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IMPROVED POWER QUALITY USING EIGHT SWITCH POWER CONDITIONER FOR POWER SYSTEM HARMONIC ELIMINATION

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***Abstract*—Power quality is an issue that is becoming increasingly important to electricity consumers at all levels of usage. Sensitive power electronic equipment and nonlinear loads are widely used in industrial, commercial and domestic applications leading to distortion in voltage and current waveforms. As a result, harmonics are generated from power converters or nonlinear loads. This causes the power system to operate at low power factor, low efficiency, increased losses in transmission and distribution lines, failure of electrical equipments, and interference problem with communication system. So, there is a great need to mitigate these harmonic, reactive current components and poor voltage regulation. A novel eight switch converter based integrated power conditioner is proposed in place of integrated nine switch converter based power conditioner for improving the overall power quality as well as at a reduced semiconductor cost. The proposed power conditioner has only eight switches, being composed by an unit for voltage sag mitigation and another unit for current harmonic compensation are discussed and the performance of the proposed eight switch power conditioner is validated through simulations using MATLAB/SIMULINK.**

***Index Terms*— Voltage Sag Mitigation, Current Harmonic Compensation, Eight Switch Power Conditioner**

I. Introduction

Distribution systems are typically spread over large areas and are responsible for a significant portion of total power losses. Reduction of Total power losses in distribution system is very essential to improve the overall efficiency of power delivery. This can be achieved by placing optimal value of capacitors at proper locations in distribution systems. Capacitors are installed at strategic locations to reduce the losses and to maintain the voltages within capable limits. The voltage on a transmission network is determined by the reactive power flows. Major industrial loads e.g. induction motors, furnaces, transformers, etc. need reactive power for sustaining the magnetic field. As in case of induction machine the reactive power is needed just to create air gap magnetic field. Series inductance in transmission lines implies consumption of reactive power. Reactors, fluorescent lamps and all inductive circuits on the whole require a certain amount of reactive power to work. Thus reactive power is not delivered as effective mechanical power output of motor unlike the real power which is effectively converted as mechanical output. Any device which is connected in shunt or series with the load and which is capable of supplying the reactive power demanded by the load is called a Reactive power compensation device.

1.1.1 *Concept of power factor correction*

The main reason for reactive power compensation in a system is: 1) the voltage regulation; 2) increased system stability; 3) better utilization of machines connected to the system; 4) reducing losses associated with the system; and 5) to prevent voltage collapse as well as voltage sag. The impedance of transmission lines and the need for lagging VAR by most machines in a generating system results in the consumption of reactive power, thus affecting the stability limits of the system as well as transmission lines. Unnecessary voltage drops lead to increased losses which needs to be supplied by the source and in turn leading to outages in the line due to increased stress on the system to carry this imaginary power. Thus we can infer that the compensation of reactive power not only mitigates all these effects but also helps in better transient response to faults and disturbances. In recent times there has been an increased focus on the techniques used for the compensation and with better devices included in the technology, the compensation is made more effective. It is very much required that the lines be relieved of the obligation to carry the reactive power, which is better provided near the generators or the loads. Shunt compensation can be installed near the load, in a distribution substation or transmission substation.

1.1.2 Shunt Compensation

Shunt compensation, especially shunt reactive compensation has been widely used in transmission system to regulate the voltage magnitude, improve the voltage quality, and enhance the system stability. The most common form of leading reactive power compensation is by connecting shunt capacitors to the line. Shunt-connected reactors are used to reduce the line over- voltages by consuming the reactive power, while shunt-connected capacitors are used to maintain the voltage levels by compensating the reactive power to transmission line. The voltage support function of the midpoint compensation can easily be extended to the voltage support at the end of the

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radial transmission, which will be proven by the system simplification analysis in a later section.

The reactive power compensation at the end of the radial line is especially effective in enhancing voltage stability. Shunt compensation, produced either by an SVC (Static VAR Compensator) or a STATCOM (Static Synchronous Compensator) is used when the utility is concerned about dynamically balancing reactive power at particular points within an AC system to prevent voltage regulation and stability issues from occurring. This is particularly the case in response to faults leading to under/over-voltage. The Shunt system can also significantly improve the transfer capacity of an AC system. Christo Ananth et al.[4] presented a brief outline on Electronic Devices and Circuits which forms the basis of the Clampers and Diodes.

1.1.3 Dynamic Voltage Restorer

Dynamic Voltage Restoration (DVR) is a method and apparatus used to sustain, or restore, an operational electric load during sags, or spikes, in voltage supply. Often used in manufacturing areas requiring significant power to run tools/equipment, and utility plants, this custom device mitigates potential damage to equipment and undesirable slowdowns to the production line caused by an abrupt change in electric load. This method uses critical devices such as an automatic Transfer switch and IGBT Modules in order to operate.

DVR (Dynamic Voltage Restorer) is a static var device that has seen applications in a variety of transmission and distribution systems. It is a series compensation device, which protects sensitive electric load from power quality problems such as voltage sags, swells, unbalance and distortion through power electronic controllers that use voltage source converters (VSC).

The first DVR was installed in North America in 1996 - a 12.47 kV system located in Anderson, South Carolina. Since then, DVRs have been applied to protect critical loads in utilities, semiconductor and food processing. Today, the dynamic voltage restorer is one of the most effective PQ devices in solving voltage sag problems. However, cost and installation restrictions have limited its implementation to where there is obvious requirement for a stable voltage supply. The basic principle of the dynamic voltage restorer is to inject a voltage of required magnitude and frequency, so that it can restore the load side voltage to the desired amplitude and waveform even when the source voltage is unbalanced or distorted. Generally, it employs a gate turn off thyristor (GTO) solid state power electronic switches in a pulse width modulated (PWM) inverter structure. The DVR can generate or absorb independently controllable real and reactive power at the load side. In other words, the DVR is made of a solid state DC to AC switching power converter that injects a set of three phase AC output voltages in series and synchronism with the distribution and transmission line voltages

II. EXISTING SYSTEM

A. Operation

Figure 1.1 shows back-to-back unified power quality conditioner. The shunt converter is usually controlled to compensate for load current harmonics and reactive power and the series converter is controlled to block grid harmonics and/or voltage sag mitigation. The development of topologies that reduce the cost of power quality systems is interesting to industries and large consumers.

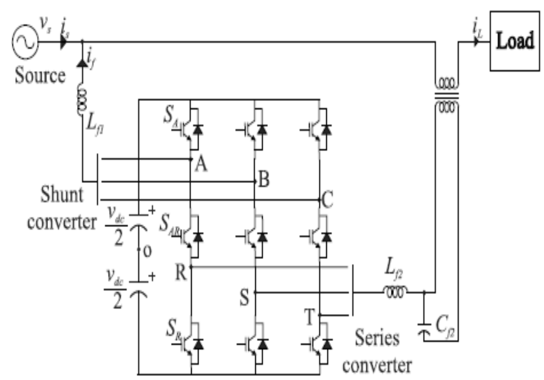

Figure 1.1 Existing topology

In this context, some topologies have been developed for this purpose and among them the nine-switch converter is detailed in this section. The nine-switch converter has less switches than the traditional back-to-back converter, but it has some limiting factors as lower amplitude of the output voltage due to sharing of the intermediate (central) switches and restricted phase difference between the two

B. Converter Analysis

. As can be seen in Fig. 1.1, the eight-switch converter is obtained removing one switch of the third leg of the nine switch converter and placing the output terminal *C* in the positive pole of the dc-link. This is feasible because the capacitors of the LC filter block the dc components generated by the connection of one phase to the positive pole of the dc-link. The complementary duty cycle expressions for the series converter are obtained by scaling the complementary duty cycles, given by (2), as follows:

$$D_{Rseries} = M_{series} D_R$$

$$D_{Rseries} = M_{series} \left(\frac{v_R{}^2}{v_{dc}} + \frac{1}{2} \right)$$

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With the removal of one switch for the shunt converter, the duty cycles of the remaining switches (*DA* and *DB*) should reflect the synthesis of the line-to-line voltages *vAC* and *vBC*, instead of the phase voltages. A slightly different approach should be carried out for deducing the duty cycles of the eight switch converter.

III. PROPOSED SYSTEM

The proposed topology is an eight-switch conditioner using a hybrid filter in shunt converter (Fig. 1.2) aiming costs reduction when compared to traditional power conditioners. The eight-switch converter performs the constant measurement of voltage and current from the grid to make control decisions, which are basically the injection signal to compensate the current harmonics and, in case of a voltage sag, increasing the range of the carrier dedicated to the series converter to inject the signal for a rated load voltage. In this topology, the compensation of current harmonics is performed by a passive filter in series with an active filter, as shown in Fig.1.2. The passive filter is tuned to the 7th harmonic, having low impedance around this harmonic and a high impedance around the switching frequency.

The reason for selecting the 7th harmonic tuned frequency is summarized as follows:

(1) The LC filter tuned at the 7th harmonic frequency is less bulky and less expensive than that tuned at the 5th harmonic frequency;

(2) The 7th harmonic tuned filter presents lower impedances at the 11th and 13th harmonic frequencies than the 5th harmonic filter does;

(3) The filtering characteristic for the 5th harmonic frequency can be significantly improved by the feed forward control.

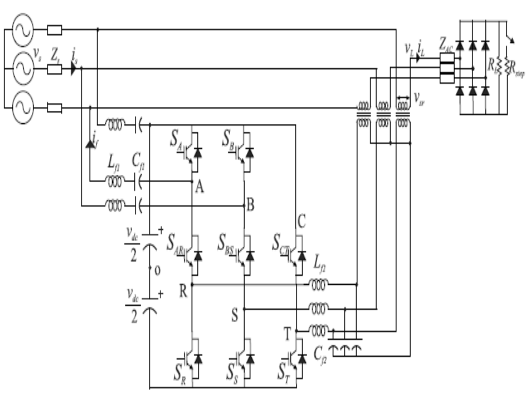

Figure 1.2 Proposed eight switch topology

IV. RESULT

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. Systems can also be multi rate, i.e., have different parts that are sampled or updated at different rates. For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. With this interface, you can draw the models just as you would with pencil and paper (or as most textbooks depict them). This is a far cry from previous simulation packages that require you to formulate differential equations and difference equations in a language or program. Simulink includes a comprehensive block library of sinks, sources, linear and nonlinear components, and connectors. You can also customize and create your own blocks. Models are hierarchical, the models are built using both top-down and bottom up approaches the system can viewed at a high level, then double-click on blocks to go 5 down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact.

After a model is defined, it can simulate, using a choice of integration methods, either from the Simulink menus or by entering commands in MATLAB's command window. The menus are particularly convenient for interactive work, while the command-line approach is very useful for running a batch of simulations. Using scopes and other display blocks, the simulation results can see while the simulation is running. In addition, the parameters can be changed and immediately see what happens, for "what if" exploration. The simulation results can be put in the MATLAB workspace for post processing and visualization.

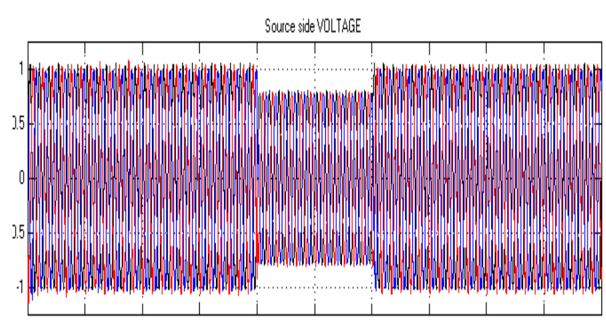

Fig. 1.3 Source voltages with sag

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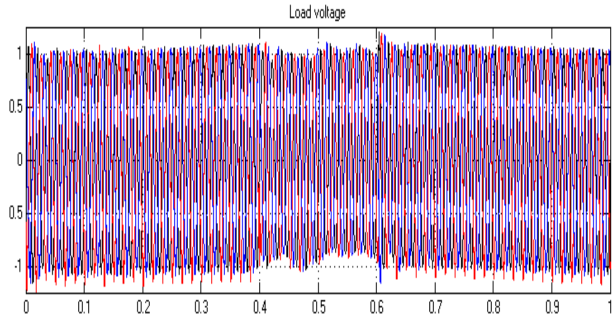

Figure 1.4 Load voltages with sag compensation

V. CONCLUSION

This project has proposed a conditioner based on a novel eight-switch converter. The proposed conditioner is divided in two units: top (shunt converter) and bottom (series converter). The top unit is connected in series with a passive LC filter tuned in 7th harmonic, keeping a good harmonic compensation performance with a reduced number of switches when compared with other topologies. The control algorithm for the top unit of the proposed system is performed through feedback and feed forward compensations and also controls the dc-link voltage. The bottom unit has the same behavior of a traditional dynamic voltage restorer, having good capability for voltage sags compensation. Simulation tests were carried out on MATLAB and the results are proving its feasibility.

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BIOGRAPHY

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