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ROLE OF SWITCHED CAPACITOR COMPENSATION METHOD IN POWER QUALITY IMPROVEMENT TECHNIQUES

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Abstract: This paper presents a FACTS-based filter/compensation scheme (SCC) developed for smart grid applications, power quality improvement and harmonic reduction. The proposed FACTS filter/compensation device comprises a hybrid series and shunt switched capacitor-banks controlled by a dynamic time decoupled multi-regulator multi-loop error driven inter-coupled controller. The growing use of nonlinear type electric loads causes a real challenge to power quality for electric utilities. The deregulated electricity market where: competition, supply quality, security and reliability are now key issues for any economic survival. Electrical power network pollution is characterized by the nonlinear electric load ability to distortion modify and change the voltage and current wave form Root Mean Square (RMS) due to its inherent nonlinearity. All these devices will cause harmonic currents to flow and some devices, actually, directly produce voltage harmonics. Any ac current flow through any circuit at any frequency will produce a voltage drop at that same frequency. Harmonic currents, which are produced by power electronic loads, will produce voltage drops in the power supply impedance at those same harmonic frequencies.

I. INTRODUCTION

The growing use of nonlinear type electric loads causes a real challenge to any power quality and harmonic mitigation for electric utilities around the world, especially in the existing era of unregulated electricity market where: competition, supply quality, security and reliability are now key issues for any economic survival. Network pollution is characterized by the nonlinear electric load ability to distortion modify and change the voltage and current waveform RMS due to its inherent nonlinearity. The global need for electrical energy sources, energy conservation measures, and rising world energy demand drive exiting power systems and transmission lines toward their crucial stability and thermal limits and grid security, reliability, and voltage stability. This can result in sustained faults, Brownouts, Blackouts, and severe power quality problems. To reduce system active and reactive power losses and resultant poor power factor problems due to poor power quality, fixed, switched, and modulated capacitor banks have been widely used. Fixed power filters which have low cost and simple robust structure are usually installed particularly in industrial utilization networks to improve power quality and reduce the level of harmonic distortion. Active power filters can be used to fulfill power quality requirements but they are expensive and consume large current rating Other option is using the switched/modulated family of passive filters and capacitive compensators developed. Advent of Flexible A. C. Transmission System (FACTS) based Switched Capacitor Compensation (SCC) utilized with dynamic control systems for compensation of reactive power and harmonics to system [2]. To reduce feeder active and reactive power losses and resultant poor power factor problems due to poor power quality, fixed, switched, and modulated capacitor banks have been widely used [2]. Fixed power filters which have low cost and simple robust structure are usually installed particularly in industrial utilization networks to improve power quality and reduce the level of harmonic distortion. However, the fixed parameter power filters and capacitor banks are limited in effectiveness for dynamic type loads and may result in resonance in some cases [3, 4]. Due to the fact that passive filters are effective based on impedance ratio of the supply and filter setting with correct parameter values to have a reliable filter operation is limited to fixed network topology and loading condition and can be a challenging task. In addition, excursions, faults, and extreme conditions due to system changes render the filtering equipment ineffective. Active power filters can be used to fulfil power quality requirements [5, 6], but they are expensive and consume large current rating. Other option is using the switched/modulated family of filters and capacitive compensators developed by the First Author [6-8].Advent of switched/modulated filter compensation schemes simplifies the concept of flexible FACTS-devices by combining low cost power filters with capacitor banks for power quality enhancement, flicker control, power factor correction, and electric energy loss reduction. These can be widely used in smart grid networks supplied by renewable wind and small hydro renewable energy sources [9-14].Moreover, different new/customized topologies/configurations of the modulated filter compensators are easy to design and customize with effective dynamic flexible control strategies. In this paper a novel low-cost switched capacitor compensator (SCC) developed by the First Author is validated for power quality and power factor enhancement with effective voltage stabilization for use in smart grid-fed industrial, commercial, and residential loads, particularly for short duration short circuit and load excursions. To switch the dual IGBT/GTO switches, a multi-loop dynamic error driven coordinated dual regulation dynamic control scheme and a weighted–modified PID controller with additional error squared and rate adjusting supplementary loops for fast action are also developed.

II. BASIC PRINCIPAL OF POWER COMPENSATION IN TRANSMISSION SYSTEM

Figure (a) shows the simplified model of a power transmission system. Two power grids are connected by a transmission line which is assumed lossless and represented by the reactance represent the voltage phasor of the two power grid buses with angle δ= δ1 - δ2between the two. The corresponding phasor diagram is shown in Figure (b).

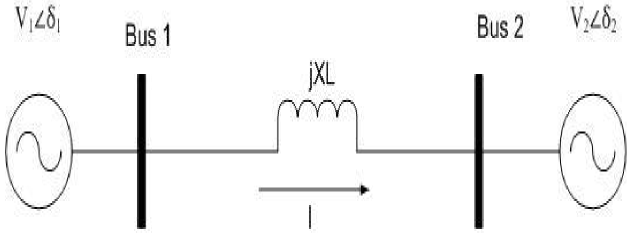


FIG-A

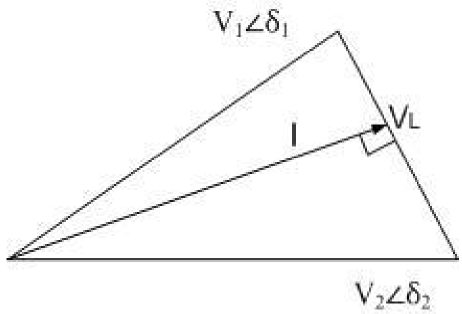


FIG-B

Fig.: Power Transmission System: (a) Simplified Model (b) Phase Diagram

A. Necessity of reactive power compensation:-

"Reactive power (vars) is required to maintain the voltage to deliver active power(watts) through transmission lines. Motor loads and other loads require reactive power to convert the flow of electrons into useful work. When there is not enough reactive power, the voltage sags down and it is not possible to push the power demanded by loads through the lines". Transformers, transmission lines, and motors require reactive power. Transformers and transmission lines introduce inductance as well as resistance; both oppose the flow of current. It must raise the voltage higher to push the power through the inductance of the lines, unless capacitance has introduced to offset of inductance. The reactive power is require when one waveform leads to other, Phase angle not equal to 0 and Power factor less than unity. The reactive power produced when the current waveform leads voltage waveform (Leading power factor), and consumed when the current waveform lags voltage (lagging power factor).

B. Series compensation:-

Series compensation aims to directly control the overall series line impedance of the transmission line. The AC power transmission is primarily limited by the series reactive impedance of the transmission line. A series-connected can add a voltage in opposition to the transmission line voltage drop, therefore reducing the series line impedance. A simplified model of a transmission system with series compensation is shown in Figure (a). The voltage magnitudes of the two buses are assumed equal as V, and the phase angle between them is δ. The transmission line is assumed lossless and represented by the reactance. A controlled capacitor is series-connected in the transmission line with voltage addition.

C. 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 [7]. 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.Asimplified model of a transmission system with shunt compensation is shown in Figure. The voltage magnitudes of the two buses are assumed equal as V, and the phase angle between them is δ. The transmission line is assumed lossless and represented by the reactance. At the midpoint of the transmission line, a controlled capacitor C is shunt-connected. The voltage magnitude at the connection point is maintained as V.

III. SWITCHED CAPACITOR COMPENSATOR (SCC)

The proposed FACTS SCC filter/compensation device is a low cost switched/modulated filter which comprises a series switched capacitor bank and two shunt fixed capacitor banks connected to the AC side of a three-arm uncontrolled rectifier. Two mode operations are defined for the proposed FACTS device by two controlled switches, S1 and S2, installed on the DC and AC sides of the rectifier, respectively. These two switches follow NOT LOGIC command, that is, while S1 is on, S2 is off and vice versa. Switch S1 operation dictates on-off state of the series capacitor bank. On the other hand while S2 is on, SCC compensates reactive power like a shunt capacitor bank. Configuration of the proposed SCC is shown in Fig.1.

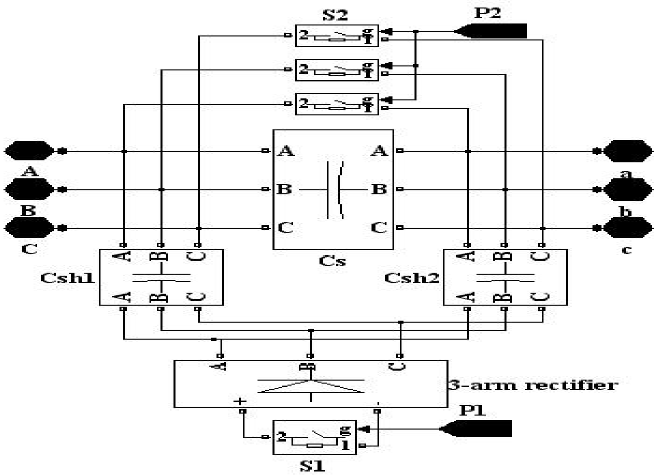


Figure. 1. Proposed FACTS-Hybrid Series-Parallel SCC configuration

A block diagram of the control scheme designed for the Switched capacitor compensation is shown in Figure 2. It is based on measurement of the current I_{rms} at the source point. The current error signal is obtained by comparing the measured I_{rms} current against a reference current, I_{rms_ref} . The difference between these two signals is processed by a PI controller in order to obtain the phase angle delta required to drive the error to zero. The angle delta is used in the PWM generator as the phase angle of the sinusoidal control signal. The switching frequency used in the sinusoidal PWM generator is $f_{s/w}$ - 900 Hz. The control Mechanism for Switched Capacitor Compensation is described here. The major parts of controlling mechanism are PI Controller, PWM, IGBT, Low Pass Filter as Transfer function and the other controlling parameters like ABS, RMS, Weighting Factor, and Limiter are described. The whole control mechanism is based on feedback control mechanism. Source Current and Source Voltage are given to controlling mechanism. After collecting source current in feedback Harmonic error are generated, overall Total error are generated on the basis of this PI Controller are operated and compensation are provided to system.

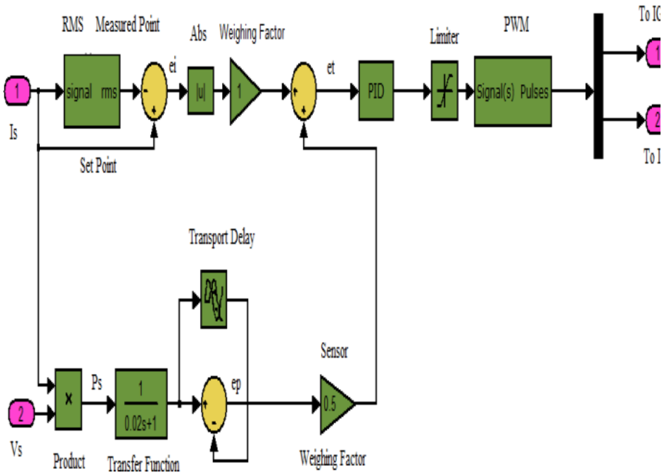


Figure 2. Block diagram of control scheme in MATLAB Software

A variable capacitor can be brought about by switch controlled capacitance which can control the fundamental component of current from zero to maximum amount. Therefore the injected reactive power to the AC bus can be controlled continuously by Switched Capacitor Compensation (SCC). Electrical loads have a combination of both active and reactive power. Active power is supplied by the generating stations while reactive power can either be supplied from the generating stations or by making use of shunt capacitor banks strategically located on the power system (or other, generally more expensive, reactive power compensation schemes).Reactive power compensation with capacitors is by far the most cost effective way to meet reactive power requirements of consumer loads. The addition of shunt capacitors releases thermal capacity in the distribution networks by reducing current flowing through the networks, which is required to supply the loads.

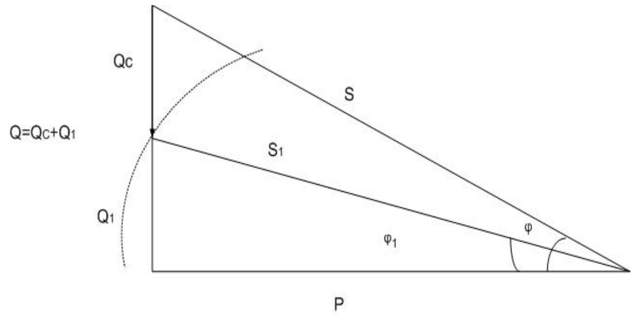
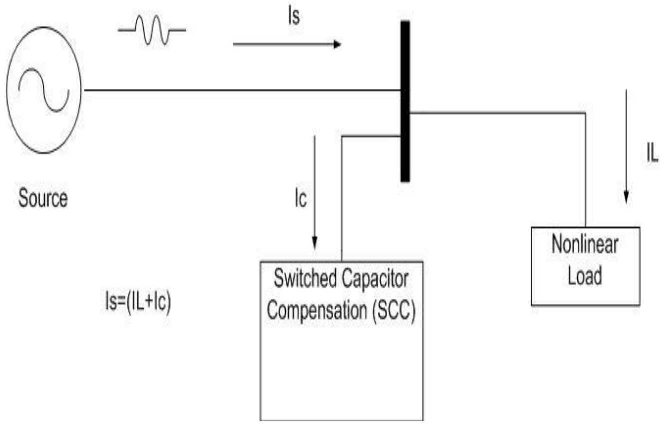


Figure 3-Effect of capacitor on reactive power

IV. SWITCHED CAPACITOR COMPENSATION FOR HARMONIC MITIGATION…

To mitigate harmonics from distribution networks switched line capacitor bank is used..



As shown in Figure switch capacitor compensation has a meaning of reactive power compensation and harmonic compensation. Switched capacitor compensation to provide or absorb the required reactive power and harmonic mitigation from power supply system. The capacitors store energy in an electric field, Inductors store energy in a magnetic field. As shown in Figure to mitigate harmonics from distribution networks switched line capacitor bank is used, i.e. Transformer tap changers, substation capacitor banks, fixed feeder capacitor banks, switched feeder capacitor banks and voltage regulators are used in case of three-phase line. The key difference between capacitor banks and voltage regulators is that capacitor banks reduce the losses across the length of the feeder and voltage regulators only improve the voltage at a particular point. Use switched capacitor banks to compensate for source current distortion of waveform.

V. CONCLUSION

This paper presents a novel low cost FACTS based switched filter compensation scheme for smart grid applications. The low-cost FACTS device developed is effective in voltage stabilization, power factor correction at key AC buses, improving power quality, and limiting inrush current conditions. A decoupled coordinated multi-regulator, multi-loop dynamic controller is utilized to adjust the pulse width modulation switching patterns for the two solid state complementary switches to ensure fast bus voltage stabilization and power factor correction. The same FACTS device and dynamic control scheme, is now being extended for hybrid renewable Wind/Micro hydro green energy systems for robust interfacing to smart AC Grid. The FACTS filter/compensator was validated using the MATLAB-Simulink software. The digital simulation results validate the fast response and effectiveness of the proposed fast acting FACTS scheme in improving voltage regulation, limiting inrush current conditions, and modifying power factor.

REFERENCE

[1] Power electronics hand book, 2nd edition by Muhammad H. Rashid.
[2] Pierre Kreidi, A.M. Sharaf, "Power Quality Enhancement Using Unified Switched Capacitor Compensation", IEEE Trans. Proceeding 0-7803-7781-8/03, May 2003.
[3] David D. Shipp, "Harmonic Analysis and Suppression for Electrical Systems Supplying Static Power Converters and Other Nonlinear Loads", IEEE Trans. Paper IPSD 78-62, February1979.
[4] Ray P. Stratford, "Harmonic Pollution on Power Systems-A Change in Philosophy". IEEE Trans. on Industry Application, VOL. IA-16, NO. 5, Oct. 1980.
[5] A.M.Sharaf and Kh.M.Abo-Al-Ez, "Harmonic Pollution on Power Systems-A Change in Philosophy",IEEE Trans. ISIE, July 2006.
[6] A.M. Sharaf& A.R.N.M. Reaz U1 Haque, "A Low Cost Stand Alone Photovoltaic Scheme for Motorized Hybrid Loads", IEEE Trans.0-803-8281-1/04, Feb. 2004.
[7] A.M Sharaf and RoshanChhetri, "A Novel Dynamic Capacitor Compensation/Green Plug Scheme for 3-Phase - 4 Wire Utilization Loads", IEEE CCECE/CCGEI 1-4244-0038-4 2006 IEEE, Ottawa, May 2006.
[8] Adel M. Sharaf& Hassan A. Mahasneh, "A Low-Cost Modulated Filter Compensator for Energy-Efficient Enhancement in AC Utilization Systems". IEEE Trans. 1-4244-1445-8/07/007, July 2007.
[9] Thomas S. Key, "The Electricity – Industrial User Partnership in Solving Power quality Problems", IEEE Trans. on Power Systems, VOL. 5, NO. 3,Aug. 1990.
[10] Hector G. Sarmiento and Eduardo Estrada, "A Voltage Sag study in an Industry with adjustable speed drives", IEEE Trans. Industry Application Magazine, Feb. 1996.
[11] Weihua Wang & A.M. Sharaf, "A Low-Cost Voltage Stabilization and Power Quality Enhancement Scheme for a Small Renewable Wind Energy Scheme". IEEE Trans. 1-4244-0497-5/06, 2006.
[12] A.M. Sharaf - Pierre: Kreidi, "Dynamic Compensation Using Switched Modulated Power Filter", IEEE Trans. Canadian Conference on Electrical & Computer Engineering 0-7803-7514-9/02, Sep. 2002.
[13] C.K. Duffey - R. P. Stratford, "Update of Harmonic Standard IEEE-519 IEEE Recommended Practices and Requirement for Harmonic control in power system". IEEE Trans. 88CH2661-7/88/0000-0249, Sep.1988.
[14] Alexander Eigeles Emanuel, "Power in Nonsinusoidal Situation A Review of definition and physical meaning". IEEE Trans. on Power Delivery, Vol. 5, No. 3, July 1990.
[15] SujoyDeb, Byron U. Sherman and Richard G. Hoft, "Resonant Converter Power Line Conditioner: Design and Evolution". IEEE Trans. 89CH2792-0/89/0000-052, 1989.
[16] B.S. Acharya R.W. Gascoigne D.M. Divan, "Active Power Filter Using Resonant Pole Inverters", IEEE Trans., 1989.

