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Hysteresis-PI Controller Based STATCOM for Harmonic Compensation in HV Distribution System

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ABSTRACT
Modern industries are able to realize their visions because they carefully investigate the cutting-edge innovations that have matured into technical advances. To guarantee constant output, it is necessary to optimize production in order to maximize earnings while cutting expenses as much as possible. High-efficiency contemporary production and processing equipment relies on a constant, reliable, and fault-free supply of high-quality electrical power throughout the manufacturing process. Due to their extreme sensitivity to power fluctuations, such devices need meticulous planning and execution throughout their development. FACTS controller may present a reliable solution to this. They are power electronic based system with extra static equipment that provides control of one or maybe more variables of an AC transmission system. According to its adaptability and speed of control, FACTS devices may regulate both active and reactive power at once, guaranteeing adaptability to voltage-magnitude control. In tis work performance analysis of on such shunt connected FACTS controller which is STATCOM is presented to rule out harmonics generated due to unbalance and nonlinear loading conditions. The precision in the maneuver and control of STATCOM is attained by generating accurate gate signal for Voltage Source Inverter (VSI).
Keywords - Flexible Alternating-Current Transmission Systems (FACTS), Static Synchronous Compensator (STATCOM) Voltage Source Inverter (VSI), , Sinusoidal PWM.

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I. INTRODUCTION

Keeping up with the increased demand for electrical power presents new issues for today's power grid, increasing its complexity. In the current day, voltage control and stability may be limiting considerations in the design and operation of certain power systems. The potential for additional transmission lines is limited by a number of factors and limits [1]. Therefore, it is essential to make the most of the available transmission infrastructure. The bus voltage has to be regulated within a narrow steady-state range. Therefore, proper voltage and reactive power regulation is required to reap major operational advantages, such as flatter voltage profiles, more effective use of transmission capacity, and larger safety margins. Multiple control strategies and operational procedures may be used to accomplish the task of voltage management in transmission and distribution. Injecting voltage in series or reactive current in a shunt at key points in the electrical grid are two approaches used by certain technologies that claim to provide answers. When a disturbance occurs, the excitation system's dynamic responses and the control devices are directly responsible for restoring the voltage to its normal reference levels. The development of controllable reactive power sources based on electronic switching converter technology has resulted from the widespread availability of Gate turn-off (GTO) devices in the last decade with improved capabilities to handle high power, as well as the increased employment of various other categories of power-semiconductor devices, such as IGBTs. The use of these power electronic devices allows for the development of switching converter-based solid-state shunt reactive compensation machinery. The developing technologies provide substantial benefits over the present ones, particularly in the areas of space reduction and increased performance. By using this idea, we may build a shunt reactive compensation device with no mechanical inertia; we call this device a Static Synchronous Compensator (STATCOM) [2]. A new class of power electronic equipment, such as STATCOM, SSSC, and UPFC, has developed to aid in the management and optimization of the power system's performance thanks to the development of Flexible AC Transmission Systems (FACTS) [3, 4]. When it comes to controlling reactive power in the next generation of power systems, voltage source inverters (VSI) have gained widespread acceptance as a replacement for traditional VAR compensation methods like "thyristor switched capacitors (TSC) and thyristor-controlled reactors (TCR)". Several studies have been seeking to use FACTS in various ways to improve power system performance [5, 6]. Voltage regulation, torsion oscillation damping, voltage management, and power system stability enhancement are the primary uses. These applications can be put into action with the right kind of command system (magnitude of the voltage and control of phase angle).

In this work STATCOM with right angle for pulse generation is designed for obtaining sinusoidal source voltage and current by eliminating load harmonics. The STACOM is a shunt compensated device which can provide 3-phase controlled waves of Various parameters like the phase angle, frequency, voltage magnitude etc. It's a solid-state switching device with two distinct power capabilities: real power generation and reactive power acceptance. The VSI, or voltage source inverter, is the brains of the STATCOM [7]. The inverter that powers the STATCOM's voltage source receives its stable dc voltage supply from a static capacitor. It is recommended to link the STATCOM's outer terminal to the system's main voltage bus through a leaking reactance. The VSI terminal of the STATCOM receives a stable dc voltage from the capacitor that has been carefully selected to provide this power. STATCOM is a one-of-a-kind gadget due to its capacity to quickly respond to power outages and absorb both reactive and actual power as required.

II. STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

The power quality of electric supply has been negatively impacted by the increasing usage of power electronics-based devices in both commercial and residential settings over the last several decades. At the same time, much of the equipment creating the disturbances is highly sensitive to variations from the ideal sinusoidal line voltage. Harmonic currents cause voltage distortion because the voltage source is not perfect. High disturbances in the power supply system may be caused by a variety of non-linear loads, including rectifiers, cycloconverters, variable speed motors, arc furnaces, and huge decaying DC components [8].

In general, the performance of a system is affected by the harmonics created by the most prevalent non-linear loads. Passive filters have long been used to combat harmonic distortion. However, passive filters are seldom used because of their shortcomings. Additionally, an adaptable and dynamic solution to power quality issues was devised by power engineers. An active filter, seen in fig. 1, is a device that can correct for voltage and current harmonics. It is a shunt connected device commonly known as STATCOM [9].

STATCOM is a one-of-a-kind gadget due to its capacity to quickly respond to power outages and absorb both reactive and actual power as required. interfacing mode as it can provide reliability as well as stability to the grid by increasing its power generation limit [10].

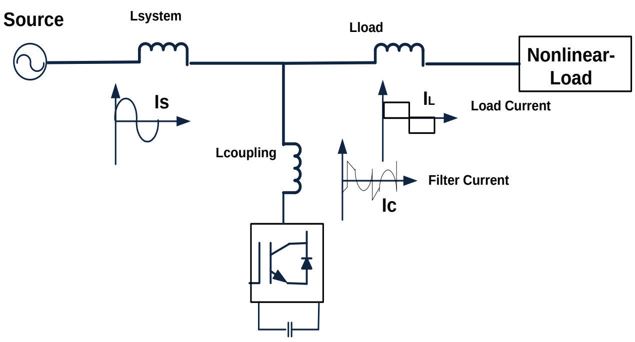

Fig. 1 Single line diagram of STATCOM

III. STATCOM CONTROL

STATCOM is a shunt active filter which uses the notion of injecting harmonic currents into the AC-system that are identical in amplitude to the load harmonic currents but have the opposite phase. Figure 2 depicts the closed-loop control system used by active power filters to actively mold the source current into a sinusoid pattern [11].

Shunt active power topology is most popular topology for current harmonics elimination due to easy implementation and good performance. Shunt active power filter (SAPF) behaves as a three phase controlled current source and it generates compensation current in phase opposition to the harmonics current that depends on the reference current generation [12, 13]. It works in a closed loop manner so that it senses the load current variation continuously to generate the required compensation current.

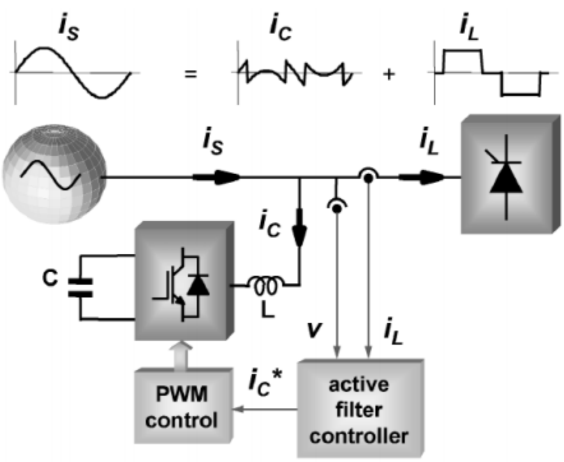

Fig. 2 Schematic diagram of STATCOM control

Figure shows that SAPF consists of two distinct main blocks;

1) Active filter controller (Reference current generation block)
2) Pulse width modulated current controller (PWM controller)

Active filter controller is used for instantaneous monitoring of load current and there by the generation of reference compensating current. Synchronous reference frame theory is the most popular reference current generation method. By using this reference compensating current and source current, gate pulses required for the VSI is generated by PWM controller. PWM controller is responsible for power processing in synthesizing compensation current required for the entire system.

IV. SIMULATION MODEL AND RESULT

The simulation model of proposed system is sown in figure 3. System has been designed for voltage level of 11 KV with fundamental frequency of operation of 50 Hz. STATCOM as a FACTS controller is connected to remove harmonics generated due to nonlinear loading as well as unbalanced loading. Both the loads are connected simultaneously in high voltage distribution system. At load bus a three-phase full bridge rectifier is connected with RL-branch. At 0.1 sec, STATCOM is enabled in the system. The STATCOM is an active filter designed with conventional 2-level VSI. The controller of the VSI for generating conduction pulses for IGBT gate signals are designed using hybrid PI-Hysteresis controller. PI-controller regulates the DC-voltage of VSI, while hysteresis controller gating signals. The controller circuit is sown in figure 4. A universal bridge block available in MATLAB library is considered as VSI. In hysteresis controller, first positive and negative components of reference source voltage and load current is extracted using clark's transformation and then P and Q are calculated to wit alpha and beta angles of t reference signals. With the help of alpha and beta compensation current is extracted to feed it to PWM generator which generates t at pulses for t switches of VSI. T coupling inductor of 10 mH is behaves as a filter to remove load harmonics.

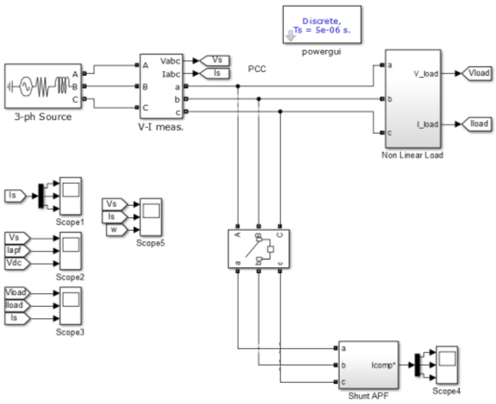

Fig. 3 Schematic diagram of STATCOM control

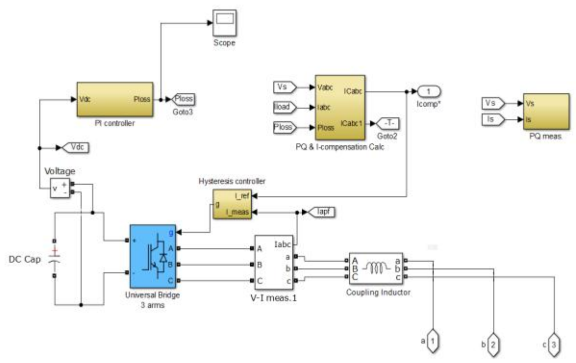

Fig. 4 Schematic diagram of STATCOM control

The level source voltage and current wavform with phase angle is shown in figure 5. From the figure it can be seen that, source voltage remains unaffeted under abnormal operating conditions and interfrnce of non-linear load. But as soon as STATCOM is conncected, source current profile improves without wasting any connection time, this means that poposed controller smooth transition of STATCOM in to the system. Figure 6 presents the load voltage and current waveform in comparison with the source current.

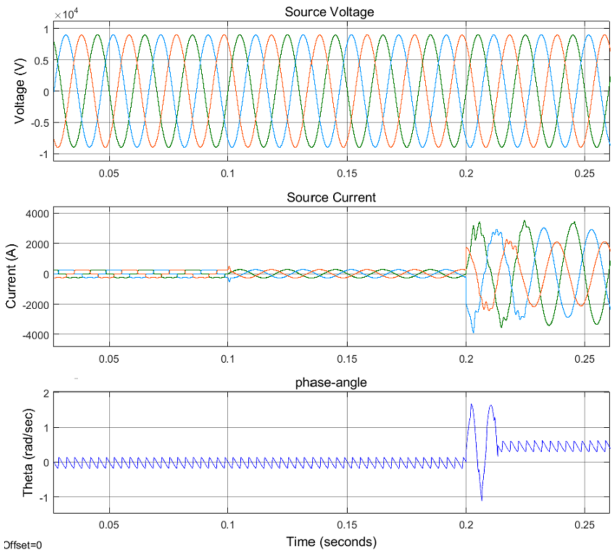

Fig. 5 Source voltage and current with phase angle

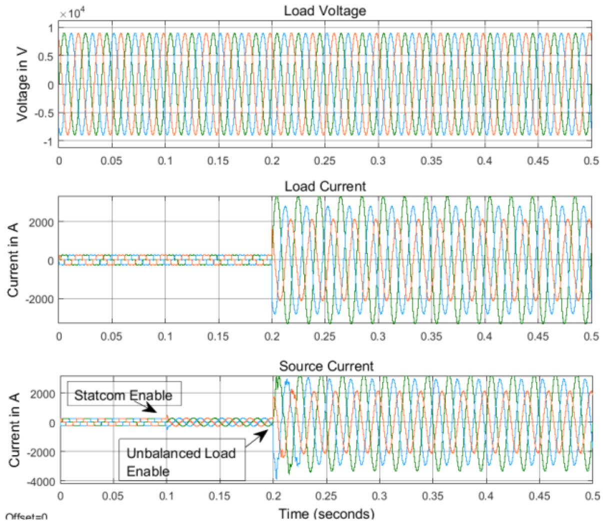

Fig. 6 Load voltage and current with and without STATCOM under nonlinear and unbalanced loading

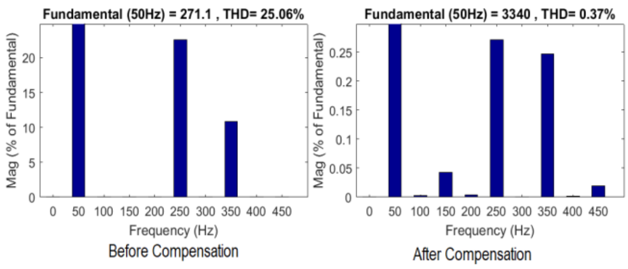

Fig. 7 THD of source current before and after compensation

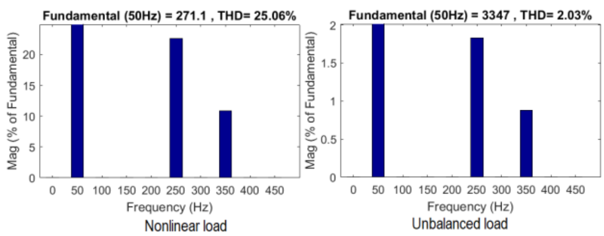

Fig. 8 THD of load current under nonlinear and unbalanced loading

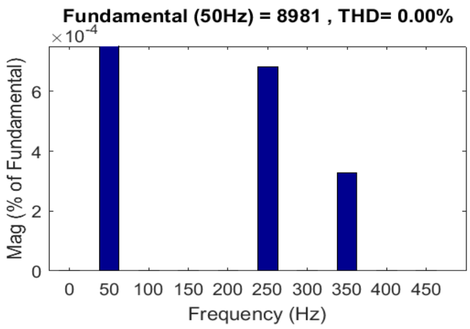

Fig. 9 THD of source and load voltage

V. CONCLUSION

The performance of STATCOM for load harmonic compensation using SRF theory and PI as well as hysteresis controller is analysed. The phase angle θ is estimated via SRF theory and which accurately generates the gate pulses to control the conduction of VSI. The hysteresis controller provides accurate frequency information which tends to give accurate reference signal estimation. Simultaneous nonlinear and unbalanced loading is connected and the STATCOM designed compensate source current harmonics and the source and load voltages remains unaffected by the load profile. The THD of source current is very low with 0.37 % with proper reference signal generation is more accurate during normal/ abnormal conditions.

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