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Power Factor Correction Different Methods – A Review

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***Abstract*: Power factor improvement leads to efficient use of an electricity. power quality is one of the major requirements in power system operation and design. A power factor that is close one is good indicator for an overall power quality, especially for an electrical power system with high demand of commercial load with large amount of inductance. A poor power factor normally leads to a less efficient electrical system, and may also be less economically efficient for system operators and end consumers. Therefore, power factor improvement plays a crucial role in the efficient system operation and electricity consumption cost reduction. This paper compares different methodologies used by researcher for power factor correction. Different methods, power factor improved to which level, value of capacitance used for compensation.**

***Keywords*: Reactive power, Power Factor Correction, Power Factor, load compensation.**

1. Introduction

Generally, demand of electricity and economic competition, industries are now forced to improve on the efficiency to have success in global market. Unbalance and poor power factor are the major contributing factors which directly influence the operational cost for both supply utilities and consumers of electricity.

The distribution systems are being faced with poor power quality problems such as excessive neutral current, increase in reactive power burden, voltage unbalance and distortion, low power factor, decrease in efficiency and pollution to other consumers connected to the same point of common coupling due to the unbalanced loads connected to the distribution network. A low PF requires an increased capacity in both generation and transmission to accommodate the same amount of active power component caused by inductive loads [1]. Therefore, to avoid the expensive installation from the expansion of additional capacity, utilities usually apply a penalty for poor PF by charging a demand charge component (based on KVA) in a period of time to the customers. On the other hand, a low PF means a higher electricity bill for the same amount of active power consumption (KW) for an end consumer.

Consequently, demand saving can be achieved by improving a site's PF, so it is important to identify an effective method for the most cost-effective way to promote the PF initiatives to the industrial electricity consumers. Various studies on PFC are performed and reported in literature [2] Corrective measures such as utilizing onsite synchronous machines and installation of PFC capacitor banks to locally support the reactive power support are analyzed both technically and economically. Moreover, a PFC of large current line commutated converters using variable series capacitors are studied in [1].

In [4] pic microcontroller is used to detect leading or lagging power factor accordingly compensation is provided. Capacitive and inductive banks are used for the compensation of power factor according to nature of load which is determined based on microcontroller algorithm. After power factor compensation the proposed method improved apparent power approximately from 18 to 40 percent.

In [5] line to line voltage keep constant using compensation. Unbalanced loads are quite common in a three- phase network and this is one of the major causes of voltage unbalance in low voltage distribution networks. The traditional three-phase compensators are mainly used for reactive power elimination without the neutral current elimination while the susceptances calculation are also based on the load admittance which is difficult to measure. A hybrid compensator containing star and delta segments can be used for neutral current elimination, load balancing and power factor improvement. In this paper, a mathematical model is derived based on the phase and sequence components of the load current using symmetrical components theory for load balancing, power factor correction and neutral current elimination. The validation of the proposed model is done through MATLAB simulation.

In [3] a superconducting reactor is implemented using high quality Q factor coil. Shunt capacitors are deployed for power factor correction (PFC) to reduce the load reactive power and to provide voltage support. Nonlinear loads, such as variable speed drives, can inject harmonics into the network. If the line impedance value produces a resonance with the PFC capacitor and the injected frequency coincides with the resonant frequency, an overvoltage is produced across the capacitor, which can lead to failure or ex- plosion. To protect the PFC capacitor, a reactor can be connected in series with the PFC capacitor and tuned at the harmonic frequency of the system resonance. This paper proposes the use of a high temperature-superconducting reactor (HTSR) as the tuned reactor. The reactor will have an extremely high-quality factor (Q) compared to the normal reactor that can never be manufactured commercially with such a high Q. The performance of the HTSR reactor in terms of its ability to protect the capacitor from overvolt- age and to reduce power losses has been investigated. The results are compared with those using the conventional (low Q) reactor and show that the HTSR can significantly improve filter performance and reduce power losses in the filter.

2. Methods used

Power quality improvement using multiple FACTS (flexible ac transmission systems) device [2] uses following methods.

A. SVC:

A shunt connected static var generator or absorber whose output is adjusted to exchange capacitive or Inductive current so as to maintain or control specific parameters of the electrical power system (typically bus voltages).

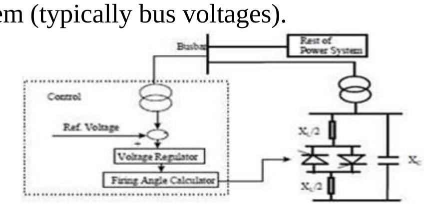

Fig.1. Schematic diagram of SVC

B. TCSC

A capacitive reactance compensator which, consist of a series capacitor bank shunted by a thyristor- controlled reactor in order to provide a smoothly variable series capacitive reactance.

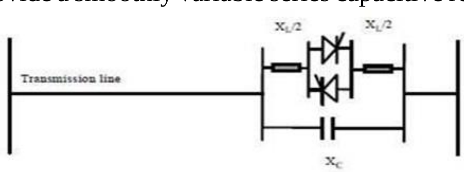

Fig. 2. Schematic diagram of TCSC

C. Multi-type facts system

Among the power quality problems like sag, swell, harmonic etc., voltage sag is the most severe disturbances in the distribution system. To overcome these problems, the concept of custom power devices is introduced lately. One of those devices is the Multi-Type flexible alternating current transmission system which is the most efficient and effective modern custom power device used in power distribution networks. Multi-type FACTS is a Recently proposed series connected solid state device that injects voltage into the system in order to regulate the load side voltage. It is generally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC).

D. Principle Operation of Multi-Type Facts Device

A Multi-type FACTS is a solid-state power electronics switching device consisting of either GTO or IGBT, a capacitor bank as an energy storage device and injection transformers. It is linked in series between a distribution system and a load that shown in Figure.

The basic idea of the Multi-type FACTS is to inject a controlled voltage generated by a forced commuted converter in a series to the bus voltage by means of an injecting transformer. A DC to AC inverter regulates this voltage by sinusoidal PWM technique. All through normal operating condition, the Multi-type FACTS injects only a small voltage to compensate for the voltage drop of the injection transformer and device losses. However, when voltage sag occurs in the distribution system, the Multi-type FACTS control system calculates and synthesizes the voltage required to preserve output voltage to the load by injecting a controlled voltage with a certain magnitude and phase angle into the distribution system to the critical load.

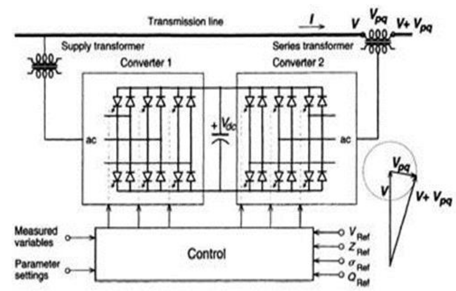

Fig. 3. Schematic diagram of Multi- type FACTS

In protecting PFC capacitors from overvoltage caused by harmonics and system resonance using high temperature superconducting reactors uses following methods [3].

Shunt capacitors are deployed for power factor correction (PFC) to reduce the load reactive power and to provide voltage support. Nonlinear loads, such as variable speed drives, can inject harmonics into the network. If the line impedance value produces a resonance with the PFC capacitor and the injected frequency coincides with the resonant frequency, an overvoltage is produced across the capacitor, which can lead to failure or ex- plosion. To protect the PFC capacitor, a reactor can be connected in series with the PFC capacitor and tuned at the harmonic frequency of the system resonance. This paper proposes the use of a high temperature- superconducting reactor (HTSR) as the tuned reactor. The reactor will have an extremely high-quality factor (Q) compared to the normal reactor that can never be manufactured commercially with such a high Q. The performance of the HTSR reactor in terms of its ability to protect the capacitor from overvolt- age and to reduce power losses has been investigated.

The results are compared with those using the conventional (low Q) reactor and show that the HTSR can significantly improve filter performance and reduce power losses in the filter.

In Pic Microcontroller Based Power Factor Correction for both Leading and Lagging Loads using compensation method [4] following methodology were used.

In figure 4 block diagram of whole system is shown. The main purpose is to detect the zero crossing of the voltage and current and then switching of capacitive and inductive banks based on microcontroller algorithm. The voltage is first stepped down using potential transformers and the current is stepped down using current transformer whose rating is decided based on maximum rating of your load. These two waves of voltage and current are passed through zero cross detectors (ZCD). The waves that appear across the output of the ZCD are the square waves and their amplitude approaches almost to the biasing of the operational amplifier. These two waves are then fed to microcontroller so that it can measure the phase delay between the voltage and current waveforms and then show the power factor accordingly based on the proposed algorithm. The microcontroller then based on number of counts decides the power factor and displays it on LCD. The measurement of voltage involves conversion from AC to DC using bridge rectifiers as it is further fed to ADC of microcontroller which further displays it on LCD.

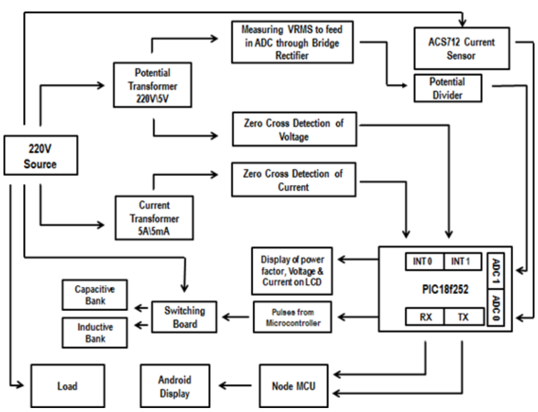

Fig. 4. Block diagram of PIC based PFC.

The current was calculated using current sensor ACS712 5A to 5mA and it is then fed to microcontroller ADC and it is then calculated based on algorithm.

After the zero cross detection based on microcontroller algorithm it is decided that either it is capacitive or inductive load and finally the microcontroller triggers the required capacitive or inductive banks through relay-based switching circuitry in order to compensate the power factor.

In load compensation in a three phase four wire distribution

System considering unbalance, neutral current elimination and power factor improvement following methodology were used [5].

Compensation involves the modification of an electrical characteristics of transmission and distribution lines to improve its power transfer capability without violating the overall stability of the system. Reactive power compensation involves two aspects: Load compensation and voltage support, the load compensation involves the balancing of the current drawn from the supply, improvement in power factor, better voltage regulation, etc. of large fluctuating loads while voltage support involves the reduction in voltage fluctuation at a point in the transmission network

In general, load compensation involves two major acts; one is the load balancing while the other is power factor correction. The combination of the two acts determine the needed reactive power for the compensation Several methods have been developed to solve the problems of unbalanced load and poor power factor correction through load compensation. It has been established that the installation of compensation devices at the load side is effective for controlling the three phase unbalanced loads in power distribution system.

In a three-phase system, Steinmetz proved that the voltage unbalance caused by unbalanced current due to a resistive load connected between two phases can be removed by connecting capacitive and inductive elements between other two phases as shown in Figure. 5.

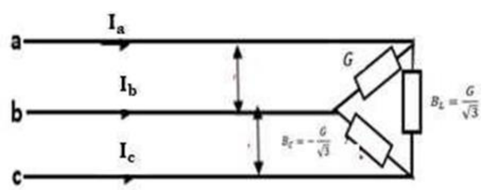

Fig. 5. The Steinmetz method of load balancing

This method was later generalized to three-phase loads and this has been used for reactive power compensation, load balancing and power factor improvement but most of the methods assumed the admittance of the load is known or can be measured, in which neither is possible practically thereby limiting the applications

Also, due to advancement in technology, some power electronics-controlled devices have been developed, such as Active Power Filters (APF), Distribution Static Synchronous Compensator (DSTATCOM), Dynamic Voltage Restorer (DVR), Unified Power Quality Conditioner (UPQC) etc. which are used for load balancing, reactive power compensation and power factor improvement but these devices are expensive and have complex control

The hybrid shunt compensator proposed in this paper performs three major functions: reactive power compensation, load balancing and power factor improvement using both the sequence and phase components of the load current and the validation of the model is achieved through MATLAB simulation.

3. Conclusions

Case study on the long-term effect of power factor correction on the industrial load. A site with a poor power factor and high peak demand is selected for demonstration. With 12- month of the data collection and analysis, the 150 kVAr PFC unit was selected to achieve the optimal outcome. The PFC unit was installed in August 2016 and the performance was carefully monitored and its analysis was carried out in this paper after 10 months. As a result, the data shows there was a significant inductive load reduction and the PF was able to be improved from 0.87 to 0.98 on average.

The presented topology illustrates the operation and control of Multi-type FACTS The system is extended by adding a series VSC in an adjacent feeder. The device is connected between two or more feeders coming from different substation. The performance of the Multi-type FACTS has been evaluated under various disturbance conditions such as voltage sag/swell in either feeder, fault and load change in one of the feeders. In case of voltage sag, the phase angle of the bus voltage in which the shunt VSC is connected plays an important role as it gives the measure of the real power required by the load. The Multi-type FACTS can mitigate voltage sag in Feeder for long duration between two adjacent feeders which are not connected.

Protecting PFC Capacitors investigates the benefits of applying HTSR to protect the PFC capacitor from overvoltage due to harmonics and system resonance. The results from the simulation show that the HTSR would greatly help in the design of the tuned filter. The use of HTSR will significantly reduce the impact of a parallel resonance between the PFC capacitor and the system inductance. Further, the HTSR with a very low resistance could reduce significantly the power loss, improve the tuned filter performance and protect the PFC capacitor from the overvoltage due to system resonance. It is to be noted that the simulated system is very small and therefore the power loss reduction is quite small, but for an actual industrial application where the load is in MW range, therefore it is expected that a significant reduction in power loss can be achieved by the use of HTSR that will provide a substantial economic savings. Also, the Q value of the HTSR can be much higher than the chosen value (10000) used in this study. A small-scale experimental setup using the LabVolt training system was developed in the laboratory. A conventional reactor module is used as the tuned reactor with a Q factor of 96.4. The observed results from the experimental setup validate the simulation performance of the filters. An HTS coil with a resistance of 1μΩ (Q > 10000) is currently being constructed and based on the above experimental results. one through this method. The proposed method is more user- friendly power factor controlling system by continuously monitoring load at every instant and then the PIC microcontroller improves the power factor using compensation method.

Load Compensation leads to load compensation method using a hybrid compensator in a three-phase four wire network through a mathematical model derived from the combination of phase and sequence components of the load current considering load balancing, power factor correction and neutral current elimination. useful application of MATLAB/Simulink for the study of load compensation which has useful application in both low and medium voltage networks. However, the proposed method only applies to linear loads and verification through simulation while the future work shall focus on the experimental validation of the proposed model. By combining all these result a new system can be designed with gap given in these systems.

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