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A SURVEY ON POWER QUALITY IMPROVEMENT USING STATCOM IN A POWER SYSTEM

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ABSTRACT

The environment for addressing and resolving power quality concerns and associated challenges has dramatically changed as a result of the rapid development and advancement of power electronics devices in recent decades. The most effective examples of these are FACTS devices. Since STATCOM is a powerful shunt controller and a FACTS device, this paper will discuss its impact and in-depth methods for enhancing power quality by reviewing prior research on STATCOM's various types and configurations. These methods include reducing harmonics and enhancing dynamic performance.

Keywords: Statcom, UPFC, Power System.

I. INTRODUCTION

Due to the existence of electricity markets, the significant impact of renewable and distributed generation, and other factors that introduce more variability and uncertainty in the operation of the power system, today's power systems are transitioning from a relatively static operation scenario to a more dynamic one. For instance, under the operation of the electricity market, there are instances where the market's results for generation and consumption are constrained by restrictions on the loadability and security of power transmission.

A large number of high power semiconductor devices are available for use in power system applications due to the power electronics industry's rapid expansion. Fast controllable reactive power sources using new electronic switching and converter technology have been developed in recent years thanks to the availability of Gate Turn-Off (GTO) thyristor switching devices with high power handling capacity and the technological advancement of other powerful semiconductor devices like IGBTs.The solid-stateshunt reactive compensation and active filtering equipment based on switching converter technology are designed with the aid of the GTO thyristor.

These power electronic converters, also known as PowerQuality Devices (PQ Devices), are connected to transmission lines either in parallel or in series. Fast dynamic adjustment of phase-angle, voltage, and impedance of high-voltage ac lines is typically accomplished using flexible alternating current transmission systems (FACTS) devices. By making greater use of current gearbox assets and enhancing the security, reliability, and availability of the gearbox system, FACTS devices improve the flow of power through the system. Additionally, it improves the grid's dynamic and transient stability and improves power quality for delicate industries.

A new family of power electronic equipment, such as STATCOM, SSSC, and UPFC, are being developed as a result of the development of FACTS systems for managing and optimizing the dynamic performance of power systems. In the 1990s, the first Flexible AC Transmissions Systems (FACTS) were created [1]. FACTS devices can assist in reducing gearbox bottlenecks as well as other power system issues, which is why this technology is increasingly being considered. Additionally, this technology has matured, and the price of these power electronics-based solutions has significantly dropped.

The Thyristor-Switched Capacitor (TSC) and Thyristor Controlled Reactor (TCR) have been widely replaced by voltage-source inverters (VSI) as the next generation of flexible reactive power compensation. Static Synchronous Compensator (STATCOM) has recently been the focus of debate and active study for many years. A shunt-connected compensator called STATCOM is utilised to give a transmission line reactive power correction. STATCOM can improve the steady-status stability limit by increasing the power transmission capability by regulating the line voltage at the point of connection.

Block diagram of single phase STATCOM is shown below

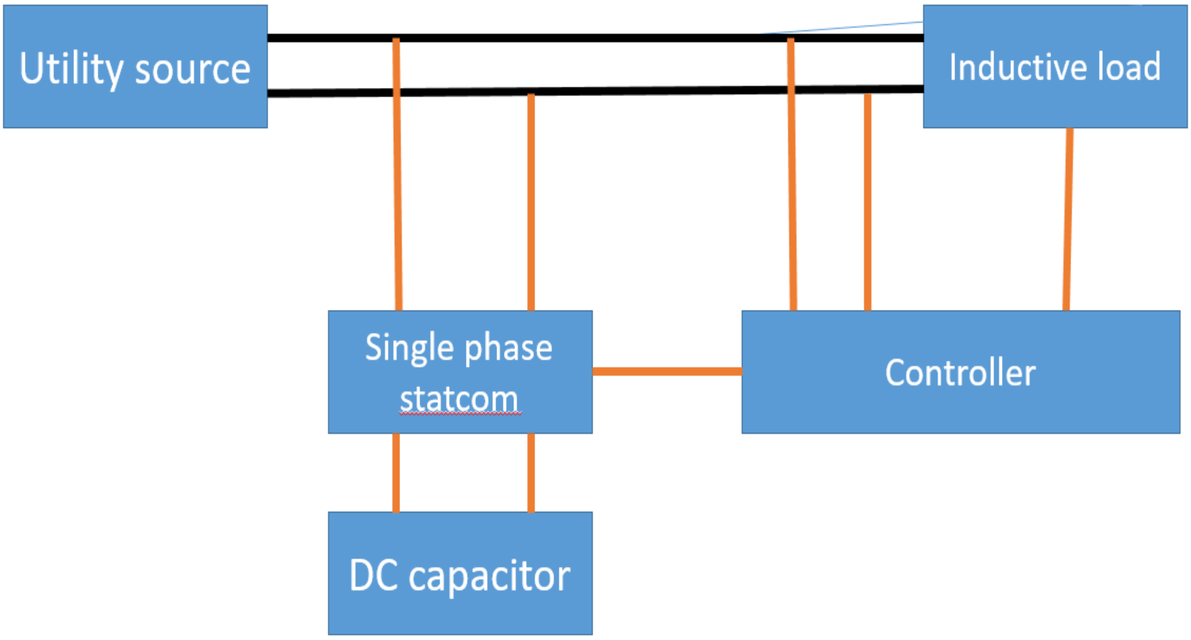

Figure 1: Block diagram of STATCOM

In order to dampen during power system transients and so increase the transientstability margin, STATCOM is also used. Theoretically, FACTS controllers can be realised by either a voltage-source converter (VSC) or a current-source converter (CSC) [2]. However, the majority of the research on STATCOM has focused on employing VSC topology [4] - [8], with the exception of the work presented in [3] more than 10 years ago. There are a number of benefits to choosing VSC versus CSC, including the following: In both the power and control circuits, a CSC is more sophisticated than a VSC. At the ac terminals of a CSC, filter capacitors are utilised to shape the waveforms of the output ac current. This raises the converter's price.

Additionally, the ac-side inductances of filter capacitors produce resonant frequencies. Due to this, portions of the output current's harmonic components may be amplified, leading to severe harmonic distortion in the ac side current. A diode must be connected in series with each of the switches in the CSC unless a switch with a high reverse voltage withstanding capability, such as a Gate-Turn-Off Thyristor (GTO), is employed. In comparison to the case of VSC, this nearly doubles the conduction losses.

In CSC architecture, the dc-side energy storage component is an inductor, but in VSC topology, it is a capacitor. A capacitor experiences less power loss than an inductor. As a result, a CSC is considered to have worse efficiency than a VSC. The foregoing situation is anticipated to change as a result of recent advancements in CSC control and semiconductor switch technology for the reasons listed below:

a) The output terminals of a CSC have good sinusoidal-shaped voltage and current waveforms because of the ac-side capacitor. A filter is not necessary for a 48-pulse VSC STATCOM [9], but the expense of the filter is passed to the cost of multiple converters and multiple winding transformers. In a VSCSTATCOM, another filter must be employed if it is utilised at a lower frequency. With just one converter, CSCSTATCOM can operate at switching frequencies lower than 900 Hz. Compared to VSC, this lowers the filtering required. By carefully choosing the filter capacitors, the issue of the resonance between the capacitances and inductances on the AC side can be resolved.easons:

The Integrated Gate Commutated Thyristor (IGCT), which boasts high ratings, high reverse voltage blocking capability, low snubber requirements, lower gate-drive power requirements than GTO, and higher switching speedthan GTO, is the best combination of the properties required in high-power applications [10]. Additionally, theseries diodes are no longer required in the CSC topology.

c) By using superconductive materials in the dc-side reactor's construction, the dc-side losses can be reduced to a minimum. There has been ongoing study on the CSC topology and its applications in power systems[11], [12].

The magnitudes of the harmonic components of both converters when STATCOM is run using the SPWM (SinusoidalPulse Width Modulation) approach [13] are inversely correlated with the magnitudes of the fundamental components of their direct output quantities. Under typical circumstances, the current injected by STATCOM in gearbox systems is relatively negligible in comparison to the line current. Thus, the harmonics of the current are similarly minimal. The output voltage of VSC, however, is enormous and extremely near to the system voltage when VSC is also utilized for the little injected current.

This will result in high voltage harmonics, which can produce current harmonics that are more expensive to filter because they are greater than those produced by CSC. The need for dc-side energy storage can be used to create the other. The dc-side current is extremely near to the peak value of the needed injected current, which is a small portion of the line current, when the STATCOM is operated as a CSC. However, when a VSC is used to provide reactive current to the system, the needed voltage needs to be higher than the system line-to-line voltage's peak value in order to allow for the transfer of reactive power between the transmission line and the STATCOM. This found that for the implementation of STATCOM, the CSC required less energy storage than the VSC.

II. WORKING PRINCIPAL OF STATCOM

The foundation of STATCOM is the VSC, which consists of parallel connections between self-commutating solid-state turn-off devices such the GTO, IGBT, and IGCT and others. Either PWM or square-wave operation is used to operate the power electronics switches. The foundation of STATCOM is the VSC, which consists of parallel connections between self-commutating solid-state turn-off devices such the GTO, IGBT, and IGCT and others. Either PWM or square-wave operation is used to operate the power electronics switches.

Harmonics are removed by using high switching frequencies. On the input side of the VSC, a DC capacitor serves as the voltage source. The output is an AC voltage with many steps. The diode is used for rectification. The fundamental goal of STATCOM is to generate and absorb controllable reactive power using a solid-state switching algorithm to provide virtually harmonic neutralised and controlled three-phase AC output voltage waveforms at the point of common connection (PCC). The following relation is used to determine STATCOM's P-Q relationship.

$$S = \frac{3VsVc}{X}\sin\alpha - j3\left(\frac{VsVc}{X}\cos\alpha - \frac{Vs^2}{X}\right) = P - jQ$$

Where X is the leakage reactance, L is the leakage inductance, f is the system frequency, and is the phase angle between Vs and Vc. Where S is the apparent power flow, P is the active power flow, Q is the reactive power flow, Vs is the main AC phase voltage to neutral (rms), and Vc is the STATCOM fundamental output AC phase voltage (rms).The variation of a has an impact on active power flow, while the size of the voltage variation between Vc and Vs has a significant impact on reactive power flow. Power (P) goes from Vc to Vs for trailing a and from leading to Vs.

flows from Vs to Vc, with P equal to 0 and Q calculated as follows for =0.

$$Q = \frac{Vs}{X}(Vc - Vs)$$

III. LITERATURE REVIEW

IN [**14**]. It is mentioned that the dynamic operation of a new control scheme for both static synchronous compensators (STATCOM) and static synchronous series compensators (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 stabilisation of the electric grid network is investigated.

Using the Power System Blockset (PSB), the STATCOM and SSSC are digitally simulated as part of the power system in the MATLAB/Simulink environment. This work proposes two innovative controllers for the STATCOM and SSSC based on a decoupled current control method. When the system was subjected to load disturbances such switching different types of loads, the suggested decoupled controllers for the 48-pulse voltage source converter STATCOM displayed great efficiency for reactive power compensation and voltage regulation. In this study, we compare the performance of the Auxiliary Tracking control with PWM switching technique in suppressing any oscillation and damping the transients that may emerge during the change from capacitive to inductivemode of operation.

This report also includes a comprehensive digital simulation study for a sample test power system using the full 48-pulse GTO-SSSC device model. The MATLAB/Simulink software environment and the PSB are used to carry out the digital simulation.

The 48-pulse GTO converter's cascade of converters, whose full digital simulation model was created using MATLAB/Simulink, serves as the fundamental building element of the SSSC device. To ensure quick controllability, minimal oscillatory behaviour, minimal inherent phase locked loop time delay, as well as system instability reduced impact due to a weak interconnected ac system, the control strategies employ decoupled current control and auxiliary tracking control based on a pulse width modulation switching technique.

In **[15],** it is mentioned that A multi-level D-STATCOM arrangement is shown that consists of a coupling transformer, a DC energy storage device, a three level voltage source converter, and related control circuits. Only the measurement of the RMS voltage at the load point is necessary for the control, which is based on sinusoidal PWM. The PSCAD/EMTDC simulation programme, which was used for its modelling and simulation, has proved the validity and effectiveness of the suggested power conditioner. In-depth simulation is also used to confirm that multi-level D-STATCOM is preferable to two level D-STATCOM. The multi-level Voltage Source Converter (VSC)'s distinctive structure enables it to achieve high voltages with low harmonics without the need for transformers or series-connected, synchronised switching components. It has been found that as the number of VSC levels increases, the output voltage and current waveforms tend to be sinusoidal in character with few harmonics.

The multi-level VSC is preferred over the frequently 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, according to this Comparison of multi-level DSTATCOM with two-level DSTATCOM.

When different levels of D-STATCOM are assessed for efficiency, % THD in voltage and current, it is discovered that as the number of levels rises, % THD in output voltage and current falls. The three-level VSC exhibits maximum efficiency and reduced voltage and current THD values. This specialised power controller can be useful in automated sectors with important loads.

In [**16],** it is mentioned that for controlling transmission line real power, a novel double loop control approach of current feed-forward + double PI loop is suggested. Voltage droop control, which consists of PI regulation and scaling factors of the droop characteristic, is used in the bus-bar voltage outer loop control system. In a double loop decoupled control system of dc capacitor voltage regulation, a current feed-forward control is added. In this work, the control system design process is briefly covered. The simulation findings for a case study as well as the actual results on 15-KVA laboratory-scale equipment show that dc capacitor voltage and bus-bar voltage can be managed effectively, demonstrating the viability and efficiency of the control scheme and controller design. In essence, we are aware that one of the most popular FACTS devices is the Static Synchronous Compensator (STATCOM) based voltage source converter.

In this study, a novel double loop control system is developed. It consists of a current controller, a dc-link capacitor voltage controller, a feed-forward controller, and a bus-bar voltage controller.The experimental and simulation results show that the bus-bar voltage and dc-link capacitor voltage are efficiently controlled, and the system performs well under dynamic and stable conditions. They also demonstrate that the current feed-forward plus double PI loop is a workable control strategy, and the controller design is precise and efficient.

In [**17],** it is mentioned that The nonlinear model is directly corrected without using a linear approximation in a flatness-based tracking control for the VSC. Straightforward open-loop control design is facilitated by flatness. A comparison with the decoupled vector control, which is the industry standard, is provided together with a comprehensive experimental validation. Investigated is the robustness of the flatness-based control, and set-point regulation for unbalanced three-phase voltage is taken into account. A linearized model of the VSC and proportional-integral (PI) feedback are frequently the foundations of conventional solutions to this issue. The

PI control for the real current is contained inside the PI control for dc voltage in this suggested control structure, which is a regularly used cascade controller structure for the real current and dc voltage. A different PI controller independently controls the reactive current.

This control is based on a linearized averaged model of a VSC that takes into consideration the key switching voltage constituents. It is logical to use model-based nonlinear control techniques that directly address system nonlinearity without calling for a linear approximation because the averaged model of the VSC is nonlinear. According to experimental findings, nonlinear control offers better transient tracking performance than a conventional vector control system.

In **[18],** it is mentioned that a 48-pulse, two-level, 100M.It is suggested to use VARSTATCOM, which uses eight, six-pulse GTO-VSCare and simplifies magnetics to single-stage employing four transformers, three of which are PSTs and the other a conventional transformer. SimPower Systems' toolbox for voltage management in the gearbox uses simple PI-controllers to replicate the model in a MATLAB environment. The overall capacity need (MVA) of the magnetics has been optimised to half that required in the commercially available compensator in a single stage arrangement, making the magnetics cost-effective. The magnetic circuit now only has four instead of nine transformers. The innercurrent control loop and the outer voltage control loop both use the conventional PI-control algorithm. Under diverse operating situations, the compensator permitted smooth management of the load voltage in the system and also provided the damping to quickly reach steady state. According to the simulation results, line voltage and current THD levels are considerably below the upper and lower bounds stipulated in the IEEE Standard for harmonic control in electrical power systems. The performance of the controller is seen to be reasonably good in both capacitive and inductive operating modes. It has also been discovered that there are very few lower and higher order harmonics in line voltage and current.

In **[19],** it is mentioned that a static compensator (STATCOM) is a control system used to adjust the voltage of a busbar where it is connected; in addition, it controls the transit of active power by the injection or the absorption of the reactive power. In this paper, we presented the so-called DPC method for the STATCOM control as well as the simula- tion results.

In **[20],** it is mentioned that one of the main responsibilities of the power engineer is to guarantee dynamic and transient angle and load stability in order to preserve the security of the power system. By increasing the stability margins and supporting reactive power over the whole power system network, FACTS Controllers are the most efficient tools for ensuring system security. SVC and STATCOM are the two main shunt compensating devices of FACTS. The Static Synchronous Compensator (STATCOM) and the Static Var Compensator (SVC), two types of shunt devices, are modelled and simulated in this article. The transfer function models of weak and strong power systems were generated from the small signal models of these devices using first principles. The Short Circuit Ratio (SCR) of a weak power system is roughly less than 3, whereas that of a powerful power system is greater than 5. Time and frequency responses have been used to assess the effectiveness of both weak and strong power systems. For both weak and strong systems, the dynamic response is derived using precise models. Next, the performance of these devices is assessed, and comparisons are made, using the root locus plots and bode plots that were obtained using MATLAB programmes. From the Bode plots, the stability margins of both the systems with SVC and STATCOM have been determined. With the help of the temporal responses of the SVC and STATCOM models, the dynamic behaviour of the two types of power systems has been evaluated. The STATCOM is superior than SVC with indices such as peak overshoot, settling time, gain margin, and phase margins, as shown by all of these data, including dynamic response, root locus, and bode plots. Time response and bode plots provide the dynamic, steady state performance indices that demonstrate STATCOM's excellent performance.

IV. CONCLUSION

This study is a review of earlier material that has been published on the various control strategies used by STATCOM. By doing this, we have discovered that as power electronics converter technology advances, power engineers increasingly have chances to create control strategies that minimise harmonics. Additionally, a multilevel cascaded multi-pulse STATCOM has found several useful uses in the current power system .The potential for creating quick adaptive controllers for STATCOM is enormous for power quality researchers.

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