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A New Technique of Automatic Power Factor Correction

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ABSTRACT: Efficient generation of power at present is crucial as wastage of power is a global concern. Power factor measures the power efficiency of a system and is an important feature in improving the quality of supply. The increasing use of inductive load in most of the power systems results in poor power factors. A power factor correction unit would allow the system to regain its power factor close to unity for efficient operation. By correcting the power factor reduces the power system losses, increased load carrying capabilities, improved voltages, and much more. The project aim is to build an Automatic Power Factor Control (APFC) unit which is capable to monitor the energy consumption of a system and improving the power factor automatically. The APFC device measures the reactive power consumed by a system's inductive load balances the lagging power factor using capacitance from the capacitor bank. For the efficient use of energy, it is important to use automatic power factor correction in industries. Although there has been much research in automatic power factor correction there is huge potential for more research in this field in the future.

KEYWORDS: Automatic Power Factor Correction, Current, Power Factor, Power Factor correction, Voltage.

1. INTRODUCTION

The objective of the power factor correction involves modifying the circuit in a way that increases the power factor and ideally increases the power factor to 1. The power factor of an electrical system gives the idea about the efficiency of the system. A low power factor increases the losses and also draws a penalty. An electric bill includes additional charges when the customer has a power factor less than the predetermined limit, typically between 80 and 90 percent. This is called the power factor penalty since it is a penalty weighed on the customer's electrical bill [1].

A poor power factor can be the outcome of either a significant phase difference between the voltage and current at the load terminals, or it can be due to a high harmonic content or distorted/discontinuous current waveform. Poor load current phase angle is generally the result of an inductive load such as an induction motor, power transformer, lighting ballasts, welder, or induction furnace. A poor power factor due to an inductive load can be improved by the addition of power factor correction, but, a poor power factor due to a distorted current waveform requires a change in equipment design or expensive harmonic filters to gain an appreciable improvement. To have an efficient system the power factor should be maintained near to 1. Utilities typically charge additional costs to commercial customers who have a power factor below some limit, which is typically 0.9 to 0.95 [2]–[5].

1.1. Reasons for poor Power Factor:

1. Lamps operated with choke.
2. Power and Distribution transformers. A transformer is very inductive and has a very low power factor.
3. Induction motor (loaded or unloaded)

1.2. Methods of Power Factor Improvement:

There are three main ways to improve power factor:

1.2.1. Capacitor Banks:

Improving power factor means reducing the phase difference between voltage and current. Since the majority of loads are inductive, they require some amount of reactive power for them to function.

A capacitor or bank of capacitors installed parallel to the load provides this reactive power. They act as a source of local reactive power, and thus less reactive power flows through the line. Capacitor banks reduce the phase difference between the voltage and current.

1.2.2. Synchronous Condensers

Synchronous condensers are 3 phase synchronous motors with no load attached to their shaft. The synchronous motor has the characteristics of operating under any power factor leading, lagging, or unity depending upon the excitation. For inductive loads, a synchronous condenser is connected towards the load side and is overexcited. Synchronous condensers make it behave like a capacitor. It draws the lagging current from the supply or supplies the reactive power [6].

1.2.3. Phase Advancers:

This is an AC exciter mainly used to improve the PF of an induction motor. They are mounted on the shaft of the motor and are connected to the rotor circuit of the motor. It improves the power factor by providing the exciting ampere turns to produce the required flux at the given slip frequency. Further, if ampere-turns increase, it can be made to operate at the leading power factor.

2. LITTERATURE REVIEW

Paul Nosike Ekemezie et al. discussed the need to keep EMI emissions by electronic power supplies below the limit specified by international standards has dictated that any new power supply design must include active power factor correction at the front end. The modern trend in power supply designs is towards digital control. The power factor correction circuit employs a zero voltage transition arrangement to minimize switching losses. Interface requirements between the power converter stage and the digital control processor are tackled. An Average current mode control method is employed in the controller. The complete design has been tested by employing Power Sim power electronics simulation software. The resulting input voltage and current waveforms show that the design is successful [7].

Kurma Sai Mallika et al. said power factor control is a major role in the improvement of power system stability. Many of the existing systems are expensive and difficult to manufacture. Nowadays many of the converters have no input power factor correction circuits. The effect of the power factor correction circuit is used to eliminate the harmonics present in the system. This type of power factor correction circuit is mostly used in the Switched Reluctance Motor controller drive. Fixed capacitor systems are always the leading power factor under any load conditions. This is unhealthy for installations of the power systems. The proposed embedded system drive is used to reduce the cost of the equipment and increase the efficiency of the system. Experimental results of the proposed systems are included. It is the better choice for effective cost processes and energy savings [8].

Reetam Sen Biswas et al. discussed the improvement of power quality by continuously monitoring the load. When the load power factor goes below a specific threshold, the line current increases, resulting in increased line loss and voltage drop. When the power factor falls below a certain level, the goal is to inject capacitances of the appropriate values. The phase

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difference is used to create a signal with a pulse width proportionate to it. The power factor of each pulse may be calculated using the ON-time period. After that, some arithmetic is used to determine the exact value of the capacitance to be injected. Finally, the calculated capacitance value must be estimated using conventional capacitance values. The microcontroller will swap all of the capacitors, bringing the total capacitance value extremely near to the precise value [9].

Md. Sohel Rana et al. provides the most effective automated power factor increase by employing static capacitors that will be controlled by a Microcontroller at a very cheap cost. Many tiny rating capacitors are linked in parallel in this experiment, and a reference power factor is programmed into the microcontroller IC as a standard value. To enhance the power factor near to unity, a suitable amount of static capacitors are automatically linked according to the microcontroller's instructions. Some techniques, such as the use of resistors instead of potential transformers and the use of a low-cost microcontroller IC (ATmega8) that reduces programming complexity, making it the most cost-effective system of any controlling system [10].

Research Question:

1. How to improve the power factor automatically?
2. What are the components used in the automatic power factor correction?

3. METHODOLOGY

3.1. Design Methodology:

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The Automatic Power Factor Correction (APFC) is a device based on the embedded system having Atmel microcontroller AT89S52. The sampled voltage and current are taken as input where the difference in the waveforms indicates phase angle difference. The system power factor is compared with the predetermined level and the difference is measured for switching of the required number of capacitors from the capacitor bank. Figure 1 shows the block diagram of the proposed system.

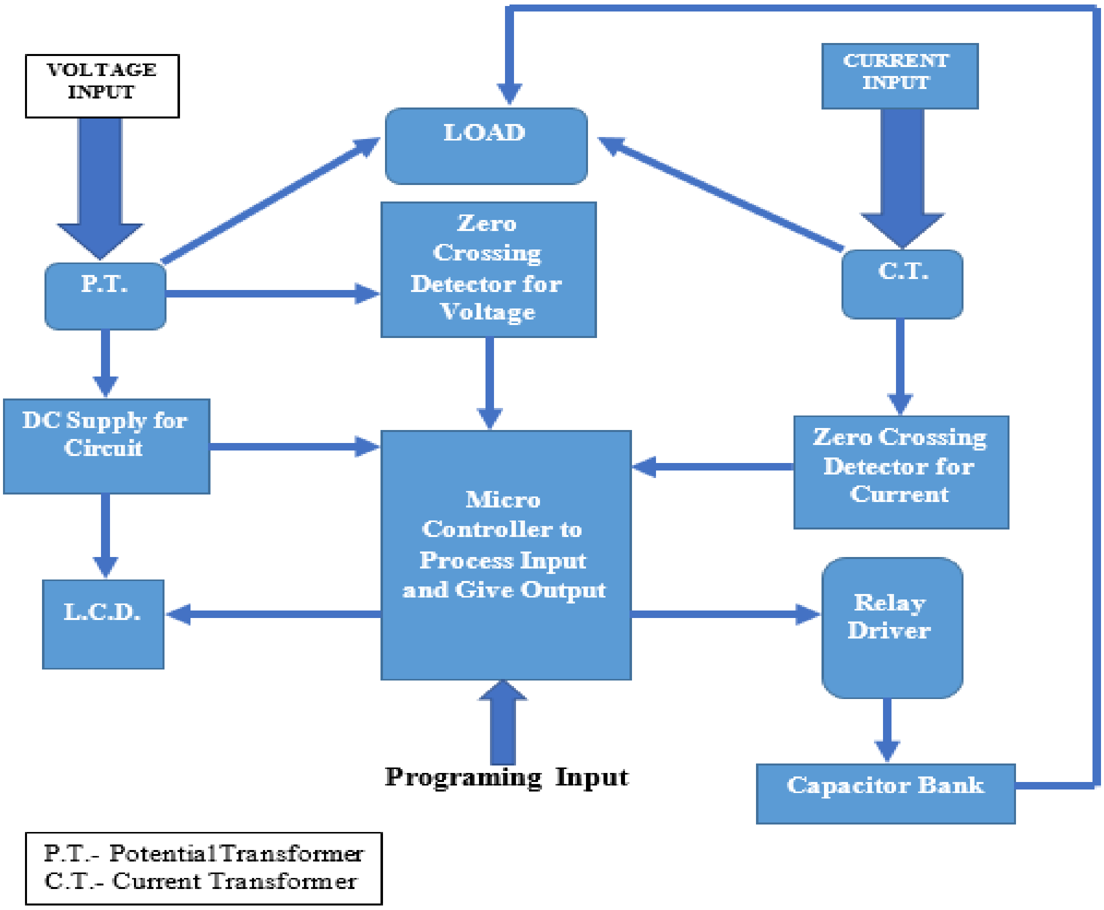

Figure 1: Block diagram of modules used in automatic power factor correction.

3.2. Components:

The whole APFC unit consists of several modules. They mutually work together to gain power factor correction. These modules are given as:

3.2.1. Power Supply:

The AC mains supplies an AC power of 230v at a 50Hz frequency. But our circuit requires dc power to operate the modules. This AC signal is then converted to DC with help of a bridge rectifier followed by filtering capacitors. The final DC output is achieved by using voltage regulator IC.

3.2.2. Zero crossing detector:

A zero-crossing detector is a sine wave to square wave converter. It detects the phase lag between the voltages and current, two detectors are used to find the arrival instance of each signal. The difference in the arrival instance is adjusted to angle gives the phase angle lag. By

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taking the cosine of this angle, the power factor of the circuit is calculated. The reference voltage in this case is set to zero. If the input voltage is a low-frequency signal, then the output voltage will be less and there will be a quick switch from one saturation point to another due to this there will be noise in between the two input nodes, the output may fluctuate between positive and negative saturation voltage Vsat. The LM339 IC is used as the comparator circuit to function as the zero-crossing detector.

3.2.3. Microcontroller:

The main component of the embedded system is the microcontroller which is responsible for all the logical processing. It takes input, processes it according to the program written to it, and then processed the output. The microcontroller used here is AT89S52 which is an 8-bit controller. A program is developed for calculation and automatic actions of the project and burned on the microcontroller. Main's voltage, mains current, real power, apparent power, and power factor of the network are calculated through the developed program.

3.2.4. Load network:

The load network is a combination of loads having inductive, resistive characteristics and consumes huge electrical power due to the lagging power factor. The network collectively acts as a highly inductive load operating at a very poor power factor.

3.2.5. Relay Driver:

Relay cannot operate with the supply provided by the microcontroller output signal. The current supplied by the output pin of the microcontroller is not sufficient for the relay coil. So, a relay driver ULN2003 is used which amplifies the signal.

3.2.6. Display:

The calculated power parameters current power factor, mains voltage, mains current, real and apparent power are continuously displayed on a 20x4 Liquid Crystal Display monitor.

3.2.7. Capacitor Bank:

A capacitor bank is the collection of capacitors of different values. Series and parallel combination of different capacitors provides the capacitance required for balancing poor power factor. The size of the capacitor is determined based on the required KVAR demand by the load network.

3.3. Data Collection:

The power factor (PF) of an alternating current (AC) system defined as the ratio between the useful (real) power (kW) and the (apparent) power (kVA) consumed by the component present in the AC circuit. Real power is the capacity of the circuit for performing work at a particular time. Apparent power is the product of the current and voltage of the circuit. Due to the components having the capacity of storing energy like inductor and capacitor there is a phase shift between voltage and current. An Inductor stores the energy in the form of magnetic energy and the capacitor stores the energy in the form of electrostatic energy, neither of them dissipates it. The phasor diagram is shown in Figure 2.

Power Factor (PF) = kW/kVA   // kW= Real Power, kVA = Total Power

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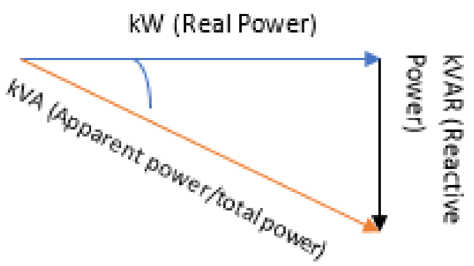

Figure 2: Illustrates the schematic diagram for the power factor.

The load with a PF of 1.0 results in the most efficient loading of the supply and a load with a power factor of 0.5 will result in much higher losses in the supply system.

3.4. Data Analysis:

Load is connected with the APFC to create a load network. Loads are connected in a manner of combinations such that different power factors could be introduced to the system for different loads. The load network consists of resistive load, inductive load having a high inductance value in series, and parallel connections with resistors.

3.1 Analysis of load without correction

The analysis of the pure restive load (R Load), series resistive-inductive loads (Series R-L Load) and parallel resistive-inductive (Parallel R-L Load) was done without using the correction equipment. The readings for different electrical loads are recorded in the Table. 1.

Table 1: Load Analysis for a different combination of load accompanied without APFC.

Sl No.	Load Type	Supply Voltage (Volts)	Supply Frequency (Hz)	Load Current (Ma)	Power Drawn (Watts)	Power Factor	Remarks
1	Pure R	234	49.87	437	101.2	0.99	No correction required
2	Series R-L	235	49.92	318	55.3	0.73	Correction required
3	Parallel R-L	235	49.89	730	129.1	0.76	Correction required

3.2. Analysis of Load with correction:

As there is a need for power factor improvement for Series R-L load and Parallel R-L load, they were connected to the supply along with the correction equipment designed to verify the expected correction. The correction equipment is plugged in and the loads are connected to the output point of the equipment. All the three loads are tried with system and observed values and recorded in Table 2.

Table. 2: Load Analysis for a different combination of load accompanied with APFC

Sl No.	Load Type	Supply Voltage (Volts)	Supply Frequency (Hz)	Load Current (Ma)	Power Drawn (Watts)	Power Factor	Remarks
1	Pure R	230	50.02	424	96.6	0.99	No improvement
2	Series R-L	234	50.10	267	59.9	0.96	31.5% increase in PF
3	Parallel R-L	232	50.06	602	134.2	0.97	29.3% increase in PF

4. RESULT AND DISCUSSION

Power factor correction (PFC) is the process of compensating a lagging current by a leading current, by connecting capacitance to the supply. Capacitors contained in most power factor correction system draws current that leads voltage and produces a leading power factor. A sufficient capacitance is connected so that the power factor is adjusted as close to unity as possible. Theoretically, capacitors could provide 100% of the needed reactive power, however, practically, correcting power factor much nearer to unity may result in harmonic distortion. If capacitors are connected to a circuit that operates nominally at a lagging power factor, the extent to which the circuit lags will reduce proportionately. Power factor correction is applied to neutralize as much of the magnetizing current as possible and to reduce losses in the distribution system. It offers many benefits to the commercial electrical consumer, including reduced utility bills by eliminating charges on reactive power, reduced losses making extra KVA available from the existing supply. Thus, it improves energy efficiency.

5. CONCLUSIONS

Automatic power factor correction techniques can be applied in industries, commercial lines, and power distribution systems to increase the stability and efficiency of the system. The power factor correction device designed was able to improve the power factor from 0.76 to 0.97 under the test load conditions. The average savings in energy consumption was about 1.7% for the designed load and different load patterns. Care should be taken so that the capacitors are not subject to rapid on-off-on conditions as well as overcorrection otherwise the lifespan of the capacitor bank decreases significantly. The APFC device helps to pull in high current drawn from the system and reduce charges on utility bills. Reduced power consumption results in lower greenhouse gas emissions and fossil fuel depletion by power stations and would benefit the environment. In factories, it is critical to utilize automated power factor correction for optimal energy usage. Despite the fact that there has been a lot of study on automated power factor adjustment, there is still a lot of room for more in the future.

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