Improvement of power factor by using a microprocessor based control system

Singhal D.K.*, Kumar D.**, Singh V.*, Bansal M.C.*

ABSTRACT

The electrical energy supplied to a system is the sum of the power required for doing the useful work (i.e conversion of electrical energy to mechanical energy), and the reactive power. The reactive power is defined by V I Sin ϕ, where $\varnothing$ is the phase angle between voltage and current and this can be minimised for improving the power factor of the system. In this paper, a micro- processor based control system has been proposed to improve the power factor of the system, which is taken as a function of useful work and reactive power Thus, by improving the power factor (by reducing the reactive power) the energy can be conserved.

Introduction :

The power factor is defined as cosine of the angle between the voltage and the current, or the ratio of active power to apparent power (Fig. 1).

The power factor of majority of the commercial loads is less than unity. This is mainly because the induction motor is the most widely used of the various a c motors, and this motor works at less than unity power factor. This is partly because of the wattless magnetizing current it draws from the line, which results in a considerable fall in power factor. On the other hand, electric lamps (resistive loads) work practically at unity power factor, and therefore a system supplying a lighting load works at a much better power factor than the one supplying power.

Table 1 gives normal range of power factors under different operating conditions. If the power factor of any electrical system can be improved, this shall lead to energy conservation by the operating system. In the paper industry roughly 15% to 20% of the manufacturing cost is for electrical energy and thus any saving in this head shall lead to substantial profitability.

Table 1. Power Factors Under Different Operating Conditions

Sl No.	Condition	P F.
1.	System supplying lighting loads only.	0 9–0.95
2.	System supplying lighting and power, with former dominating.	0 8–0 85
3.	System supplying lighting and power, with later dominating.	0 75
4.	Three phase system, supplying power only.	0 65–0 7
5.	Single phase system, supplying power only.	0 4–0.45

Disadvantages of Low Power Factor :

It is always advantageous to operate any electrical system at the highest possible power factor. The disadvantages of operating the system at low power factor are as follows :

* Institute of Paper Technology, Saharanpur—247001 (U.P.)

** NITIE Bombay.

Active or Resistive Power

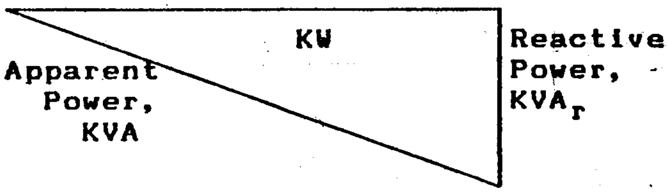

Fig. 1

(a) The power consumed by an electrical system (apparent power) comprises of active power and reactive power i.e.

Apparent power $= \sqrt{(KW)^2 + (KVAR)^2}$

Where,

KW = Active power = KVA × Cos ϕ

KVAR = Reactive power = KVA × Sin ϕ

As the consumer pays for apparent power, while only the active power is used, it is necessary for the consumer to reduce the reactive power for increasing the power factor.

(b) The amount of true power is less than the KVA capacity of the central station because of low power factor, although the central station or power station may be fully loaded from the point of view of current output. The same applies to the cables, switchgears, transformers etc. located between power station and the consumer. Therefore, if the power factor of any system can be raised, the profitability of the system can be increased without additional load on the central station. For example, if the power factor is raised from 0 6 to 0.9, the possible income may increase by 50% additional power can be made available without additional load from the power station.

(c) A poor power factor causes a large drop of voltage in the alternators. As a result, the excitation at low power factors is much greater than on high power factors, in order that the terminal voltage may be maintained at the proper value.

(d) Overloading of any transmission line leads to decreased power factor. This also results in voltage drop of the transmission line which may require installation of expensive appliances to maintain constant voltage at the far end of the line.

(e) A good voltage regulation is specially important on the circuits supplying power to induction motors, as torque of these motors is proportional to the square of the applied voltage. Therefore, a large sudden fall in voltage, may stall the motor.

Improvement Strategy :

The reactive power is of two following types :

1. Capacitive (leading) reactive power.
2. Inductive (lagging) reactive power.

The two types of the reactive power are in opposite direction to each other, hence, a decrease in any of the two may be achieved by supplying the other. Often, the power apparatus draws inductive power and hence suitable compensation needs to be done by supplying the capacitive reactive power. A capacitor increases leading reactive power and hence decreases lagging reactive power for the same KVA. This will improve the power factor of tne system.

Normally, one capacitor is installed at a suitable location in the system. This can help in achieving the objective in the absence of power factor variatinons; but with varying power factor, either the power factor is not fully improved or the capacitor rating becomes more than that required for the safe working of the system. In other words, we need high rating capacitor to get a higher power factor, but if the rating of the capacitor is more than that required for the system, then damaging overvoltages or transient torques may occur which may lead to damage of the system too.

One of the most common strategy is to install the capacitor banks at suitable locations and to switch ON/OFF the desired number of capacitors depending upon power factor requirement. These capacitors then absorb the extra capacitive reactive power from the source In this method, the power factor is increased or decreased in steps based on the number and capacity of the capacitors.

In the proposed method, the overall capacitance of the capacitors can be controlled by using a microprocessor, which may be kept in a loop to determine the power factor conditions at any time and switching actions may be performed by the software controlling the output of microprocessor interfaced with the switching circuit via a suitable coupling apparatus (Fig. 2).

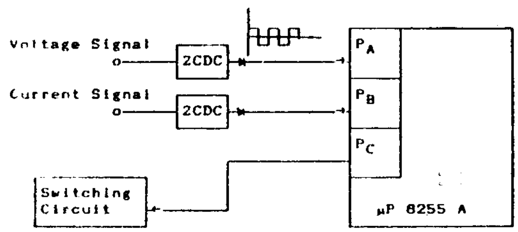

Fig. 2

8255A is a general purpose programmable parallel I/0 device[2], with 40 pins, out of which 16 pins are used for the power supply, reset etc.

The phase angle determination between signals of the same frequency requires the instants when both the signals attain a reference value, assumed to be zero volt in this case. ZCDC detects the moment at which the input signals crosses a reference of zero volt.

ZCDC basically uses a 741 op. amp. as a voltage comparator[1,3,4] (Fig.4), where the comparison is made with zero volt by earthing the pin 3. with a sinusoidal input at pin 2, a full wave square voltage is achieved at pin 6 having the voltage amplitude equal to the supply voltage at pins 4 & 7 (i. e. +15V), where the negative half of the square wave is clipped by using a diode. This diode must have its cutoff voltage more than +15V, else the system will not work.

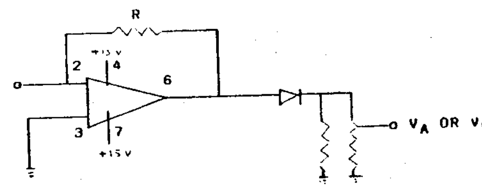

Fig 4.

Hardware :

Phase angle is the phase difference between the two waveforms of Voltage and Current. As microprocessor only accepts the voltage signal, the current signal can be converted into the voltage signal by using the principle that the voltage across a pure resistance is in phase with the current flowing through it (Fig.3).

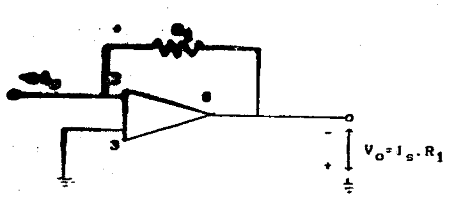

Fig 3.

Now, these waveforms are fed to Zero Crossing Detector Circuit (ZCDC) and a half rectified square wave is obtained, which is fed to the microprocessor. Similarly, the output from the microprocessor is in form of voltage signals and can be fed to LED display unit or capacitor switching circuit.

The above information exchange between the microprocessor and peripherals is done with the help of a 8255A 1/0 device.

The microprocessor cannot be supplied more than +5 volts, hence a potentiometer is required at the output of the ZCDC.

Software Description :

The software program analyses the input waveforms at port A (Fig.2) and detects the positive going instant. Then it switches over to port B. This may lead to the following three possible situations.

Phase Angle Lead :

In this case, the signal at port B will already be higher than that at A. Microprocessor increases the BC register pair contents until the port B signal goes low.

Phase Angle Lag

Here the port B input signal will be low. Here again the BC register pair contents are increased until the BC register pair count goes high.

Unity Power Factor

In this case, since both of the signals are in phase, the signals fed to the microprocessor attain logic O or logic I simultaneously. The microprocessor is checking B port after analyzing the A port signal. It may indicate a leading power factor condition. However, this inaccuracy is very small and can be ignored. The phase angle can be checked by interrupting the microprocessor, and checking the memory locations 2250 (Hex) and 2251 (Hex).

Now as the power factor has been measured, corrective action may be taken, by comparing the values of the BC register pair count in the microprocessor memory, for various ranges of power factor. For the present simulation, five power factor ranges, as given in Table 2, have been selected. More number of ranges can be incorporated by suitable modifications in the software and by addition of more capacitors. After comparison, the necessary corrective action shall be taken by the microprocessor controlled switching circuit. The corrective actions for the five selected power factor ranges are also given in Table 2.

Table 2. Corrective Actions To Be Taken By The Microprocessor

Power Factor	BC register pair count	Corrective action
1.00 to 0.80	Upto 008B	No Action
0.80 to 0.71	008C-00A7	Capacitor C_o ON
0.71 to 0.60	00A8-00C2	Capacitor C_o-C_1 ON
0.60 to 0.37	00C3-00ff	Capacitor C_o-C_2 ON
Below 0.37	Above 0100	Capacitor C_o-C_3 ON

Here the corrective action is the switching ON of the capacitors, as and when the power factor goes down.

The proposed scheme can provide the output only once. In practical cases, the power factor must be measured at regular intervals, and corrective action has to be taken accordingly every time. This can be easily done by introducing a delay period. After this delay, the microprocessor repeats the whole cycle and thus the corrective action is taken repeatedly at regular intervals. In this case, the time delay has been provided equal to 50 cycles of microprocessor (L 11 MVI D, 50), which is roughly equivalent to 0 26 seconds.

Software :

```
      MVI A, 92
      OUT OB
L12   MVI D,00
      MVI E,01
      LXI B,0000
L1    IN O8
      CMP D
      JNZ L1
L2    IN OB
      CMP E
      JNZ L2
      IN 09
      CMP E
      JZ L3
L4    INX B
      IN 09
      CMP E
      JNZ L4
      JMP L5
L3    INX B
      IN 09
      CMP D
      JNZ L3
L5    LXI H,2250
      MOV M,C
      INX H
      MOV M,B
      MOV A,B
      CMP E
      JNC L6
      MOV A,C
      CPI 89
      JC L7
      CPI A 9
      JC L 8
      CPI C5
      JC L9
      CPI FF
      JC L10
L6    MVI A, 47
      OUT OA
      JMP L11
L7    MVI A,00
      OUT 0A
      JMP L11
L8    MVI A,01
      OUT OA
      JMP L11
L9    MVI A,03
      OUT 0A
      JMP L11
L10   MVI A,07
      OUT 0A
L11   MVI D,50
L14   DCR D
      JZ L12
      LXI B,FFFF
L13   DCX B
      MOV A,C
      ORA B
      JNZ L13
      JMP L14
```

Conclusion

The microprocessor can be used to control the power factor of the system by reducing the reactive power and thus to save energy. The program given here results in only five actions as indicated in Table 2. The program can easily be modified for a higher accuracy of power factor control limits and for a higher number of capacitors to be switched ON or OFF in the capacitor battery.

References:

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