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Automatic Power Factor Correction Using Capacitive Bank

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ABSTRACT
The power factor correction of electrical loads is a problem common to all industrial companies. Earlier the power factor correction was done by adjusting the capacitive bank manually [1]. The automated power factor corrector (APFC) using capacitive load bank is helpful in providing the power factor correction. Proposed automated project involves measuring the power factor value from the load using microcontroller.
The design of this auto-adjustable power factor correction is to ensure the entire power system always preserving unity power factor. The software and hardware required to implement the suggested automatic power factor correction scheme are explained and its operation is described. APFC thus helps us to decrease the time taken to correct the power factor which helps to increase the efficiency.
Keywords   -   APFC,   Apparent   power,   Capacitor   bank,   Power   factor

I. INTRODUCTION

Majority of the loads in the industries are highly inductive in nature such as induction motors, AC/DC drives, welding machines, arc furnaces, fluorescent Lightings, electronic controls and computers. There may be a few resistive loads for heaters and incandescent bulbs. Very rarely industries may have capacitive loads such as synchronous motors [2].

Net industrial load is highly inductive causing a very poor lagging power factor. If this poor power factor is left uncorrected, the industry will require a high maximum demand from Electricity Board and also will suffer a penalty for poor power factor. Standard practice is to connect power capacitors in the power system at appropriate places to compensate the inductive nature of the load.

II. PROBLEM STATEMENT

An electrical load that operates on alternating current requires apparent power, which consists of real power plus reactive power. Real power is the power actually consumed by the load. Reactive power is repeatedly demanded by the load and returned to the power source, and it is the cyclical effect that occurs when alternating current passes through a load that contains a reactive component.

The presence of reactive power causes the real power to be less than the apparent power, and so, the electric load has a power factor of less than 1. The reactive power increases the current flowing between the power source and the load, which increases the power losses through transmission and distribution lines. This results in operational and financial losses for power companies.

$$P = \text{true power} \qquad P = I^2R \qquad P = \frac{E^2}{R}$$
*Measured in units of **Watts***

$$Q = \text{reactive power} \qquad Q = I^2X \qquad Q = \frac{E^2}{X}$$
*Measured in units of **Volt-Amps-Reactive (VAR)***

$$S = \text{apparent power} \qquad S = I^2Z \qquad S = \frac{E^2}{Z} \qquad S = IE$$
*Measured in units of **Volt-Amps (VA)***

Therefore, power companies require their customers, especially those with large loads, to maintain their power factors above a specified amount (usually 0.90 or higher) or be subject to additional charges. Electrical engineers involved with the generation, transmission, distribution and consumption of electrical power have an interest in the power factor of loads because power factors affect efficiencies and costs for both the electrical power industry and the consumers [3] [4].

In addition to the increased operating costs, reactive power can require the use of wiring, switches, circuit breakers, transformers and transmission lines with higher current capacities.

Power factor correction attempts to adjust the power factor of an AC load or an AC power transmission system to unity (1.00) through various

methods. Simple methods include switching in or out banks of capacitors or inductors which act to cancel the inductive or capacitive effects of the load, respectively [5] [6].

Non-linear loads create harmonic currents in addition to the original AC current. The simple correction techniques described above do not cancel out the reactive power at harmonic frequencies, so more sophisticated techniques must be used to correct for non-linear loads [7].

III. BLOCK DIAGRAM

Given below is the block diagram of automatic power factor correction system. The input to the circuit is applied from the regulated power supply. The AC input i.e., 230V from the mains supply is step down by the transformer to 12V and is fed to a rectifier. The output obtained from the rectifier is a pulsating DC voltage. So in order to get a pure DC voltage, the output voltage from the rectifier is fed to a filter to remove any AC components present even after rectification.

The supplied voltage and current signals, taken through a potential transformer and a current transformer. The two sinusoidal waveforms are being changed to square waves through two zero-crossing detectors. These digital square waves are used by microcontroller to calculate phase difference and thus power factor.
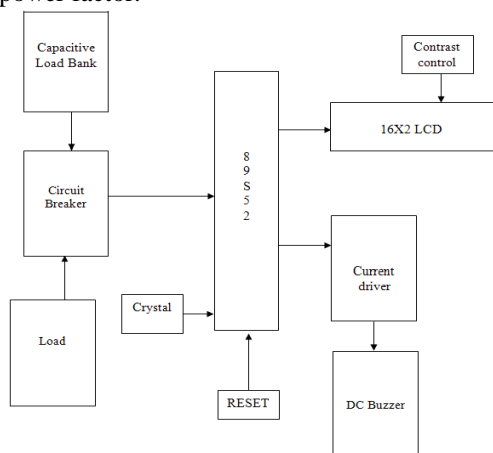

Figure 1: Block diagram of APFC

A capacitive load bank is used which develops an electric load, applied to an electrical power source and converts or dissipates the resultant power output of the source. In this way help to improve power factor.

The status of APFC system is displayed on the LCD such as lagging or leading, calculated power

factor etc. If there is any error or alarm condition then buzzer is used to indicate the information to user. Microcontroller used is AT89S52 which is heart and brain of the entire APFC system. It takes input from user and zero crossings of current, voltage waveforms. It controls the capacitor bank as required to compensate for leading or lagging power factor.

IV. SIMULATION AND OBSERVATIONS

The simulation tool used for the analysis of the APFC system is Proteus VSM. It is an interactive circuit simulation tool in the design environment. It is possible to draw a complete circuit for a micro-controller based system and then test it interactively, all from within the same piece of software. For the educational user and engineering purpose, ISIS also used for producing attractive schematics.

Following figure shows how APFC system looks like when running interactively.
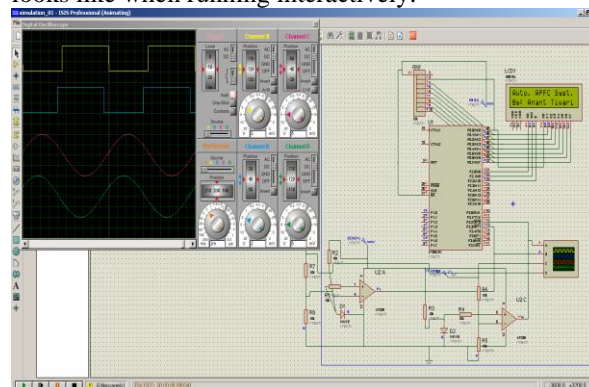

Figure 2: APFC Simulation on Proteus VSM

It shows input waveform of voltage and current with phase difference. Both of the waveforms are fed to zero crossing detectors, which give square waves in digital format. These digital waveforms are used by microcontroller to calculate power factor. Microcontroller takes decision to switch appropriate capacitor bank to compensate for power factor.

Figure given next represent the situation when power factor is very poor at 0.767. Low power factor is not accepted as per standard because poor or low power factors affect efficiencies and costs for both the electrical power industry and the consumers. In addition to the increased operating costs, reactive power can require the use of wiring, switches, circuit breakers, transformers and transmission lines with higher current capacities. Poor power factor needs to be compensated by capacitor bank.
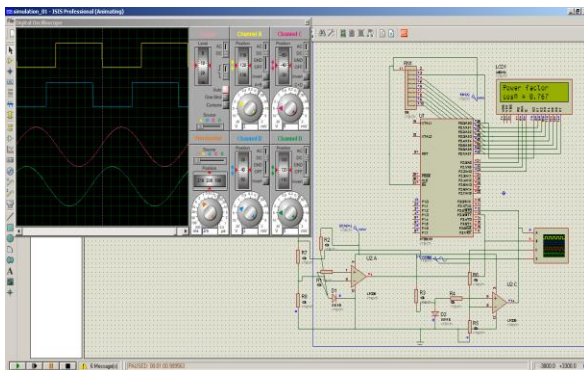
Figure 3: Poor power factor detection

After detecting poor power factor, APFC system switches one capacitor at a time out of a group of eight capacitors. If required goal to achieve power factor is meet then next cycle repeated else switching of capacitor continue till compensation is not under control. Figure given next shows APFC system when system achieves the optimum power factor value of 0.940 as required.
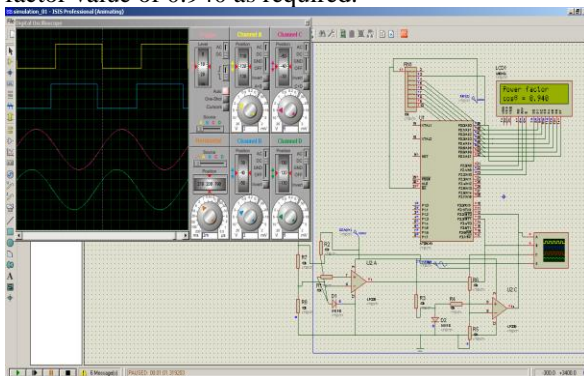

Figure 3: Improved power factor by APFC

Thus we observe that before actual implementation of APFC system in real physical world, we can verify the proof of concept using Proteus VSM.

V. RESULTS AND CONCLUSIONS

By observing all aspects of the power factor it is clear that power factor is the most significant part for the utility company as well as for the consumer. Utility companies get rid from the power losses while the consumers are free from low power factor penalty charges.

By installing suitably sized power capacitors into the circuit the Power Factor is improved and the value becomes nearer to 0.9 to 0.95 thus minimizing line losses and improving the efficiency of a plant [8]. By using this APFC system the efficiency of the system is highly increased.

VI. FUTURE ENHANCEMENTS

The automotive power factor correction using capacitive load banks is very efficient as it reduces the cost by decreasing the power drawn from the supply. As it operates automatically, manpower are not required and this Automated Power factor Correction using capacitive load banks can be used for the industries purpose in the future.

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