Mitigation of Power Quality Issues in a Smart Grid Using MPFC

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Abstract—This paper describes different power quality problems in distribution systems and their solutions with power electronics based equipment.Shunt, hybrid and series active power filters are described showing their compensation characteristicsand principles of operation. A novel modulated power filter compensator (MPFC) is used for power quality improvement on transmission side for the smart grid stabilization and efficient utilization. Use of nonlinear loads, such as thyristor controlled inductor for FACTS devices converters for HVDC transmission and large adjustable speed motor drives, is accepted to grow rapidly. All of these loads injected harmonic currents and reactive power into the power system. The shunt active power filters are used in power systems for the compensation of harmonic currents generated for nonlinear loads. The MPFC is controlled by a novel tri-loop dynamic error driven inter coupled modified PID controller. The Mat lab digital simulation models of the proposed MPFC scheme has been fully validated for effective power quality improvement, voltage stabilization, power factor correction and transmission line loss reduction.This paper presents a Digital validation conducted for different cases of load, excursions and fault conditions using the Mat lablab/ Simlink/ Sim-Power software environment without and with the modified power Filter Compensator scheme for effective voltage stabilization, power factor correction and transmission line loss reduction.

I. INTRODUCTION

With significant development of power electronics technology, the proliferation of nonlinear load such as static power converters has deteriorated power quality in power transmission/distribution system [9].Most of the more important international standards define power quality as the physical characteristics of the electrical supply provided under normal operating conditions that do not disturb the customer's processes. Therefore, a power quality problem exists if any voltage, current or frequency deviation results in a failure or in a bad operation of customer's equipment.

A power quality problem will arise if any variation in voltage, current or frequency results a failure or due to bad operation of customer apparatus.In these modern days, in an electrical distribution system there will be sudden increaseof power-electronic based loads. Such as power supplies, rectifier equipment used in telecommunication network, domestic appliances, adjustable speed drives etc. and there loads offer highly nonlinear characteristics [10].

To improve the efficiency, capacitors are employed which also leads to the improvement of power factor of the mains [6]. The different technical options are available to the mitigation of power quality troubles, a capable and adaptable solution to voltage quality trouble is obtained by active power filters since modern active filters are smaller in size, and more flexible in application compared to traditional passive filters and these active power filters compensate current and voltage disturbances in distribution system. Shunt active filters compensate harmonics, reactive power, regulation of terminal voltage and improve voltage balance in three phase system [8].

Several hundred shunt active filters consisting of voltage fed pulse width modulator(PWM) inverters using insulated gate bipolar transistors(IGBT'S) or gate turn off (GTO) thyristors are operating successfully in Japan. These filters have provided the required harmonic filtering and control performance in comparison to conventional shunt passive filters and static var compensator consisting of capacitors bank at thyristor controlled reactors[9].

II. AC STUDY SYSTEM

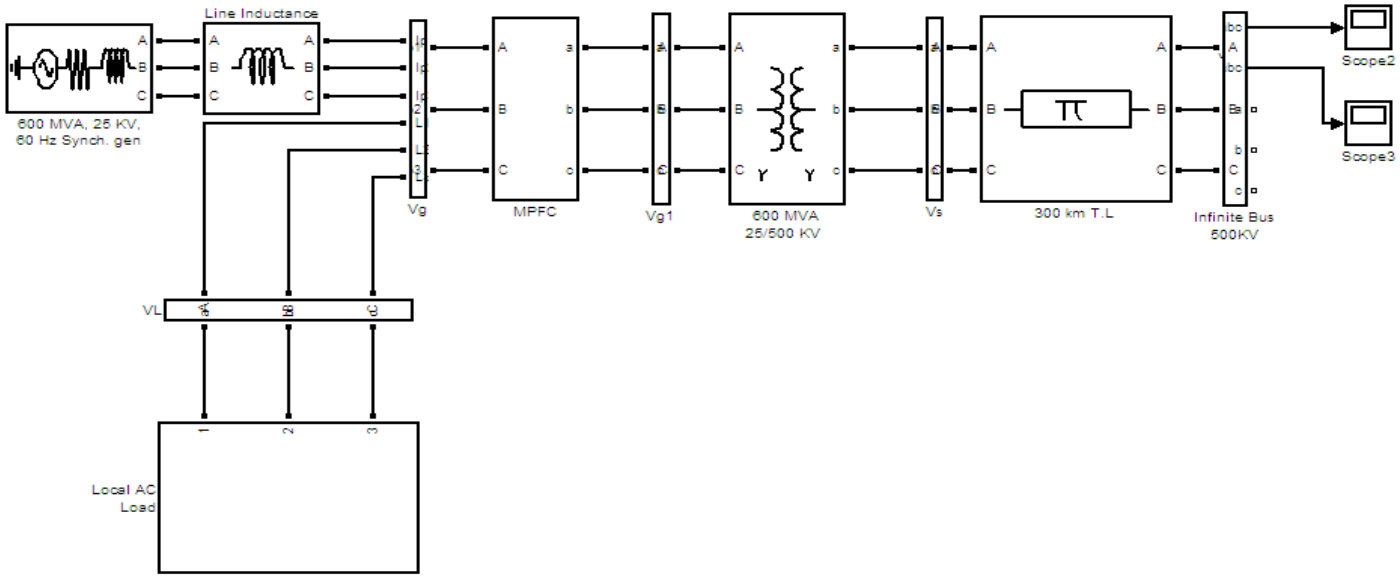


Figure: Single Line Diagram of AC Study System.

The sample study AC grid network is shown in Fig. It comprises a synchronous generator (driven by steam turbine) delivers the power to a local hybrid load (linear, non-linear and induction motor load) and is connected to an infinite bus through 300 km transmission line.

III. METHODOLOGY

1. MODULATED POWER FILTER COMPENSATOR (MPFC)

MPFC controller is used to provide voltage stabilization against varying load. In order to improve the power quality problem in distribution system that is merged with distributed generation, a switched modulated power filter compensator driven by a tri-loop error controller is used.

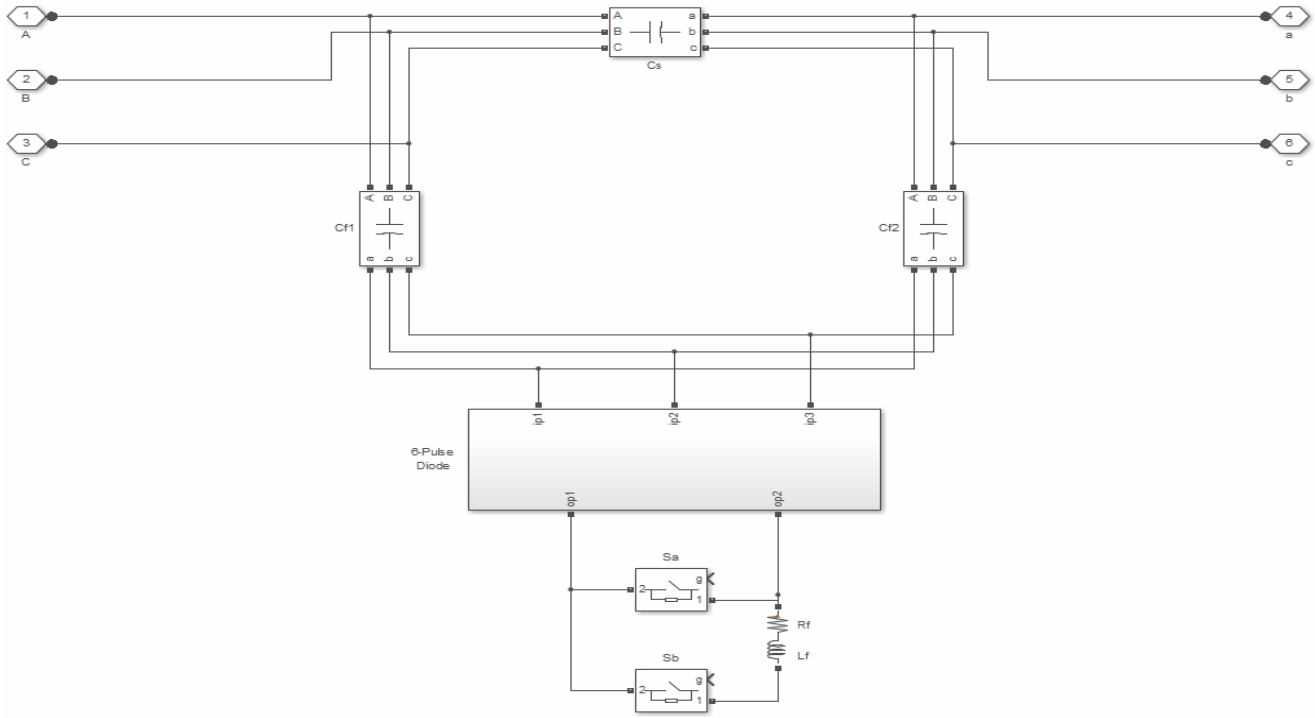


Figure: Modulated Power Filter Compensator

MPFC controller consists of the following elements:

- A filter capacitor bank
- A filter inductance

- A filter resistor
- A six pulse diode rectifier and
- Two switches

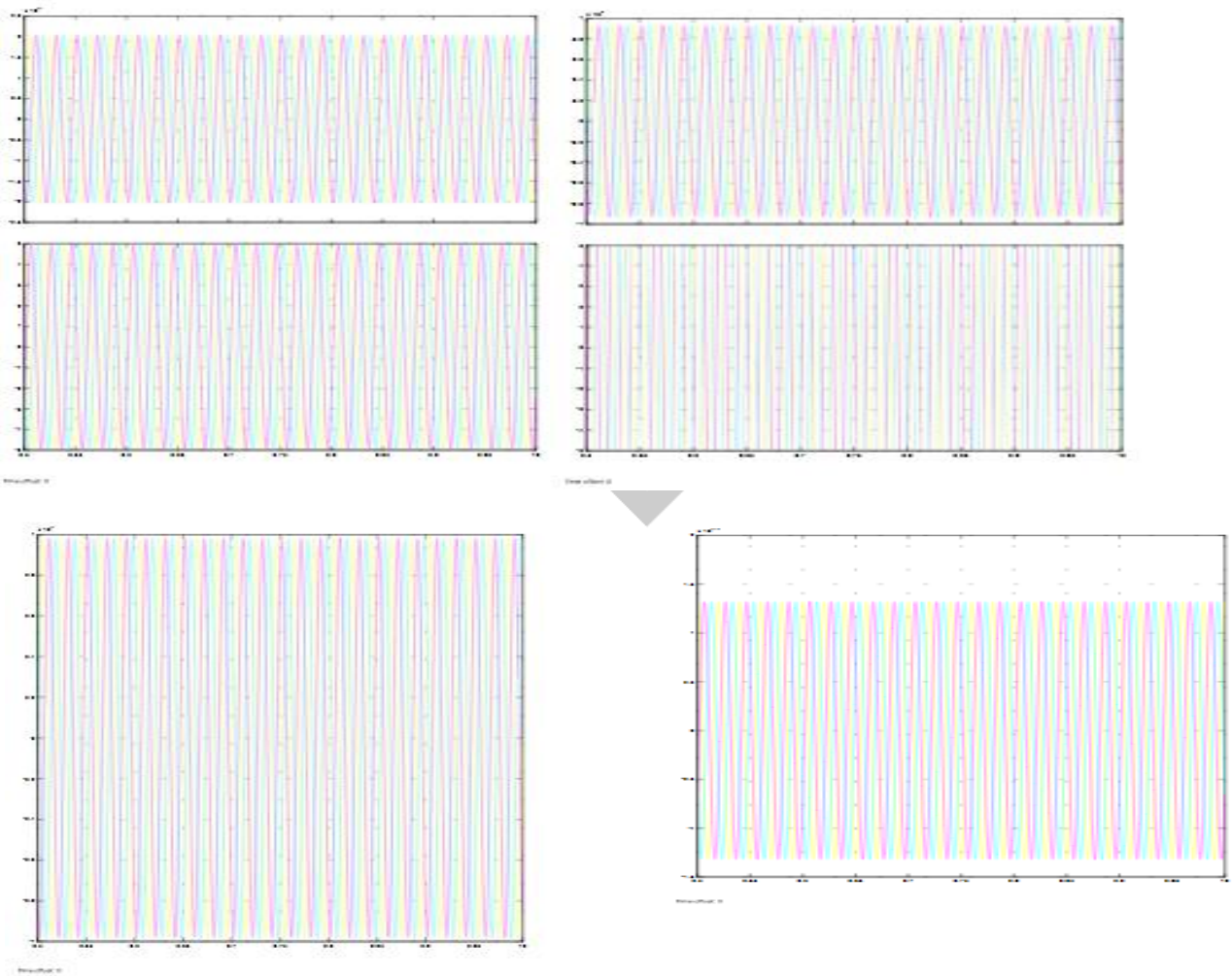
The low cost MPFC scheme is effective in voltage stabilization for both linear and non-linear electric load excursions.
Two IGBT/MOSFET switches (s1 and s2) are controlled by two complementary signals with switch s1 is opened and switch s2 is closed, the resistor and inductor will be part of the circuit and the capacitor forms a low-pass filter with the inductor via the diode bridge. If switch s1 is closed position and switch s2 is open position, the resistor and inductor will bypass and the capacitor bank will form a capacitive admittance and gives reactive power to the ac utility grid. In order to control the IGBT switches, a novel tri-loop dynamic error-driven PID controller is being employed.

2. TRI LOOP ERROR DRIVEN MODIFIED PID CONTROLLER

The tri loop dynamic error driven PID controller is used to generate the required sequence of pulses for a PWM switching device and stabilize the voltage at the load bus by regulating pulse width switching pattern of two complementary switched GTO devices as shown in fig .The tri-loop error-driven controller is a novel dual action control used to modulate the power filter compensator. The global error signal is an input to the controller to regulate the modulating control signal to the PWM switching block. This controller comprises three basic regulating loops for RMS load voltage, dynamic load current and minimum current-ripple loops. These three weighted and dynamically acting loops play an important role in effective dynamic voltage stabilization and reactive power compensation. The scaling and time delay selection of these key loops is done using an offline guided trial and error method to ensure fast response and minimize the trial error.
Loop 1: Themain loop for the dynamic voltage error using the RMS voltage at the load bus. This loop is to maintain the voltage at the load bus at a reference value by modulating the admittance of the compensator.
Loop 2: The RMS dynamic load current is used in this loop as an auxiliary signal to compensator for any sudden electrical load excursions.
Loop 3: The third current-ripple loop is added to minimize the total harmonic ripple content in the load current.

IV. SIMULATION RESULTS

Results with MPFC



V. CONCLUSION

This paper has presented a FACTS based modulated power filter compensator (MPFC) scheme for effective power quality improvement, voltage stabilization, reduction of losses and power factor enhancement distribution grid networks with the dispersed renewable energy interface**.** The MPFC is controlled by a dynamic tri-loop dynamic error driven modified PID controller. The compensation characteristic of each topology with the respective control scheme is proved by simulation.

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