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Design and Implementation of APFC panel using microcontroller 8051

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***Abstract*—**

This abstract presents a microcontroller-based Automatic Power Factor Correction (APFC) panel design that continuously monitors and optimizes power factor by dynamically switching capacitor banks to compensate for reactive power, thereby improving system efficiency and reducing energy costs. Power factor is a crucial aspect of electrical systems, reflecting the efficiency with which electrical power is converted into useful work output. A low power factor indicates poor efficiency and results in higher energy costs and increased strain on the electrical infrastructure. Automatic Power Factor Correction (APFC) systems help maintain the power factor close to unity by automatically compensating for reactive power. Microcontroller IC (AT89C51) reduce programming complexity that make it one of the most economical system than any other controlling system. Automatic 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 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 country 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 APFC .

I. Introduction

Most of the electrical loads are inductive in nature resulting in severely lagging power factor. The most practical and economical solution to improve the power factor (PF) is to provide reactive compensation by installing power capacitors of suitable rating at strategic locations. PF correction is more important in electrical distribution systems. For accomplishing the same, low voltage (LV) capacitors are being extensively used both as fixed capacitor banks and in Automatic Power Factor Correction (APFC) panels. Application of APFC panels is becoming more attractive due to their techno-commercial advantages like (1) Ability to maintain PF at the required high value (close to unity) and hence avoid penalties imposed by electricity supply companies due to low PF, (2) A void over compensation during low load conditions and (3) Improved efficiency of the system due to reduction in losses. These desired features of the APFC panels can be efficiently achieved with appropriate design, material, construction and application.

II. Importance of power factor correction

The power factor plays an important role in the AC system since the power consumed depends upon this factor. The load on the power system is inductive (e.g. induction motors, arc lamps, transformer, etc.) in nature, which have low lagging power factors. This low power factor increases the current, which results in an increase in losses and causes a decrease in the efficiency of the system. Hence, it is necessary to improve the power factor of the system, in order to ensure economic transmission and distribution of electric power. Power factor improvement refers to the process of increasing the power factor of an electrical system, which is the ratio of the real power to the apparent power consumed by the system. A low power factor can result in increased energy consumption, reduced efficiency, and additional costs. Power factor improvement techniques include the use of capacitors, harmonic filters, and active power factor correction devices to reduce reactive power and improve overall system performance.

III. Proposed system

The variation of power factor in a frequent manner is not possible. So static capacitors are used for power factor correction. In large industries the loads are not constant in nature. With respect to our requirements the loads can be frequently switched on and off. For fluctuating loads the power factor correction with the help of static capacitors is not effective. In this place the APFC (Automatic PowerFactor Corrector Panel) comes into picture. According to the variation of the power factor level the APFC panel automatically switches capacitor banks and it brings the power factor unity. The failures in the capacitor banks are identified with the help of microcontroller and it alerts the user by developed android mobile applications. Due to the failure in the capacitor banks affects the power factor. If low power factor is continually maintained for some period of time, it influences the changes of maximum demand in an industry. In order to maintain the maximum demand at the right level unwanted loads in the industry can be switched in an automatic manner to maintain the right maximum demand.

IV. BLOCK DIAGRAM

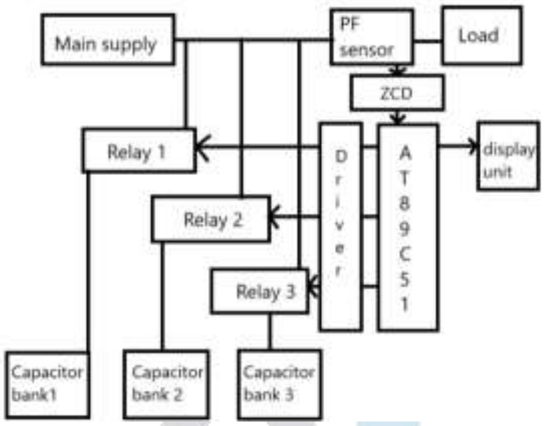


Fig 1. Block diagram

The above fig. shows the block diagram of the entire system. The main element in the block diagram is microcontroller. The low cost microcontroller called AT89C51 is used for efficient operation. The entire operation of the circuit is enhanced with the help of the controller.

Microcontroller: A microcontroller or processor is a central unit that monitors the power factor and controls capacitor switching.

Capacitor Banks: A collection of capacitors used to provide reactive power correction.

Switching Devices: These are often contactors or solid-state switches that connect or detach capacitor banks from the system.

Sensors: Current and voltage sensors for measuring power factors and other electrical factors.

Display Unit: The Display Unit displays information on the power factor, the status of capacitor banks, and other important data. Protection Devices include fuses, circuit breakers, and other components that ensure safe operation.

V. FLOWCHART

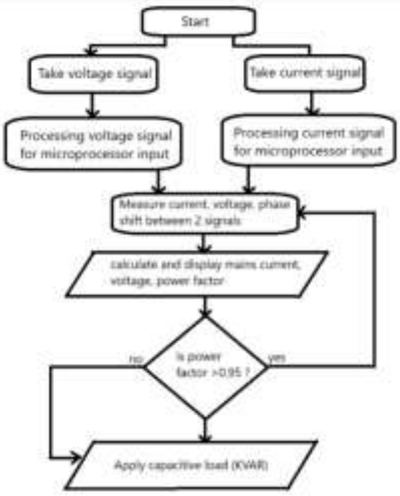


Fig 2. flowchart

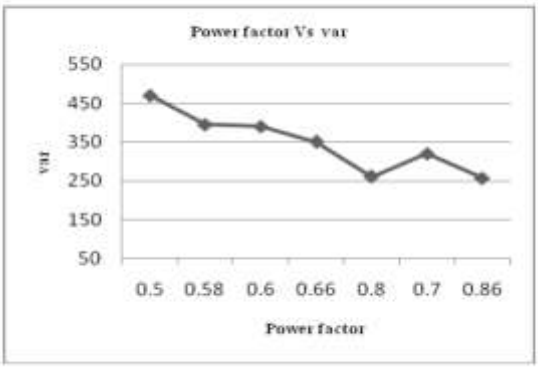


Fig 3. Graph (pf vs var)

The graph is drawn between the power factor and var demand. The graph shows the power factor is inversely proportional to the var. The switching of capacitor is done according to the variation of the power factor due to the changes in loads. Initially the power factor is very low and the corresponding reactive power required by the system is very high. The controller sensed the variation of the power factor and it switches the appropriate capacitor. So the required reactive power will be supplied to the load. Power factor is improved by adding a capacitor to the system and the required reactive power is reduced. The capacitor bank failure is indicated in the graph, which clearly shows the improved power factor is dipped from higher values to the lower values. Again by adding a capacitor banks the required var is reduced and also the power factor is improved to 0.86.

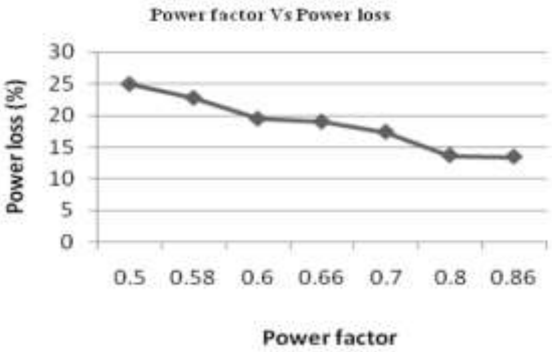
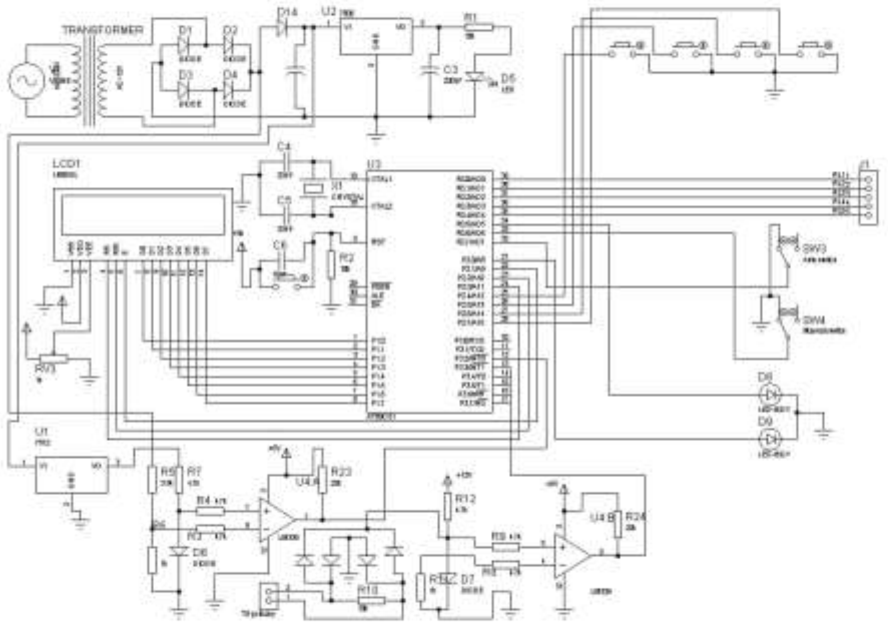


Fig 4. Graph (pf vs power loss)

The above Fig. gives that at initial condition the power factor is very low and the corresponding power loss is very high. The line losses are directly proportional to the square of the current. Therefore the consumption of high current will increase the loss. Current is inversely proportional to the Cos Φ. If the power factor falls below 0.5 then the losses are four times greater than the nominal power factor. So the percentage of power loss with respect to power factor is shown in the Fig. After adding a capacitor to the system the power factor comes very close to the unity level. With the help of the proposed system the power loss is reduced by improving a power factor.

VI. CIRCUIT DIAGRAM



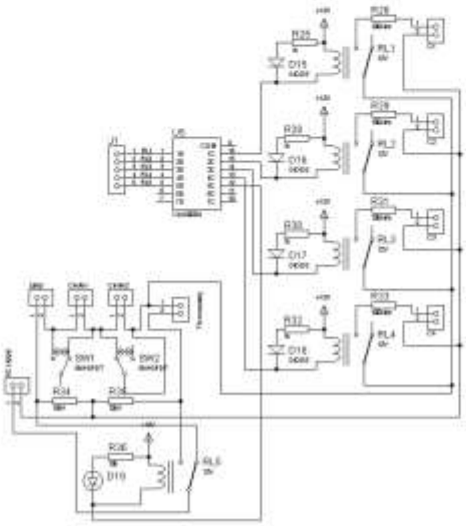


Fig 5. Circuit diagram

The figure shows circuit diagram of APFC panel simulation on proteus. Given below are few components used in circuit diagram.

Vsine : A vsine source typically represents an AC voltage source whose output varies sinusoidally with time, often defined by parameters like:

- Amplitude: The peak value of the voltage.
- Frequency: How many cycles the sine wave completes per second (in Hertz).
- Phase: The phase shift of the sine wave.
- Offset: The average or DC component of the sine wave (i.e., shifting the sine wave up or down).

Transformer : A "2P2S" transformer, in the context of configurable transformers, refers to a component with two primary coils (2P) and two secondary coils (2S).

Diode: A diode is a two-terminal electronic component that allows current to flow primarily in one direction (from anode to cathode), acting as a one-way switch or rectifier.

AT89C51: The AT89C51 is a low-power, 8-bit microcontroller from the 8051 family, featuring 4KB of Flash memory, 128 bytes of RAM, 32 I/O lines, two 16-bit timers/counters, and a serial communication interface, suitable for various embedded applications.

Diode LED: A light-emitting diode (LED) is a semiconductor device that emits light when an electric current flows through it, and it's a type of diode that converts electrical energy into light.

Resistor: A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. 100k and 10k resistors are used.

Crystal: A frequency-selective element, typically represented by a lumped circuit model (inductor, capacitor, and resistor), used to simulate crystal oscillator behavior and determine loading capacitance for specific frequencies.

IC7805: The 7805 is a popular, three-pin integrated circuit (IC) voltage regulator that provides a stable +5V output from a higher input voltage (typically 7-35V).

IC7812: The 7812 is a common, fixed-voltage, positive linear voltage regulator that outputs a stable +12V and is part of the 78xx family.

Display: WH1602W 16x2 LCD Displays are built-in controller ST7066 or equivalent. It is optional for + 5.0 V or + 3.0 V power supply. The LEDs can be driven by pin 1, pin 2, or pin 15 pin 16 or A/K.

LM339: The LM339 is a low-power quad voltage comparator, meaning it contains four independent comparators that can be used for tasks like zero-crossing detection or window detection. It's designed to operate from a single power supply and has open-collector outputs.

SWSPDT: In circuit simulations, an SPDT (Single Pole, Double Throw) switch, often represented as "SW" or "SPDT", models a switch that can connect a single input to either of two output ports controlled by a signal.

Button(switch): In the context of simulation, a "button component" typically refers to a clickable element that triggers actions or events, allowing users to interact with the simulation and control its behavior.

VII. Hardware Implementation

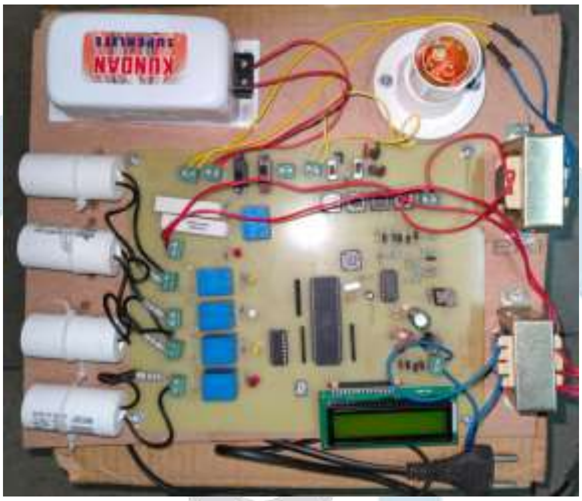


Fig 6. Hardware implementation

The complete hardware implementation of the APFC system is shown in Fig. Load having inductive nature(Induction motor) is used for testing the prototype of the system. Also mixed load such as inductor connected in series with the resistive load suck as incandescent lamp is also tested.

VIII. Test Result and Conclusion

From the economic stand point of every industry, it is necessary to maintain the power factor very close to unity. This paper proposed a possible solution for the problems faced by a APFC panel in industries. Investigations of power factor variations were carried out for different load conditions. It has been observed that the variation in the load can change the power factor abruptly. Then it brings the power factor very close to unity by adding appropriate capacitive banks to the load. In case of any failure occurs in the capacitive banks that can be identified by microcontroller and the user can monitor the live status of the entire panel by developed android applications. Also the future energy consumptions can be predicted by using cloud analytics.

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