INTERNATIONAL JOURNAL OF ENHANCED RESEARCH IN SCIENCE TECHNOLOGY & ENGINEERING

VOL. 1 ISSUE 1, OCTOBER-2012 ISSN No: 2319-7463

STATCOM Analysis for improving Power Quality Constraints - A Literature Survey

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Abstract- With the development and advancement of power electronics devices in recent years, changes in the scenario in the field of controlling and handling the power quality issues have been very effective. FACTS devices are the outstanding approach. In this manuscript,we choose one such FACTS device known as STATCOM, a powerful shunt controller, for discussing its impact and depth how to tackle the power quality issues by reviewing the past literature published on the various types and configurations of STATCOM generally current source inverter based or voltage source inverter based, pulses (6, 12, 24, 48 pulse) based, level based (two, three and multilevel) and PWM based.

Keywords- VSI, SVC, CSI, GTO

I. NOMENCLATURE

STATCOM - *Static Synchronous Compensator*

FACTS - *Flexible AC Transmission System*

SPWM - *Sinusoidal Pulse Width Modulation*

VSC - *Voltage Source Converter*

CSI - *Current Source Inverter*

GTO - *Gate Turn Off Thyristor*

SSSC - *Static Synchronous Series Compensator*

SVC - *Static VAR Compensator*

II. INTRODUCTION

Rapid development of the power electronics industry, a large number of high power semiconductor devices are available for power system applications. In the last decade, commercial availability of Gate Turn-Off (GTO) thyristor switching devices with high-power handling capability and the advancement of the other types of power-semiconductor devices such as IGBTs have led to the development of fast controllable reactive power sources utilizing new electronic switching and converter technology. The GTO thyristor enable the design of the solid-state shunt reactive compensation and active filtering equipment based upon switching converter technology. These Power Quality Devices (PQ Devices) are power electronic converters connected in parallel or in series with transmission lines, and the operation is controlled by digital controllers. The interaction between these compensating devices and the grid network is preferably studied by digital simulation. Flexible alternating current transmission systems (FACTS) devices are usually used for fast dynamic control of voltage, impedance, and phase-angle of high-voltage ac lines. FACTS devices provide strategic benefits for improved transmission system power flow management through better utilization of existing transmission assets, increased transmission system security and reliability as well as availability, increased dynamic and transient grid stability, and increased power quality for sensitive industries (e.g., computer chip manufacture). The advent of FACTS systems is giving rise to a new family of power electronic equipment for controlling and optimizing the dynamic performance of power system, e.g., STATCOM, SSSC, and UPFC. The use of voltage-source inverter (VSI) has been widely accepted as the next generation of flexible reactive power compensation to replace other conventional VAR compensation, such as the thyristor-switched capacitor (TSC) and thyristor controlled reactor (TCR). **A**s an important member of the FACTS controllers' family, Static Synchronous Compensator (STATCOM) has been at the centre of attention and the subject of active research for many years. STATCOM is a shunt-connected device that is used to provide reactive power compensation to a transmission line. Through regulation of the line voltage at the point of connection, STATCOM can enhance the power transmission capability and thus extend the steady-state stability limit. The basic Power flow description of three-phase 4-wire compensated system is shown in Fig.1.1

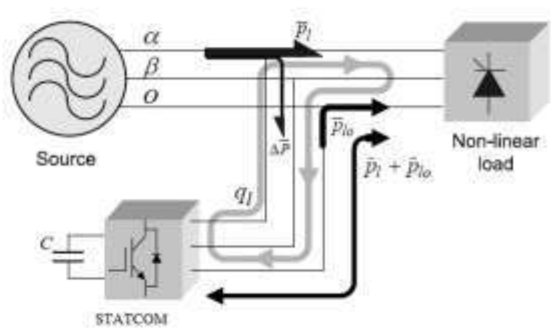

Fig. 1.1 Power flow description of three-phase 4-wire compensated system

.STATCOM can also be used to introduce damping during power system transients and thus extend the transient stability margin. Theoretically, FACTS controllers can be realized by either a voltage-source converter (VSC) or a current-source converter (CSC) [12]; however, except for the work reported in [13] more than 10 years ago, the focus of all the published work on STATCOM has been on using VSC topology [14]–[18]. The reasons behind the choice of VSC over CSC are as follows:

1) A CSC is more complex than a VSC in both power and control circuits. Filter capacitors are used at the ac terminals of a CSC to improve the quality of the output ac current waveforms. This adds to the overall cost of the converter. Furthermore, filter capacitors resonate with the ac-side inductances. As a result, some of the harmonic components present in the output current might be amplified, causing high harmonic distortion in the ac-side current. Besides, conventional bi-level switching scheme cannot be used in CSC.

2) Unless a switch of sufficient reverse voltage withstanding capability such as Gate-Turn-Off Thyristor (GTO) is used, a diode has to be placed in series with each of the switches in CSC. This almost doubles the conduction losses compared with the case of VSC.

3) The dc-side energy-storage element in CSC topology is an inductor, whereas that in VSC topology is a capacitor. The power loss of an inductor is expected to be larger than that of a capacitor. Thus, the efficiency of a CSC is expected to be lower than that of a VSC. As a result of the recent developments in the control of CSC and the technology of semiconductor switches, the above situation is likely to change for the following reasons:

- Due to the presence of the ac-side capacitors, both voltage and current waveforms at the output terminals of a CSC are good sinusoids. The capacitors are the inherent filter for the CSC. Although a 48-pulse VSC STATCOM does not require a filter [18], the cost of the filter is transferred to the cost of multi-converters and multi-winding transformer. Additional filter has to be used in a VSC STATCOM if operating at a lower frequency. It is possible to operate a CSC STATCOM under 900 Hz of switching frequency with a single converter. This reduces the filtering requirements compared with the case of a VSC. The problem of the resonance between the capacitances and inductances on the ac- side can be overcome by careful designof the filter capacitors and introduction of sufficient damping using proper control methods. Furthermore, all the switching problems faced in the early stages of CSC development can be overcome by employing tri-level switching scheme [20], which has become a standard technique in the control of CSC.
- Featuring high ratings, high reverse voltage blocking capability, low snubber requirements, lower gate-drive power requirements than GTO, and higher switching speed than GTO, Integrated Gate Commutated Thyristor (IGCT) is the optimum combination of the characteristics demanded in high-power applications [21]. Using the state-of-the-art technology of the semiconductor switches, there will be no need for the series diode in the CSC topology anymore.
- The dc-side losses are expected to be minimized using superconductive materials in the construction of the dc-side reactor. The research on the CSC topology and its applications in power systems has been an on-going process [22], [23]. When applied to STATCOM, CSC topology offers a distinct advantage over VSC topology. The direct output of a CSC is a controllable ac current, whereas that of a VSC is a controllable ac voltage.

When operated under SPWM (Sinusoidal Pulse Width Modulation) technique [24], the magnitudes of the harmonic components in both converters are directly proportional to the magnitudes of the fundamental components of their direct output quantities. In most transmission systems, under normal operating conditions, the current injected by STATCOM is a small percentage of the line current. Thus, when CSC is used, the current harmonics are also small. But, when VSC is used, for a small injected current, the output voltage of VSC is large and very close to the system voltage. This results in large voltage harmonics, leading to current harmonics that are larger than those generated by CSC, and thus more costly to filter. The other aspect of comparison is the dc-side energy storage requirement. When the STATCOM is realized by a CSC, the dc-side current is just larger than the peak value of the required injected current which is a small percentage of the line current. However, when a VSC is used to inject reactive power to the system, the dc-side voltage must be larger than the peak value of the system line-to-line voltage so that the reactive power can be transferred between the STATCOM and the transmission line. This means that the dc energy storage requirement of CSC is lower than that of VSC when used to realize a STATCOM.

III. Literature Background

A. Modelling, Analysis, and Control of a Current Source Inverter-Based STATCOM [1]

In this paper a new approach is proposed for the dynamic control of a current source inverter (CSI)-based Static synchronous compensator (STATCOM). The d-q frame model and the steady-state characteristic of the CSI STATCOM are proposed as a basis for control design. Traditional PI controllers leads to a poorly damped high frequency oscillation between the inductance and capacitance of the CSI output filter. This new proposed approach includes a fast ac current control inner loop and a slower dc current control outer loop. The inner loop, which is a combination of multivariable full state feedback and integral control, allows for rapid non-oscillatory dynamics of the ac current without overshoot or steady-state-error. For validating this proposed control design as well as the simulation results the author performed the experimental tests on a 5-kVA laboratory CSI STATCOM setup. In fact, there are two control variables for the CSI: the modulation index and phase angle .The combination of full state feedback for assigning the non-oscillatory fast system dynamics and integral control for ensuring the elimination of steady-state errors. This controller adjusts the modulation index and firing angle of the CSI simultaneously and is able to eliminate the high frequency oscillation. By this approach, the dynamic behaviour of the CSI is greatly improved. The steady-state characteristics are also derived based on the model. In steady-state operation, the output reactive current is only dependent upon, and modulation index only influences the dc side current. The described CSI STATCOM may be operated using one of the two distinct control methods:

• Type I: phase angle control while the modulation index is kept constant;

• Type II: the modulation index and are both controllable.

The Type II CSI STATCOM offers a better transient response than the Type I form due to better utilization of both control variables. Use of full state feedback, results in the rapid dynamics of the output ac current without overshoot. These dynamics are comparable to those obtained from a VSI STATCOM. Introduction of integral control in the presented manner is shown to both simplify the overall control design and eliminate the steady-state errors. Thus, the proposed control scheme, which is a combination of full state feedback and integral control, gives the CSI STATCOM a good dynamic response and excellent steady- state tracking ability. The dynamic simulation results demonstrated the need for both modulation index and phase angle control if high frequency oscillations are to be avoided in the ac side LC filter.

B. *Novel Controllers for the 48-Pulse VSC STATCOM and SSSC for Voltage Regulation and Reactive Power Compensation [2]*

In this literature, the dynamic operation of novel control scheme for both Static Synchronous Compensator (STATCOM) and Static Synchronous Series Compensator (SSSC) based on a new full model comprising a 48-pulse Gate Turn-Off thyristor voltage source converter for combined reactive power compensation and voltage stabilization of the electric grid network is investigated. The digital simulation of the STATCOM and SSSC within the power system is performed in the MATLAB/Simulink environment using the Power System Blockset (PSB). Two novel controllers for the STATCOM and SSSC are prposed in this paper based on a decoupled current control strategy. The operating performance of both STATCOM and SSSC schemes connected to the 230-kV grid are evaluated. The use of voltage-source inverter (VSI) has been widely accepted as the next generation of flexible reactive power compensation to replace other conventional VAR compensation, such as the thyristor-switched capacitor (TSC) and thyristor controlled reactor (TCR) .This paper contained a novel cascaded multilevel converter model, which is a 48-pulse (three levels) source converter and it is harmonic neutralized, 48-pulse GTO converter. It consists of four three-phase, three-level inverters and four phase-shifting transformers. In the 48-pulse voltage source converter, the dc bus is connected to the four three-phase inverters. The secondary windings of four zig-zag phase-shifting transformers connected in Y or Δ is supplied by four voltage generated by the inverters. The four transformer primary windings are connected in series, and the converter pulse patterns are phase shifted so that the four voltage fundamental components sum in phase on the primary side. The operation of the STATCOM is validated in both capacitive and inductive modes using the sample power transmission system. The proposed decoupled controllers for the 48-pulse voltage source converter STATCOM demonstrated high efficiency for reactive power compensation and voltage regulation with the system subjected to load disturbances such as switching different types of loads. The performance of the Auxiliary Tracking control with PWM switching technique in suppressing any oscillation and damping the transients that may appear during the transition from capacitive to inductive mode of operation compared with the decoupled current control strategy are described in this paper.. A complete digital simulation study using the full 48-pulse GTO-SSSC device model for a sample test power system is also presented in this paper. The digital simulation is performed in the MATLAB/Simulink software environment using the PSB. The basic building block of the SSSC device is the same cascade of converters forming the 48-pulse GTO converter whose complete digital simulation model was implemented using MATLAB/Simulink. This new full SSSC device compensator can be more accurate in providing fully controllable compensating voltage over a specified identical capacitive and inductive range, independently of the magnitude o f the line current, and better represent realistic improved power quality reduced harmonics. The novel decoupled control strategy for the SSSC is also validated in both capacitive and inductive operating modes when the system is subjected to severe disturbances of switching electric loads contingencies.. The control strategies implement decoupled current control and auxiliary tracking control based on a pulse width modulation switching technique to ensure fast controllability, minimum oscillatory behaviour, and minimum inherent phase locked loop time delay as well as system instability reduced impact due to a weak interconnected ac system.

C. *Current-Source Converter Based STATCOM: Modelling and Control [3]*

In this paper, a STATCOM topology is proposed based on the current-source converter.The nonlinear model of the current- source converter, which is the source of the difficulties in the controller design, has been modified to a linear model through a novel modelling technique. The main limitation of the CSC-based STATCOM will be due to the dc-side losses. Even if superconductive material is used on the dc side, the CSC-based STATCOM is still more costly than the VSC-based STATCOM. The final decision on the selection of the CSC topology for STATCOM should be made based on a careful compromise between the cost and performance. Since the focus of the paper is mainly on the topology and modelling, only balanced steady-state condition is considered to show the effectiveness of the topology and validity of the model. Further study regarding the unbalanced, transient and fault conditions, are beyond the scope of this paper..The proposed modelling technique is not based on the linearization of a set of nonlinear equations around an operating point. Instead, the power balance equation and a nonlin ear input transformation are used to derive a linear model independent of the operating point. This model also acts as the basis for the design of a decoupled state-feedback controller. The proposed STATCOM has been simulated using the PSCAD/EMTDC package. The simulation results show that a CSC-based STATCOM can result in excellent current and voltage waveforms as well as very short response time while operating at a low switching frequency. This makes the proposed scheme suitable for high power applications**.** The decoupled state-feedback control with a reduced-order state estimator is formulated and applied to the CSC-based STATCOM. The performances of the STATCOM at steady-state and in response to step changes in the reference values of the system voltage and the dc-side current are evaluated using the simulation results from PSCAD/EMTDC package. The simulation results indicate that the CSC-based STATCOM can attain all the objectives of a STATCOM. Because of its fast response and low harmonic distortion in the injected current while being operated at a very low switching frequency the CSC- based STATCOM has the potential of becoming a new FACTS device.

D. Multi-level Distribution STATCOM for Voltage Sag and Swell reduction [4]

In this paper a multi-level D-STATCOM configuration consisting of a three level voltage source converter, a DC energy storage device, a coupling transformer and associated control circuits is introduced. The control is based on sinusoidal PWM and only requires the measurement of the RMS voltage at the load point. The validity and effectiveness of the proposed power conditioner has been demonstrated through PSCAD/EMTDC simulation tool used for its modelling and simulation. Extensive simulations are also carried out to verify the superiority of multi-level D-STATCOM with two level D-STATCOM. By this unique structure of the multi-level Voltage Source Converter (VSC) allows it to reach high voltages with low harmonics without the use of transformers or series-connected, synchronised switching devices. The diode clamped multi-level VSC with its simple configuration and control structure is used as Distribution STATCOM (D-STATCOM) in custom power conditioners. For high power applications this inverter has emerged as a solution. Electromagnetic transient models D-STATCOM using two-level and three-level VSC are modelled and simulated based on a SPWM control scheme has been designed to control the two level VSC and three-level VSC used in the D-STATCOM. The PI control scheme used for voltage regulation requires only voltage measurements at the load point. This characteristic makes it ideally suitable for low voltage custom power applications. The control scheme is tested under a wide range of operating conditions and it is observed to be robust in every case. Extensive simulation studies are conducted to gain insight into the impact of three-level D-STATCOM for voltage sag/swell elimination, harmonic suppression, speed of response of the PWM control and transient overshooting. It is observed that for increased numb er of levels of VSC the output voltage and current waveforms approaches a sinusoidal nature with minimum harmonics. With the help of this Comparison of multi-level D-STATCOM with two-level DSTATCOM finds that the multi-level VSC is preferred over the commonly used two-level VSC for high power applications from the standpoint of harmonic components, %THD in voltage and current, efficiency, DC link voltage and inverter switching frequency. The efficiency, % THD in voltage and current for various levels of D-STATCOM are evaluated and finds as the number of level increases, the THD of the output voltage and current decreases. The three-level VSC shows max efficiency, with decreased values of %THD in voltage and current. This custom power controller may find application in automated industries with critical loads.

E. Voltage Stabilization And Reactive Compensation Using A Novel FACTS STATCOM Scheme [5]

This work presented a novel dual loop current decoupled controller scheme for the 48- pulse GTO based voltage source converter used as a STATCOM for providing the voltage regulation and reactive compensation of the power system. The decoupled controller scheme is based on a decoupled current strategy using direct and quadrature component of STATCOM current. The performance of this controller is evaluated by ±100 MVAR STATCOM scheme connected to the 230-kV grid. Reactive power compensation and voltage regulation is validated for load and system excursions in both the capacitive and inductive modes of operation. The controller is modelled using simulink and the STATCOM or power grid is simulated using MATLAB/SIMULINK by using power system block-set. The dynamic simulation results have demonstrated the high quality of the 48 pulse STATCOM for reactive power compensation and voltage regulation while the system subjected to disturbances such as switching different types of loads. The full 48 pulse model can be utilized in other Facts device studies such as Active Power Filters and new hybrid stabilization topologies.

F. A Novel Double Loop Control Design and Analysis of STATCOM [6]

In this research a novel double loop control strategy of current feed-forward plus double PI loop for adjusting transmission line real power is proposed. Bus-bar voltage outer loop control system adopts voltage droop control which consists of PI regulation and scaling factors of droop characteristic. A current feed-forward control is introduced into double loop de-coupled control system of dc capacitor voltage regulation. Designing process of control system is discussed briefly in this paper. The experimental results on a15-KVA laboratory-scale equipment and also simulation results for a case study indicate that dc capacitor voltage and bus-bar voltage can be controlled efficiently, and proved that the control scheme and controller design are viable and effective. Basically we know that the Static Synchronous Compensator (STATCOM) based on voltage source converter is one of the most used FACTS device. The primary purpose of a STATCOM is to support bus-bar voltage and maintain the stability of the dc-link capacitor voltage so a feed-forward of converter current is provided to the outer loop of dc- link capacitor voltage/active control, and a voltage droop control is introduced into the outer loop of bus-bar voltage/reactive regulation in the proposed controller. The proposed novel double loop control system, including current controller, dc-link capacitor voltage controller, feed-forward controller and bus-bar voltage controller are designed independently and briefly presented in this paper. The experimental and simulated results indicates that the dc-link capacitor voltage and bus-bar voltage is controlled efficiently, and the system has good dynamic and stable performances and also verify that current feed-forward plus double PI loop is a viable control scheme and controller design is accurate and effective.

G. A Generalized Control Strategy of Per-Phase DC Voltage Balancing for Cascaded Multilevel Converter-based STATCOM [7]

In this paper, a generalized per-phase DC-bus voltage balancing scheme of a CMC-based STATCOM is proposed. The cascade multilevel converter (CMC), comprising a number of modular H-bridge voltage source converter (VSC) in each phase, is considered as one of the most promising topologies for STATCOM application now days because of its modularity, scalability and good power quality,. However, how to maintain a balanced DC-bus voltage is not well known so for this the author are reviewed the STATCOM small signal model and existing control scheme first. The basis of proposed per-phase DC-bus voltage balancing scheme is based on the loop-gain shaping control design method and an “imaginary” dq /abc park transformation. The open-loop transfer function is also derived from STATCOM small-signal model in dq0 coordinates so that the compensator parameters of the proposed control strategy can be easily designed to achieve a flexible control bandwidth and desired stability margins without any tuning. The simulation results on the detailed switching model show the consistency of the proposed control scheme. The control is verified by experimentally using a STATCOM transient network analyzer (TNA). Compared to the conventional two-level converters and other multilevel converters, the cascaded multilevel converter (CMC) comprising a number of modular H-bridge voltage source converters (VSC), has compact structure, easy scalability, fast response and good power quality. Particularly the modularity of CMC simplifies the manufacturing and packaging of VSC hardware, thereby reducing the system costs and improving the system reliability. At present, the CMC is deemed as one of the most promising topologies for one of the challenges in CMC is how to balance the capacitor DC bus voltages among many isolated DC buses. A seven-level CMC STATCOM, for example, will have nine DC bus voltages, three for each phase. The proposed per-phase DC voltage balancing scheme is based on the loop-gain shaping method with a derived open-loop transfer function and so-called “imaginary” dq/abc park transformation. The features of the proposed scheme are listed below:

• Small-signal model-based design without any tuning;

• Control bandwidth is flexible through the design;

• Stability margin is guaranteed through the design;

• Easy to implement into DSP;

The verification of proposed per-phase DC voltage control strategy is done by extensive switching simulations as well as by TNA experiments. To inject unbalanced reactive power for each phase, which is important for STATCOM application for unbalanced system the proposed control scheme can even be extended.

H. Experimental Validation of Nonlinear Control for a Voltage Source Converter [8]

In this paper a flatness-based tracking control for the VSC is proposed where the nonlinear model is directly compensated without a linear approximation. Flatness leads to straightforward open-loop control design. A full experimental validation is given as well as a comparison with the industry-standard decoupled vector control. Robustness of the flatness-based control is investigated and set-point regulation for unbalanced three-phase voltage is considered. Traditional approaches to this problem are often based on a linearized model of the VSC and proportional-integral (PI) feedback. This proposed control commonly used cascade controller structure for the real current and dc voltage where the PI control for the real current is contained inside the PI control for dc voltage. The reactive current is independently controlled by a separate PI controller. This control is based on a linearized averaged model of a VSC which accounts for the fundamental components of the switching voltages. As the averaged model of the VSC is nonlinear, it is natural to apply model-based nonlinear control strategies which directly compensate for system nonlinearity without requiring a linear approximation. By avoiding approximation, nonlinear control can provide consistently high performance over a broad operating range. On the other hand, taking reactive and direct current as the output leads to an input output linearization with stable zero dynamics. The zero dynamics convergence suffers from parameter uncertainty and an uncontrolled and slow rate of convergence. To address these problems and assuming the direct current has very fast convergence to its desired value, a PI control for the reference value of the direct current is used to control the dc voltage. The flat output components can be interpreted as the lead components of the state feedback linearizing coordinate transformation. Unlike state feedback linearization, the flatness framework is natural for achieving trajectory planning. The main contribution of this proposed implementation and experimental validation of the flatness-based control technique which allows open-loop motion planning. A flatness-based control has been successfully implemented on an actual VSC test stand.. Experimental results illustrates that the nonlinear control provides improved transient tracking performance relative to a traditional vector control method.

I. Analytical Modelling of a Square-Wave-Controlled Cascaded Multilevel STATCOM [9]

In this work, an analytical state-space model with an indirect voltage-controlled cascaded-type, multilevel static synchronous compensator (STATCOM) with “square wave control is proposed. The model is divided into a dynamic and static part for an accurate presentation of all internal feedback connections. Each voltage component is analyzed in detail and described mathematically by an averaged expression with an equivalent capacitance. The model is linearised and linked with a D-Q frame ac system model and the controller model, and they implemented in MATLAB. The controller gains are selected by analyzing the root locus of the analytical model to give optimum responses. The proposed model are verified and validated against non-linear digital simulation PSCAD/EMTDC in the time and frequency domain. The model is very accurate in the sub-synchronous range, and it is adequate for most control design applications and practical stability issues below 100 Hz. The developed model can also be used for multilevel cascaded converters which exchange real power. The main types of multilevel converters are diode clamped, flying capacitor, and cascaded inverter and while considering the harmonic level, losses, and component costs, the cascaded multilevel converter with “square wave control” is found to be the optimum solution for static synchronous compensator (STATCOM) applications. The presented modular structure of this converter, with a number of identical H-bridges, makes this converter very flexible in terms of power-handling capability. The use of “square wave control” results in a single switch on and off per cycle for each switch, which brings benefits of low switching losses. The author also attempts to establish generic modelling principles that are applicable for a range of multilevel-cascaded converters, even those which exchange real power. A modular modelling approach is adopted to represent the complexity of the system with the benefit that each individual subsystem can be analyzed independently. This analytical model employs all parameters and variables with physical meaning and, therefore, it can study variations in ac and dc system structures. Moreover, the past models used are static and completely ignores the control influence since the model neglects the transfer of active power, so they cannot be used for dynamic modelling. So in this paper we can see a dynamic analytical model of a multilevel-cascaded STATCOM converter that is convenient, suitable and accurate analytical model of an indirectly controlled cascaded multilevel STATCOM with square-wave control. The converter voltage components are analyzed in detail for a single-cell and the results are then generalized for a multi-level cascaded converter. The converter ac voltage waveform is of a nonlinear, discrete, and dynamic nature, which is described mathematically by appropriate averaged expressions. The dynamic, analytical state-space model is built of subsystems to enable model application to a wide range of system configurations and various dynamic studies. Eigen-value studies are conducted for each particular test system in order to select optimum open-loop controller gains. When the proposed model is tested in the frequency domain and it is observed that the presented model can be used for dynamic studies below 100 Hz.

J. Analysis of a Harmonics Neutralized 48-Pulse STATCOM with GTO Based Voltage Source Converters [10]

In this research, a two-level 48-pulse ±100MVAR STATCOM is proposed where eight, six-pulse GTO-VSC are employed and magnetic is simplified to single-stage using four transformers of which three are PSTs and the other is a normal transformer so that it reduces the magnetic to half of the value needed in the commercially available compensator. Simple PI-controllers is adopted so that, the model is simulated in a MATLAB environment by SimPower Systems toolbox for voltage regulation in the transmission system. Multi-pulse topology of converters using elementary six-pulse GTO - VSC (gate turn off based voltage source converter) operated under fundamental frequency switching (FFS) control is widely adopted in high power rating static synchronous compensators (STATCOM). Practically, a 48- pulse (6x8 pulse) configuration is used with the phase angle control algorithm employing proportional and integral (PI) control methodology. These kinds of controllers, employs two stages of magnetic viz. intermediate transformers (as many as VSCs) and a main coupling transformer to minimize harmonics distortion in the line and to achieve a desired operational efficiency. The magnetic circuit needs altogether nine transformers of which eight are phase shifting transformers (PST) used in the intermediate stage, each rating equal to or more than one eighth of the compensator rating, and the other one is the main coupling transformer having a power rating equal to that of the compensator. Modelling and simulation of a 48-pulse 2-level, ±100MVAR STATCOM device employing eight elementary 6-pulse GTO-VSCs operated at FFS for a single stage of magnetic to obtain a harmonic neutralized and close to sinusoidal AC output voltage waveform by means of SimPowerSystem toolbox in MATLAB environment. In the proposed STATCOM, there is no requirement of intermediate transformers and only four transformers including three numbers of PSTs providing phase shifts of
–15°, +15°, and +30° .In the control algorithm, simple PI controllers in voltage and current control loops are adopted in d-q rotating frame reference for control of the converter phase angle (α) voltage in respect of the line voltage across the leakage
reactance. With the use of eight numbers of six-pulse converters, interfacing magnetic have been conceptualized and designed in single stage in the compensator circuit instead of the conventional two stages topology adopted in the high power rating 48-pulse STATCOM. This compensator has also been configured for voltage regulation in the high voltage 132kV system. Under single stage configuration of magnetic, the overall capacity requirement (MVA) of the magnetic has been optimized to half of that
needed in the commercially available compensator and thus, becomes cost effective. The number of transformers in the magnetic circuit has been reduced from nine to four. With the standard PI-control algorithm adopted in the inner current control and outer voltage control loops, the compensator has enabled smooth control of load voltage in the system under various operating conditions and it has provided the damping to rapidly settle to steady state condition. The simulation results show that the THD levels in line voltage and current are well below the limiting values specified in the IEEE Std for harmonic control in electrical power systems. The controller performance is observed reasonably well during capacitive and inductive modes of operation. The presence of lower and higher order harmonics in both line voltage and current has also been found to be appreciably low.

CONCLUSION

In this research, a review of past literature published on the various control strategies of STATCOM is presented. In this work, we have found that with the advancement of power electronics converters, the power engineers find various occasions to develop the control strategy so that harmonics are reduced as possible. We can also see that a multilevel cascaded multi-pulse STATCOM have found great applications in today power system .There is a great scope for power quality researchers for developing fast adaptive controllers for STATCOM.

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