An Overview of Power Factor Improvement Techniques in Domestic and Industrial Loads

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Abstract— In the present world which is continuously looking towards advancement in technology power is very precious. So it is necessary to find out the causes of power pollution and methods must be adopted to minimize the same. Industries mainly have inductive and nonlinear loads. Thus the overall power factor of industries are very low due to the increased intake of reactive power by the inductive loads Embedded technology comes into picture for the very first time when we are thinking about any programmable device for power factor improvement. Today embedded technology is very much popular and efficient and microcontroller based embedded technology is chosen to develop most products. A suitable circuit for Automatic power factor correction can be developed and the same technique can be applied to the industries, power systems and households such that stability of the system can be increased. It is economical to use microcontroller for the development of the circuit.

Keywords: Power Factor Improvement Techniques, Domestic and Industrial Loads

I. Introduction

The use of electronic devices such as computers, monitors, servers and photocopiers is increasing day by day. These devices are mostly powered by switched mode power supplies (SMPS). Hence the increased use of these kinds of electronic apparatus in industries and households would cause power pollution. If the design part of these devices is not done properly, these nonlinear loads can inject harmonic currents onto the main power supply. As a result power factor reduces below unity. A load with unity power factor results in the most efficient loading of the supply and if the power factor of the load falls below 0.5 much higher losses are produced in the power supply system. As a result of reduced power factor there exist a phase difference between voltage and current at the load end. Phase angle that exist between then current and voltage at load terminal is the result of inductive loads such as an induction motor, power transformer, welder or induction cooker. Power quality has become an increased concern to many industries. Correspondingly industries now employ methods that calculate parameters such as harmonic distortions and power factor. Most of the industrial loads are inductive and nonlinear loads. Inductive loads include induction motors, transformers and ballast type lighting. Power degradation is caused due to load switching, motor starting, intermittent loads and arc furnaces. Non-linear loads are introduced due to the switching action in industries. Personal computers, PLC's, refrigerators, fax machines, printers etc are few examples of nonlinear loads [1-4]. Personal computers use switched mode power supplies and these schemes introduce current harmonics. Power factor is the ratio of actual electric power supplied by the ac system to the product of rms value of current and voltage. Thus the introduction of current harmonics deteriorates the power factor of the system. Automatic capacitor banks are the most commonly used method to improve power factor. Recent studies on solar power generation schemes are presented [5-11].

II. Current Scenario

A non-linear load with poor power factor is responsible to generate harmonics. Harmonics and poor power factor has got many undesirable effects and so it must be reduced by some suitable means. Continuous use of non-linear loads in domestic side is increasing day by day which would obviously lower the power factor below unity. A non-linear load is expected to generate harmonics if it is having a poor power factor. Harmonics and poor power factor has got many undesirable effects. At the very fundamental level we could say the power factor of an electrical device is the ratio of the power drawn by the device from main supply and the actual power consumed by the device. An electric or electronic device is said to be ideal if it is able to consume all the power that it draws. In other words an ideal device has got unity power factor. The concept of unity power factor represents a load which is linear and purely resistive. It will not have any significant changes with the change in input voltage and its inductance and capacitance would be negligible. Power factor can be two types 'displacement' power factor and 'distortion' power factor. They can be differentiated by considering two important reasons for poor power factor. Power factor of a device lowers when it draws a current out of phase with respect to supply voltage. In this case power factor is known to be displacement power factor which is typically associated with electric motors used in industries. Similarly power factor associated with a device when it draws a non- sinusoidal current is known as distortion power factor. Distortion power factor is typically associated with electronic devices such as photo copiers, switched-mode power supplies (SMPSs) driven battery chargers, and computers. It is very necessary to pay attention to both displacement and distortion power factor. But for power system designers' displacement power factor has got great importance than distortion case.

The presence of inductive loads such as an induction motor, induction cooker, power transformer, welder is responsible for the phase angle that exist between voltage and current at the load end. The increased use of power electronic equipment obviously reduces the quality of power supply. Inductive loads such as induction cookers are extensively used in domestic side now days. The current drawn by such nonlinear loads comprises of two components: The resistive component and the inductive component. The actual or useful work is done by the resistive component and the inductive component or magnetic component does no work. As mentioned earlier current through a resistive component is in phase with supply voltage. Hence it draws active power which is measured by the power meter. Whereas the current flowing through an inductive component is 90 degrees out of phase with respect to the supply voltage and it does not contribute to the active power recorded by the power meter.

Electric power can be classified into three categories: active power, reactive and apparent power. The actual current and voltage required to do useful works such lighting, heating etc. represents the active power. Active power is expressed in kilowatt (kW) and same is measured in kilowatt hour (kWh). Reactive power does not perform any useful work. Even though, it is necessary to generate electromagnetic fields in induction machine. Reactive power is expressed in kilovolt ampere reactive (kVAR). The sum of both active and reactive components of power which is required by the system represents the total capacity of the system. Same is known as apparent power and is expressed in kilovolt amperes (kVA). When reactive power increases power factor decreases. The increased use of non-linear loads at households causes power pollution in an undesirable level. Hence necessary steps must be taken to improve the power quality by eliminating harmonics and improving power factor. This must be done at the source itself so that power quality of the grid is ensured.

III. EXISTING TECHNOLOGY

Power factor improvement is very much important since low power factor has got many disadvantages. Requirement of greater conductor, larger KVA rating of the machine since KVA rating of the equipment is inversely proportional to power factor, increased copper loss and poor voltage regulation are some of the disadvantages of low power factor. For improvement of power factor some device capable of taking a leading current has to be connected in parallel with load. An example of such kind of device is a capacitor. That is power factor of a circuit having an inductive current flow can be corrected and adjusted to unity by simply connecting a capacitor bank. The capacitive current is also reactive in nature, but it is in the opposite direction to the inductive current and so it cancel out the inductive current through the system. If capacitive and inductive current is equal, they will cancel out and the net reactive current through the system reduces to zero. If the capacitive current is less than the inductive current, the total reactive current will reduce to some low value. If the capacitive current has got a value which is greater than the inductive current, the resultant current through the system will be capacitive. There are several methods by which a capacitor bank can be included in the system whose power factor is to be corrected. A single capacitor can be connected near to an inductive load for simple power factor improvement. When the system is loaded, capacitor gets energized. Capacitor bank of fixed size can be added into the system in order to improve the power factor. But this method of improving power factor is least efficient. Synchronous condenser is the other device which is used for power factor improvement. Synchronous condenser is nothing but an over excited synchronous motor. Same takes a leading current like a capacitor and hence can be used for power factor correction. Whenever a synchronous condenser is connected in parallel with the supply, it will a leading current which can partly neutralize the reactive component of load current. Thus the power factor can be improved. But because of considerable losses in motor, requirement of an auxiliary device for starting motor and noise produced by the motor this method is very rarely used.

A phase advancer can also be used or power factor improvement. A phase advancer is used for the power factor improvement of induction motors. It is used as an exciter for induction motors which is mounted on the shaft of the motor. When the stator of an induction motor is energized, it takes a current which lags behind the supply voltage. By exciting the stator winding with an external ac source, this can be eliminated. Thus power factor can be improved. As the exciting ampere turns are supplied at slip frequency, the reactive power drawn reduces and as a result power factor gets improved. This can be considered as the advantage of phase advancer over other methods of power factor improvement.

Above described existing technologies have many disadvantages which make them not suitable for a domestic consumer. The disadvantages can be discussed one by one. The major disadvantage of using a static capacitor system is that at reduced loads the reactive voltages could be so high that it could burn the devices. Same indicates the lack of reliability of a static capacitor system. Synchronous condenser is very expensive and it requires frequent maintenance and hence maintenance cost required is pretty high. It also produces considerable noise which makes them not suitable for domestic applications. Phase advancer is not economical for motors below 150KW. Hence the same cannot be used for domestic applications.

IV. PROPOSED TECHNOLOGY

The solution to overcome the limitations of commonly used power factor improvement scheme is to develop an automatic power factor controller using capacitors. The objective of the system is to maintain a constant power factor at all times irrespective of load conditions by switching the required capacitances into the system. In this method, the problem of over capacitance and over voltages at light loads is eliminated. Figure below shows the block diagram of an automatic power factor controller using PIC microcontroller.

V. METHODOLOGY

The proposed algorithm has mainly three sections: a comparator section, a microcontroller section and finally a correction section. The input AC voltage is given to a current transformer and a voltage transformer. This part of the system is referred as comparator section. Voltage transformer step down the input voltage and current transformer is used to extract the waveforms of current. The output of the voltage transformer is proportional to the voltage across the load and output of current transformer is proportional to the current through the load. The output of both voltage transformer and current transformer is given to a comparator which acts like a zero crossing detector. Comparators are constructed using LM358 op-amp. The output of the comparator changes during the zero crossing of voltage and current waveform. These outputs are given to the PIC which does the further power factor calculations. PIC 16F877A microcontroller is the heart of the automatic power factor controller which finds, displays and finally controls the Power Factor. The current power factor is found out first. This is found by taking tangent of ratio of time between zero crossing of current and voltage waveforms and also between any two successive zero crossing of the voltage waveform. The PIC microcontroller calculates the power factor of the system when the load is connected. If the calculated power factor is less than 0.9 then the capacitor is switched on using relay circuits. Driver circuits that implement a driver IC ULN2003 are used to switch the relays. Current lag in non-liner loads is compensated by current lead in capacitors. In this method the phase difference between the voltage and current will be reduced.

This method eliminates the need to install smaller capacitor units and the corresponding switching devices on the distribution system. Thus the installation costs are gravely reduced.

The active and reactive power is measured and the microcontroller calculates the power factor of the load .the capacitors are then automatically switched to get the desired power factor. Thus this algorithm is more suitable and efficient than commonly used methods.

Since we are not living in an ideal world the proposed algorithm has some minor limitations. One limitation is that the response time of relays is in the order of 30 to 120 seconds which is quite slow. Due to the large inrush current the life of the capacitor is 2 to 3 years. The regular maintenance cost is high.

Proposed system using PIC16F877A microcontroller can be equipped with low power factor, hunting, low or overvoltage sensors or alarms. Specifically designed fuses for capacitors can be installed to provide additional protection from faults. The system can also be designed to switch the capacitors in specified KVAR increments which would improve the performance of the controller.

VI. CONCLUSION

It can be concluded that automatic power factor correction are best suited for households to make them stable. The use of methods such as synchronous condensers and phase advancers are not suitable for household loads. The use of microcontroller reduces the costs. Care should be taken for overcorrection otherwise the voltage and current becomes more due to which the power system or machine becomes unstable and the life of capacitor banks reduces.

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