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FACTS BASED SWITCHED CAPACITOR COMPENSATION FOR POWER QUALITY IMPROVEMENT AND HARMONIC REDUCTION

Mr.Nirav S. Patel[1], Mr.Maulik C.Pandya[2]
[1]PG Scholar, [2]Asistant Professor
Ldrp-Itr, Gandhinagar, Gujarat

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 effectiveness of the proposed low cost Pulse Width Modulated (PWM) scheme is validated using MATLAB-Simulink digital simulation results. This scheme can be used for single phase or three phase four wire load of nonlinear nature. Feedback control logic is applied to this U.S.C.S. scheme, it contain dual loop controller of current and power, error is generated by this loops which is given to PID controller, PID output is given to PWM which operates two switches, from this Switched Capacitor Compensation is provided to system. The reactive power and harmonic compensation can be achieved from this paper method by using passive shunt filter.

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 weighted–modified PID controller with additional error squared and rate adjusting supplementary loops for fast action are also developed.

II. 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.

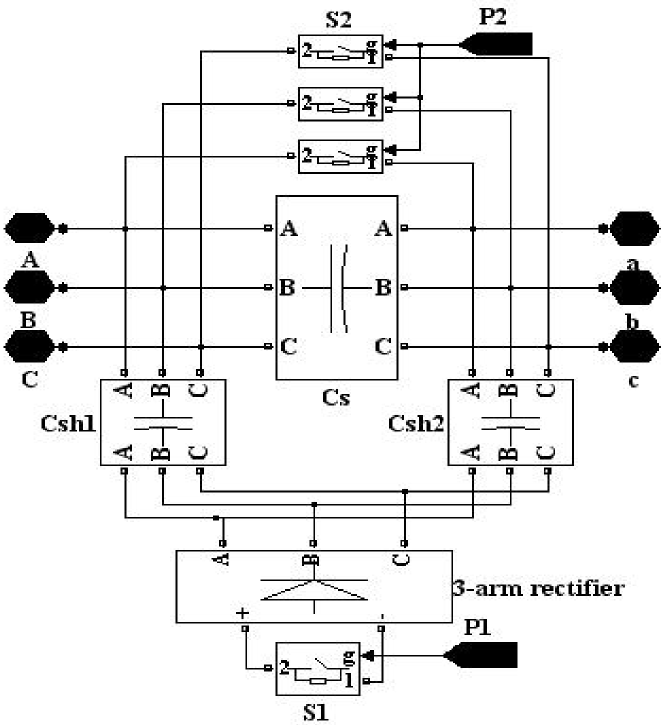


Figure. 1. Proposed FACTS-Hybrid Series-Parallel SCC configuration

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.

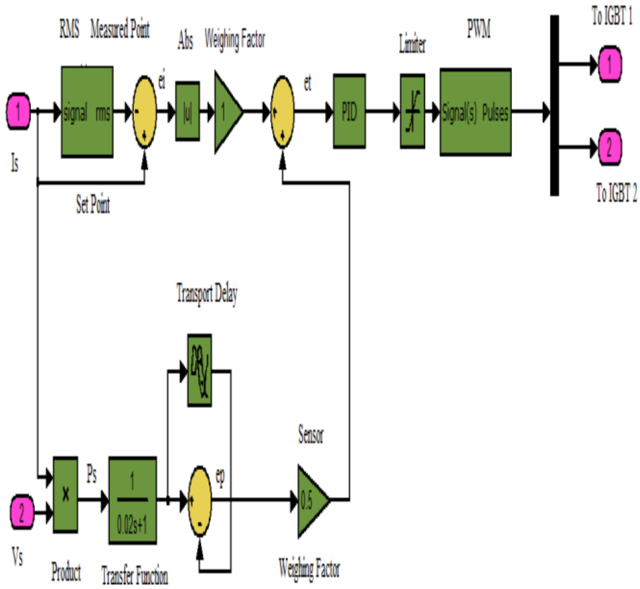


Figure 2. Block diagram of control scheme in MATLAB Software

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.

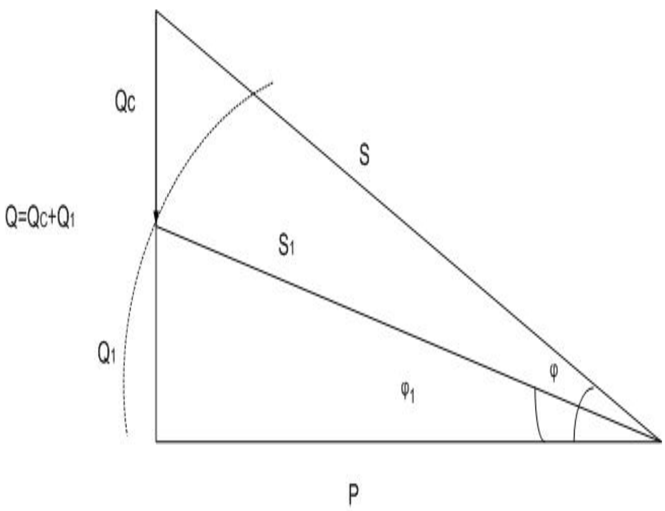
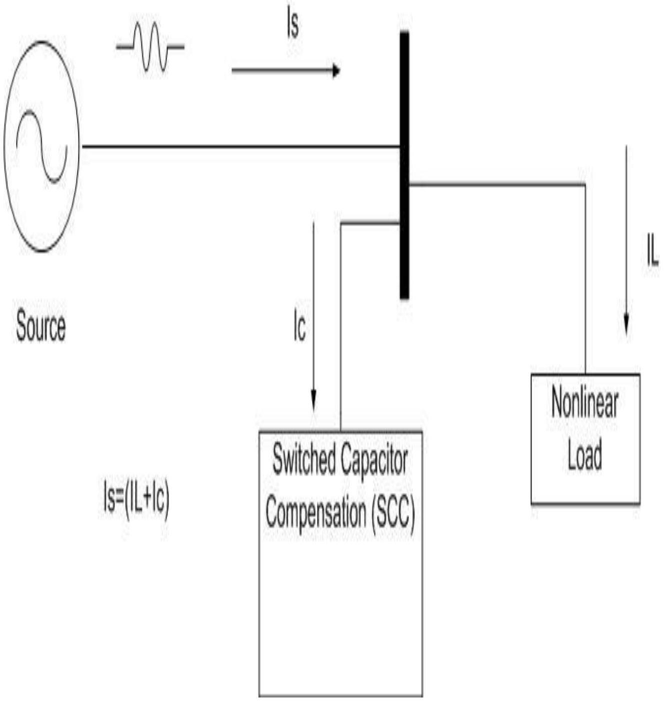


Figure 3-Effect of capacitor on reactive power

III. 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.

IV. PULSE WIDTH MODULATOR TRANSFER FUNCTIONS

It is often referred to as the pulse width modulation (PWM) voltage mode control, the output voltage u c (t) of the error (between desired and actual output) amplifier plus regulator, processed if needed, is compared to a repetitive or carrier waveform r(t), to obtain the switching variable δ(t) (Fig.). This function controls the power switch, turning it on at the beginning of the period and turning it off when the ramp exceeds the u c (t) voltage. In Fig. the opposite occurs (turn-off at the end of the period, turn-on when the u c (t)voltage exceeds the ramp).

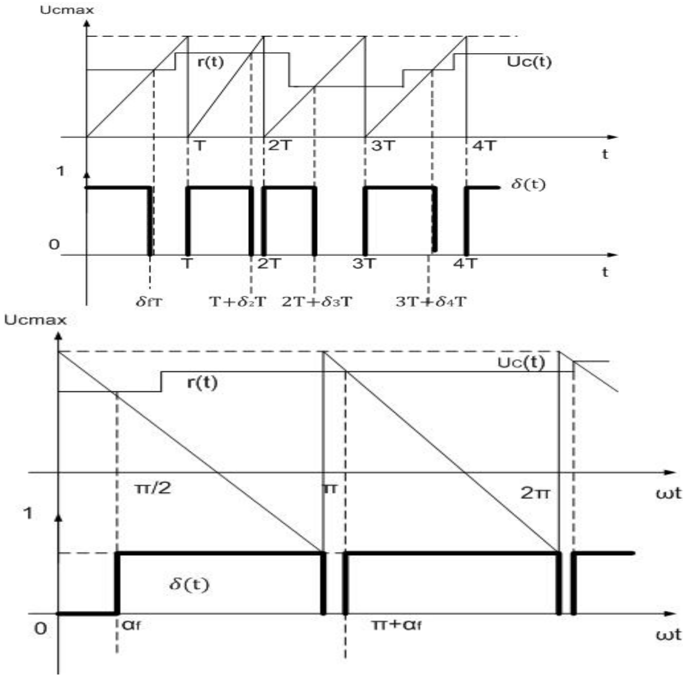


Fig 4.Waveforms of pulse width modulators showing the variable time delays of the modulator response: (a) r (t) = ucmax t /T and (b) r (t) = ucmax − 2ucmaxωt /π

V. SIMULATION AND RESULTS

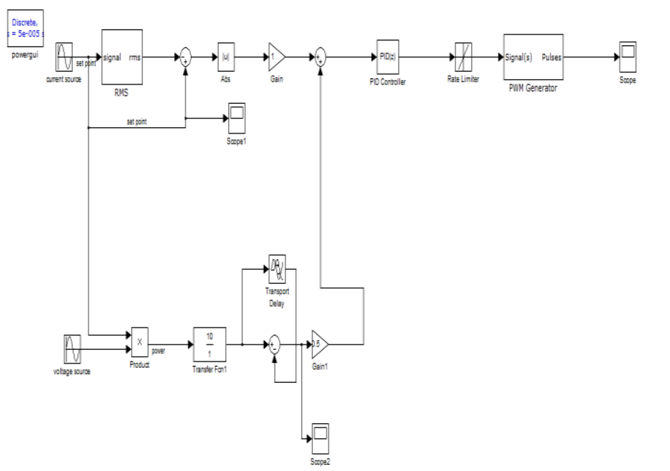


FIG 5. MATLAB MODEL

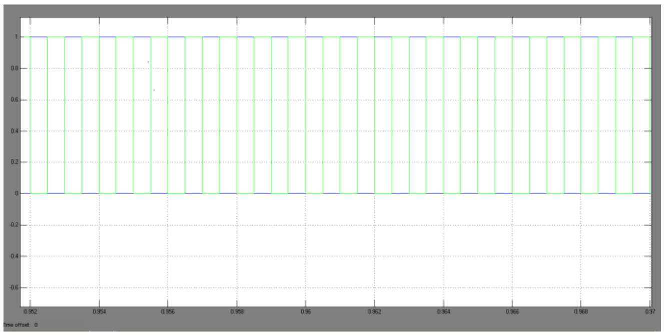


FIG 6.-PULSE OF PWM GENERATOR

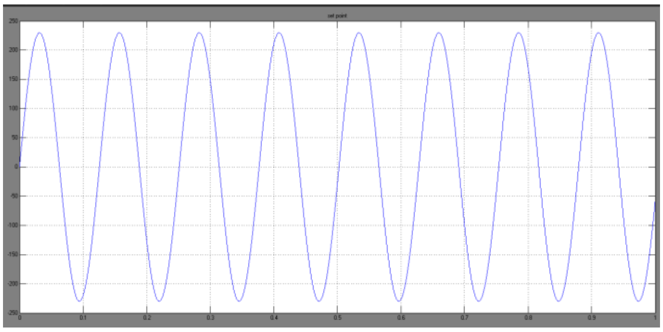


FIG 7.-DISTORTED WAVEFORM

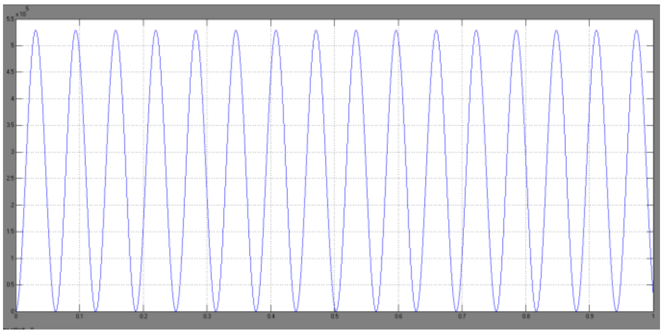


FIG 8.- OUTPUT WAVEFORM

VI. 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-Simu link 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.

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