor is the ratio of KW and KVA. KW is the actual load power and KVA is the apparent load power. It is a measure of how effectively the current is being converted into useful work output. Most of industrial electric loads have a low power factor not transcending from 0.8 and thus imparts to the distribution losses. Poor power factor can be the result of significant phase angle is generally the result of an inductive load such as an induction motor, power transformer or induction furnace. [1] The existing of reactive power does not included in the electric bill yet this probably causes dissipation power lost at the load which results to an increment of electricity bill charge. Penalty charge is just one of the problems however there are more other problems occur if power factor is low. They are

A) Extra losses in feeder cables
B) Significant voltage drop
C) Reduction of effective capacity of cables
D) Voltage drop at the secondary of the transformer
E) Losses in transformer

This paper focuses on the design and implementation of power factor correction using PIC microcontroller chip, determine the power factor of the loaded power system, and generate proper action to calculate and to add sufficient capacitor.

II. PROPOSED SYSTEM

Microcontroller base automatic controlling of power factor with load monitoring is shown in fig.1.

Fig.1 block of PFC using PIC

The principal element in the circuit is PIC microcontroller. The current and voltage single are acquired from the main AC line by using Current Transformer and Potential Transformer. These acquired signals are then pass on the zero crossing detectors. Bridge rectifier for both current and voltage signals transposes the analog signals to the digital signal. Microcontroller read the RMS value for voltage and current used in its algorithm to select the value of in demand capacitor for the load to correct the power factor and monitors the behavior of the enduring load on the basis of current depleted by the load. In case of low power factor Microcontroller send out the signal to switching unit that will switch on the in demand value of capacitor. The tasks executed by the microcontroller for correcting the low power factor by selecting the in demand value of capacitor and load monitoring are shown in LCD.

III. CIRCUIT DESIGN

The design aims to monitor phase angle continuously and the event of phase angle deviation a correction action is initialized to compensate for this difference by continuous changing variable capacitors value via switching process.

A. SENSORS

The alternative voltage and current signals are both sensed and scared down using sensors, while the current is converted into an equivalent voltage representation. the voltage transducer is able to read both DC and AC signal by converting the captured signal into smaller scale with ratio of 2500:1000. The current transducer scares down input signal with ratio of 1:1000.

B. ZERO CROSSING DETECTOR:

As the name indicates the zero crossing detector is a device for detecting the point where the voltage crosses zero in either direction. As shown in the circuit diagram 2 the first section is a bridge rectifier, which provides full wave rectified output. This is applied to the base of the transistor through a base resistor, R2. The capacitor charges to maximum of the bridge rectified output through the diode, D2. This charge is available to the transistor as VCC. The capacitance value is kept large in order to minimize ripple and get perfect dc. The transistor remains OFF until the Cut-in voltage VBE is reached. During the OFF period of the transistor the output will be high and approximately equal to VCC.
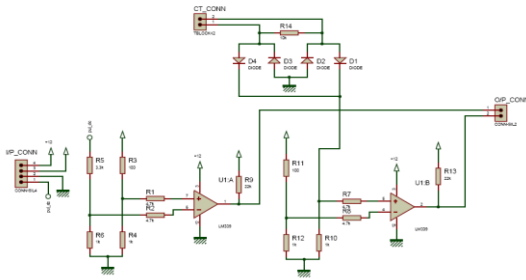
Fig 2.Zero crossing detector

Once the transistor is ON and IB increases according to the input wave, the transistor moves slowly towards saturation where the output reduces to the saturation voltage of the transistor which is nearly equal to zero Initially VBE = Cut-in voltage of diode, the capacitor will charge through the diode Vm where Vm is the maximum amplitude of the rectified wave. Now the diode is reverse biased and hence does not provide a discharging path for the capacitor, which in turn has two effects. Variation in VCC. It will provide base current to the transistor in the region where both diode and transistor are OFF. Thus an output square wave is produced whenever the input voltage crosses zero thereby acting as a zero crossing detector. A zero crossing detector literally detects the transition of a signal waveform from positive and negative, ideally providing a narrow pulse that coincides exactly with the zero voltage condition. At first glance, this would appear to be an easy enough task, but in fact it is quite complex, especially where high frequencies are involved. In this instance, even 1 kHz starts to present a real challenge if extreme accuracy is need.

C. CAPACITOR BANK

Capacitors are commonly used within a lot of power system, especially electronic constructed circuitry. In three phase power system, capacitors normally installed within an isolating nonconductor metal box, which called capacitor bank, they are fixed or switched. Fixed banks are connected permanently to the primary conductors through fused switches. Switch capacitors banks are tied to primary system through automated switch, allowing them to be put on line and taken off line as needed. Distribution power system usually connects capacitor in parallel rather connecting in series. The function of shunt power capacitor is to provide leading KVARS to an electrical system when and where needed.

The actual capacitor in farads of a capacitor bank can be calculated using the following equation:[3]

$$C = VAR/2\pi f * V_R 2$$

Where, VAR = capacitor unit var rating

C = capacitor in farad

F = frequency

V_R = capacitor unit rated voltage

D. RELATION OF CAPACITOR WITH POWER FACTOR

as majority power system has inductive load thus normally only lagging power factor occurs hence capacitors are used to compensate by producing leading current to the load to reduce the lagging current, there by shrink the phase angle distance between the real power and apparent power. Table 1 describes the common loads appear in general industrial systems and their typical power factor. In general, power capacitors shall be Y connected on the three phase distribution feeder. Grounding the neutral is essential for the fuses to operate in case of any event of capacitor fault.

TABLE 1: Typical Power factor of various loads [5]

Load	Typical Power Factor
Incandescent Lamps	1.0
Florescent lamps	0.95-0.97
Synchronous Motors	1 to 0.8 leading
Squirrel cage motors	
High speed	0.75-0.9
Low speed	0.85-.92
Wound rotor	0.8-0.9
Induction motor	
Fractional HP	0.55-0.75
1-10 HP	0.75-0.85

IV. DETERMINE THE SIZE OF CAPACITOR BANKS

Standard capacitors sizes are 50,100,150,200,300 and 400 KVAR. Since capacitors can be connected more than one per phase in order to increase the bank size, it is recommended to select two or at most three capacitor unit sizes to avoid stocking the sizes. [7] In a fixed capacitor installation, one should at first determine desired power factor value before attempting to design one. By installing fixed capacitor can approximately improve the power factor around 94% to 96%. When using switched capacitor to correct the power factor of a circuit, the switch control is set to close the bank onto the line when the load KVARs equal to two-thirds of the banks rated

KVAR. This scheme is tend to reduce loss by driving the line leading with first turn on before it is turn off, this is referred as the "two-thirds rule". Taking a daily load cycle, compare with fixed capacitor bank, switching capacitor bank is generally more expensive thus it is essential to take accounting of the cost of installation so that its time value worth for the investment.

A. CAPACITOR SIZE

1) First step is to measure present (old) KVA and PF, or. get them from power bill
2) Then to calculate active power,'
Active Power (kW) =PF_{old} * KVA_{old}
3) Calculate system $kVAR_{sys}$
$kVAR_{sys} = [KVA_{old}^2 - KW^2]^{1/2}$
3) Identify a target PF_{new}
4) Calculate the new kVA using target PF_{new}:
$KVA_{new} = kW/ PF_{new}$
5) Calculate $KVAR_{new}$ once target PF_{new} is achieved:
$KVAR_{new} = [KVA_{new}^2 - KW^2]^{1/2}$
7) $KVAR_{new}$ is the difference between $kVAR_{sys}$ added capacitor's kVAR:
$KVAR_{new} = kVAR_{sys} - KVAR_{cap}$
8) So kVAR of the capacitors to be installed is _
$KVAR_{cap} = kVAR_{sys} - KVAR_{new}$

EXAMPLE:-

Given: PF = o.82 and motor with nameplate info of 100 hp and 94% efficiency.
Find: - Capacitor kVAR needed for PF_{new}= 0.96.
Solution :- Calculate present power requirement :
kW = 0.746 / hp * 100 hp/0.94
: 79.4 kW.
Calculate present kVA
KVAold =79.4 / 0.82 = 96.8 kVA
Calculate present (system) kVAR :
KVARsys = $(96.8^2 - 79.4^2)^{1/2}$ = 55.4kVAR
Calculate new KVA if PF = 0.96 is reached.
$kVAR_{new}$ = 79.4kW /0.96 = 82.7kVA
Calculate combined kVAR after capacitor added :
$kVAR_{new}$ = $(82.7^2 - 79.4^2)^{1/2}$=23.l kVAR
Find kVAr of capacitor to be installed :
$kVAR_{cap}$ = 55.4 -23.1 = 32.3kVAR
The nearest standard size would be installed, probably 30 kvAR. A larger std. capacitor than actually needed would be avoided if PF= 1.

V. HARDWARE IMPLEMENTATION

Whole system may be divided into three stages. First stage is concern with the step down arrangement of the incoming voltage and current signals into the PIC voltage level (e.g. 5V). Here we have used the step down arrangement of the transformer. Second stage is concerned with zero crossing level detection by using an IC (LM35g) for voltage and current, the incoming signals. Voltage signal can be acquired by using Opto-coupler (TC # 4N25) at the output of Potential

Transformer for detection. Current Signal can be acquired by using Current Transformer connected at main AC line. In third stage block diagram represents the automatic power factor control with continuously load monitoring of the system as shown in Fig.3.
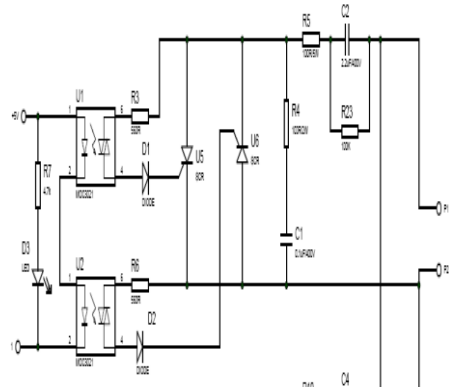
Fig 3.connection of capacitor bank with PIC

The main part of the circuit is Microcontroller (18F452) with crystal of Il MHz After acquiring voltage and current signals they are then passed through the zero cross detector block (ZCD V and ZCD l), that converts both voltage and current waveforms in square-wave that are further provided to microcontroller to detect the delay between both the signals at the same time instant. Two bridge rectifier circuits are utilized to convert both AC voltage and current signal into pulsating DC signal that is further provided to ADC pin of Microcontroller for its conversion into digital signal, so that the microcontroller performs Its further necessary task after this the checking of RMS value for voltage and current is performed, these values are used in the algorithm of Microcontroller to select the Capacitor of desired value to counteract the effect of low power factor of the load and monitor continuously which load is operated on the basis of current consumed by the load. Results of corrected power factor, needed capacitor value to correct the low power factor to desired value are shown on LCD.
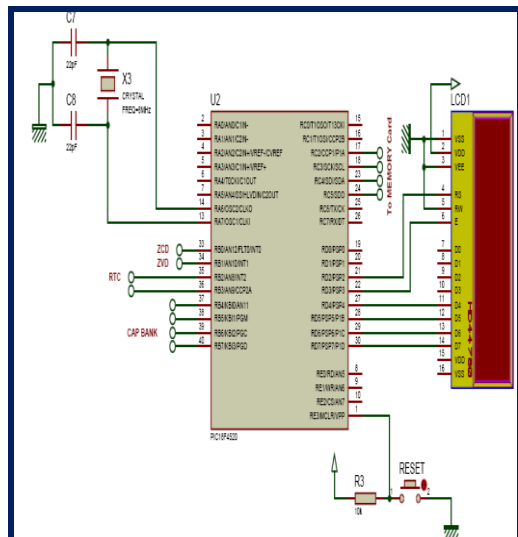
Fig 4. Connection of PIC with MMC and LCD

VI. HARDWARE RESULTS AND DISCUSSION

CASE 1: RESISTIVE LOAD

When resistive load is ON, as shown in Fig. There is no phase relay between current and voltage signals and they are in phase. In this case the power factor would be 0 .9 as referenced value so there is no insertion of capacitors In case of resistive load the V and I are in phase so there is no insertion of capacitors to improve power factor .The load monitoring of resistive load by microcontroller is shown on LCD.
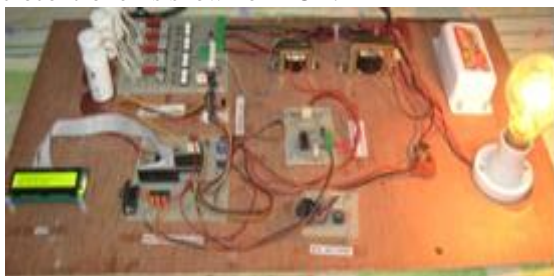

Fig 4. Resistive load is ON.

CASE 2: WHEN CHOCK (INDUCTIVE LOAD) IS ON:

There is phase delay between voltage and current signals, Microcontroller senses the Delay produced by the load, and according to the delay it inserts the desired value of capacitor to improve the power factor of the system. When the desired value of the capacitors added the required reactive power to the system, the current and voltage waveforms are in phase. After the insertion of required value of capacitor, the V and I zero cross detector signals are also in phase in accordance with the set referenced value of power factor (0.9).

VII. MICROCONTROLLER ALGORITHM SCHEME

A. ALGORITHM FOR CONTROL SCHEME

Step 1- Set the user define lower and upper power factor (LPF & UPF).
Step 2- Set the user define threshold value of current (TUC).
Step 3- Determine power factor.
Step 4- determine value of current.
Step 5- if value of current is less than TUC, take no action and go to step 3.
Step 6- if the value of power factor is between LPF and UPF take no action and go to step 3.
Step 7- if the value of power factor is less than LPF switch on the next off capacitor and wait for 1.0 seconds. Go to step 3.
Step 8- If the value of power factor is more than UPF or as leading, switch off the first on capacitor and wait for 1.0 second. Go to step 3.

B. ON/ OFF OF CAPACITOR

For the equally utilization of capacitors, we have chosen a method. In this method on/ off of capacitor is done in ascending order. 1st, 2nd and so on. If it reaches to 8th then it rolls back to 1st.

C. ALGORITHM FOR DETERMINING POWER FACTOR

Step 1- Check for voltage cross zero from negative to positive.
Step 2- Timer T starts (T).
Step 3- Timer $\triangle$T starts ($\triangle$T).
Step 4- Check for current cross zero from negative to positive.
Step 5- Timer $\triangle$T stops.
Step 6- Check again for voltage cross zero from negative to positive.
Step 7- Timer T stops.
Step 8- Phase $\varphi = (\triangle T / T) * 360^0$.
Step 9- Get cos φ from look up table.
Step 10- If $\triangle$T > T/4 report power factor is leading.
Current and voltage waveform with time period (T) are shown in figure 5 and 6 and combined waveform with time gap ($\triangle$T) is shown in figure 7.
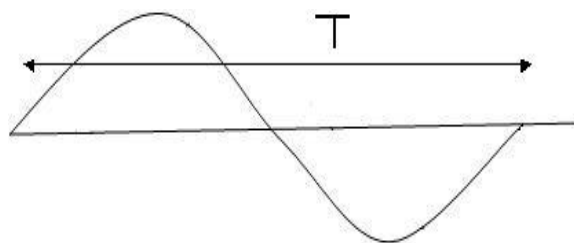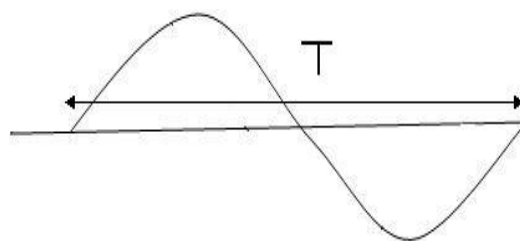

Fig 5: Voltage with time period

Fig 5: Current with time period
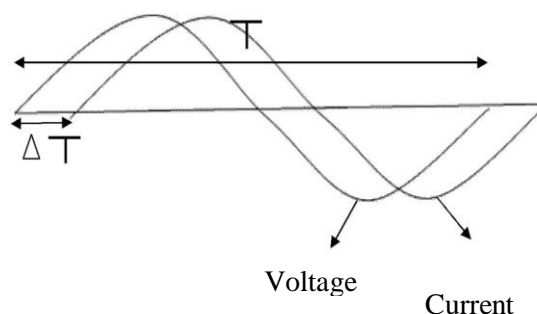

Voltage

Current

Fig 6: Current and voltage with time gap

Here we take the value of count and value of count1 then take the ratio of count1 to count. This will give the ratio between time gap and time period. Now the angle is calculated as-

$$\text{Angle} = (coun1 \,/count) * 360$$

And then

$$\text{Power factor} = \cos(\text{angle})$$

The preferred scale is 1:4.

VIII. FLOW DIAGRAM FOR ZERO CROSSING

IX. CONCLUSION

This thesis work is an attempt to design and implement the power factor controller using PIC micro controller. In this work there is a provision to define the own current minimum range and power factor minimum and maximum range. PIC monitors both continuously and then according to the lagging or leading power factor it takes the control action. This thesis gives more reliable and user friendly power factor controller. This thesis makes possible to store the real time action taken by the PIC microcontroller. This thesis also facilitates to monitor the power factor changes on LCD in real time.

X. FUTURE WORK

This thesis work is not tested on power converter based systems or synchronous motor because of the requirement of huge amount of expense. It needs the further enhancement of the system. Finance is a critical issue for further enhancement.

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