A Model Predictive Controller Based Performance Analysis of a Three Phase Shunt Active Power Filter

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Abstract - A race is as of now occurring between expanding PE contamination and sensitivity, from one perspective, and the new PE-based restorative devices, which can lessen the issues made by PE, then again increment in such non-linearity causes diverse undesirable components like low system productivity and poor power factor. The impact of such non-linearity may wind up plainly sizeable throughout the following couple of years. Consequently it is essential to defeat these unwanted highlights. To acquire effective active filter performance, it is vital to pick both a legitimate current reference and a adequate current control strategy. Active power filters are currently observed as a reasonable option over the established passive filters, to compensate harmonics and reactive power necessity of the non-linear loads. The advancement in the innovation of power electronic devices also impelled active power filter. The fundamental concept is that using power electronic devices dismiss out the harmonic currents from nonlinear loads. To achieve desired filtering and harmonic compensation a model predictive controller based three phase shunt low and high pass active power filter has been proposed in this work.

Keywords - Model Predictive Control (MPC),Active power filter (APF), Shunt active power filter (SAPF), Harmonics, Distortion, Power quality control.

I. INTRODUCTION

The increased usage of power electronic devices in power system including renewable power generations led to a number of power quality (PQ) problems for the operation of machines, transformers, capacitors in power systems. PQ covers all aspects of power system engineering from transmission and distribution level analyses to end-user problems. Therefore, electric power quality has become a serious concern for both utilities and end users.

The PQ, at distribution level, broadly refers to maintaining a near sinusoidal power distribution bus voltage at a rated magnitude and frequency. In addition, the energy supplied to a customer must be uninterrupted. Therefore, the term PQ includes two aspects, namely voltage quality and supply reliability [1]. The voltage quality side comprises various disturbances, such as rapid changes, harmonics, interharmonics, flicker, imbalance and transients, whereas the reliability side involves phenomena with a longer duration, such as interruptions, voltage dips and sags, over and under voltages and frequency deviations. The above issues are significant in depicting the actual phenomena that may cause PQ problem. One of the major issues namely harmonic distortions is not a new phenomenon in power system. It was discovered as early as the 1920s and 30s [2]. At that time, the major sources of harmonics were the transformers and the main problem was inductive interference telephone systems. Harmonics are qualitatively defined as sinusoidal waveforms having frequencies that are integer multiples of the power line frequency. In power system engineering, the term harmonics is extensively used to define the distortion for voltage or current waveforms. Primarily, the power electronic converters inject nonsinusoidal (i.e., harmonic) currents into the AC utility grid and the harmonics injected into the power system cause line voltage distortions at the Point of Common Coupling (PCC) where the linear and nonlinear loads are connected, as displayed in Fig. 1.1. As a consequence, harmonic distortion can have detrimental influences on electrical distribution systems. Identifying the problems associated with sources and impacts of harmonics as well as the methods to decrease the harmonic will increase the overall efficiency of the distribution system.

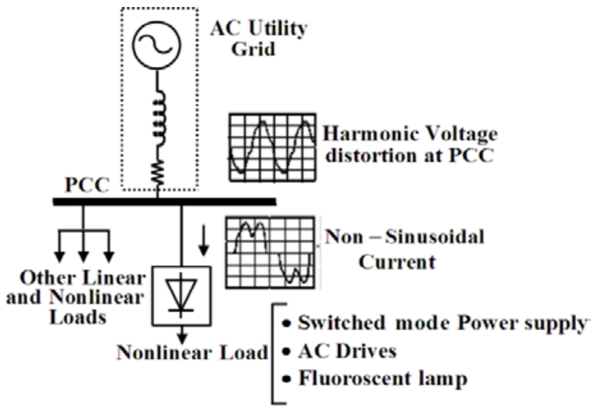

Figure 1.1 Harmonics distortion at PCC.

Harmonics is a great problem in power systems that has become serious recently owing to the wide utilization of force hardware-related supplies. Besides, the information force component of the vast majority of this supplies is poor. Conventionally, a passive power filter and capacitor were used to attenuate the harmonics and improve the input power factor. Static VAR compensators are introduced with many configurations to come out of the situations of power factor correction. But some SVC configurations have very long response time that they are not acceptable for fast fluctuating loads and also lower order harmonics are generated by themselves. Many harmonics-suppression methods based on the technique of power electronics have been developed to solve harmonics problems. One of them is the active power filter.

Nonlinear loads such as rectifiers in televisions, ovens, and commercial lighting can lead to significant unbalance currents, reactive currents and harmonic currents in the power system. These nonlinear currents will cause more heating, false tripping and resonance. The level of distortion in a waveform is related to the amplitudes of harmonic components in the waveform compared with its fundamental component; it is measured by Total Harmonic Distortion (THD) [1]. For non-sinusoidal waveforms, THD is the ratio of the sum of the RMS value of the harmonics to the RMS value of the fundamental.

harmonics compensation it is called Active Power Filter (APF) [2, 7, 8]. In some literature, an APF can provide both PFC and harmonics reduction. Fig. 1.2 shows a typical configuration of a STATCOM or APF which is shunt connected across the utility and load. A digital control generates appropriate PWM gating signals for the VSC so that it injects the required current to the line and compensates reactive power or harmonic currents. A STATCOM or APF can be a two-wire single-phase, three-wire three-phase, or four-wire three- phase configuration. The four wire VSC is used for compensating imbalanced loads. Furthermore, an APF can be shunt connected as in the example or series connected between the source and load.

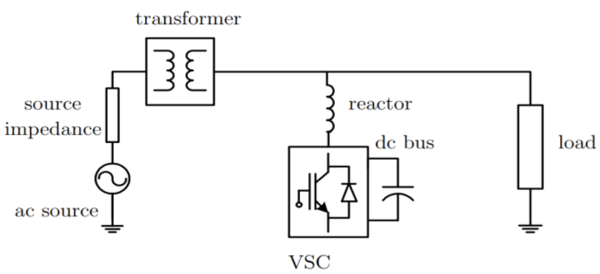

Figure 1.2 A shunt connected VSC system for APF applications.

II. SYSTEM MODEL

It is a form of control algorithm in which the current control action is obtained by solving a finite horizon of open loop optimal control problem using the current state of the plant as the initial state. This process is repeatedly done for each sampling point. The optimization yields an optimal control sequence and the first control in this sequence is applied to the plant.

These models compensate for the effect of nonlinearities present in the variables and the chasm caused by non coherent process devolution. Hence the models are used to predict the behavior of dependent variables or outputs of the modeled dynamical system with respect to changes in the process independent variables or inputs.

The main motive of Model Predictive Control is to find the input signal that best corresponds to some criterion which predicts how the system will behave applying this signal. The problem is converted into a mathematical model at a given state. The feedback strategy is derived solving this problem at each sampling time and using only the current control horizon. This is called the Receding horizon technique.

Model Predictive Control method consists of three main components. Those are namely:

- The process model
- The cost function
- The optimizer

The process model includes the information about the controlled process and it is used to predict the response of the process values according to manipulated control variables.

There after minimization of cost function ensures that the error is reduced. In the last step different optimization techniques are applied and the output gives the input sequence for the next prediction horizon.

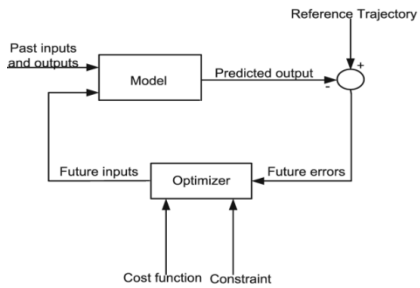

Figure 2.1 The basic structure of model predictive control.

III. PROPOSED METHODOLOGY

A model predictive control-based control for a three-phase shunt low & high pass active power filter has been proposed in this work to compensate effects of harmonics in system. Fig. 3.1 shows the simulink model of the system, which consists suppy grid, transmission line unbalanced load and parallel connection with the control section with predictive control section. A model of predictive control has been shown in figure 3.2. the model has been segmented in three sections hysteresis, PI controller and model predictive controller.

MPC depends on the way that only a limited number of conceivable switching states can be created by VSI and that models of the system can be utilized to predict the behaviour of the vectors for each switching state. For the determination of the proper switching state to be connected, a selection rule must be characterized. This selection paradigm is represented as a quality capacity that will be assessed for the anticipated estimations of the variables to be controlled. The switching state that limits the quality function is chosen. A block representation of the MPC connected to the present control for a three phase inverter is appeared in Fig. 3.2.

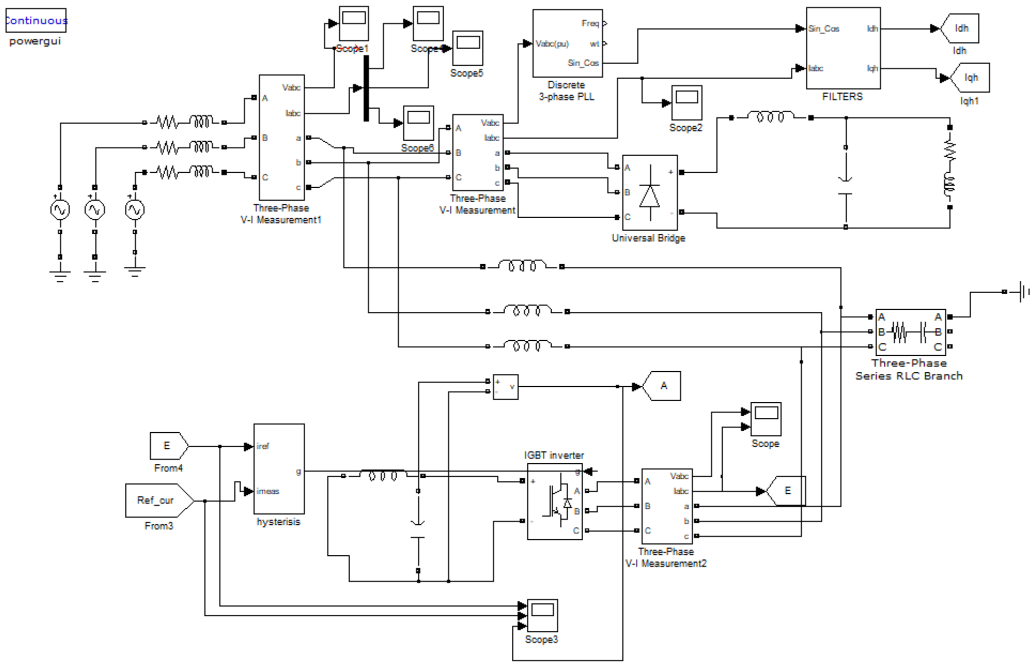

Fig. 3.1 Simulink Model of Proposed Model

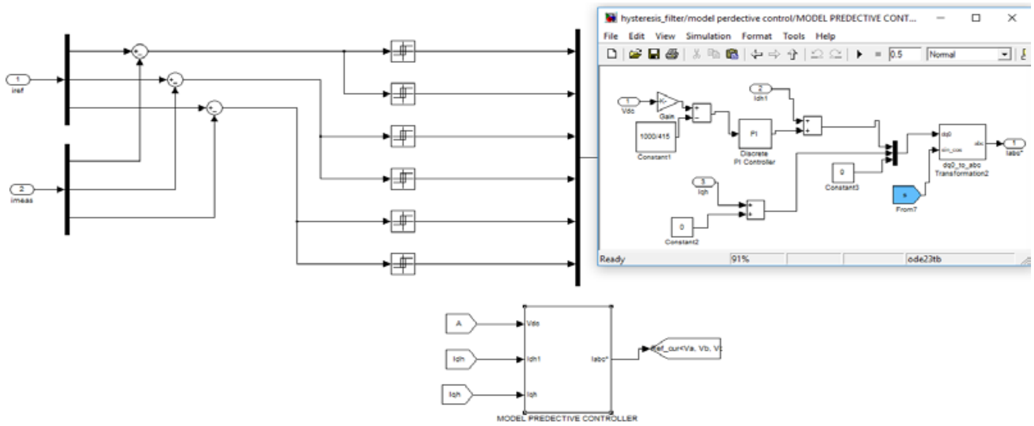

Fig. 3.2 Model Predictive Control of Proposed System.

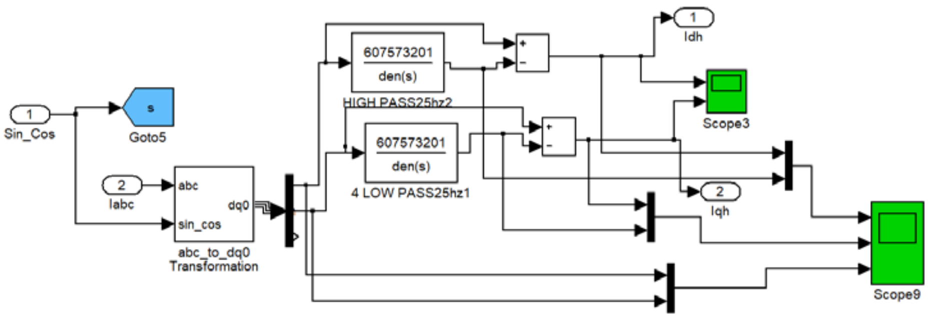

Fig. 3.3 Combination of Low & High Pass Filter of Proposed System.

The combination of low & high pass filter of proposed system shown in figure 3.3 can be controlled to compensate the ac line current harmonics introduced by non-linear load. The SAPF consists of a VSI, whose dc side is connected to a capacitor bank C, whereas its ac side is connected to the mains through series impedance and the schematic of VSI power circuit. The proposed scheme exploits the estimation of essential part of distorted PCC voltage alongside the estimation of distortion in current with all grids considered.

IV. SIMULATION RESULTS

The steady state response of proposed MPC based Low & High Pass Filter system is depicted using MATLAB Ra2009. From the Fig. 4.7, figure 4.6, and figure 4.5. it is observed that the response of compensating current is quite effective than existing work. figure 4.7 shows the waveform of filter control signals u_a, u_b, corresponding sliding surfaces s_a, s_b and s_{ab}, s_{ba} top to bottom of proposed system. figure 4.6 shows the grid currents and load currents and output DC voltage of proposed system. Figure 4.5 shows the grid voltage and grid current of proposed system. The total harmonic distortion THD in proposed system has given in figure 4.4 and figure 4.5.

The evaluated THD of proposed system before compensation is recorded 24% demonstrated in figure 4.4. The total harmonic distortion THD of proposed system after compensation is recorded 1% which is less enough demonstrated n figure 4.5.

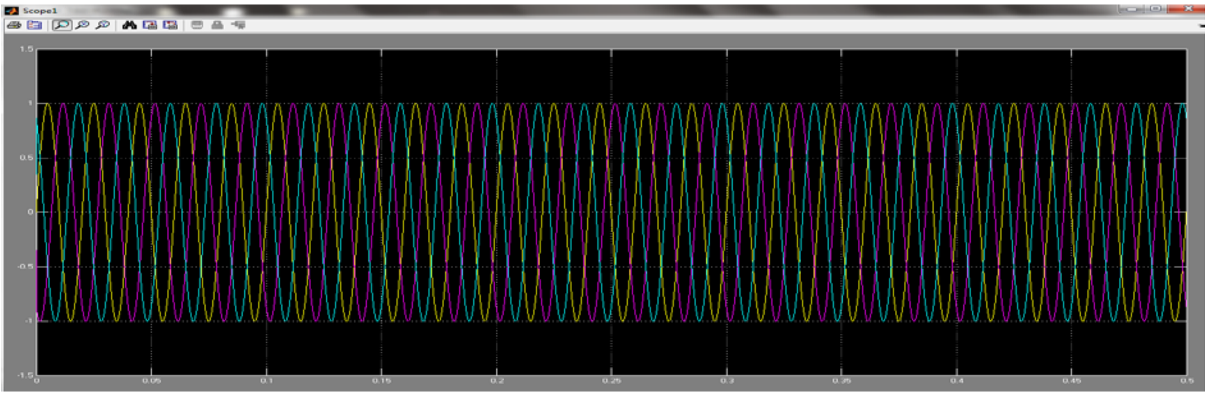

Fig. 4.1 Three Phase Source Voltage

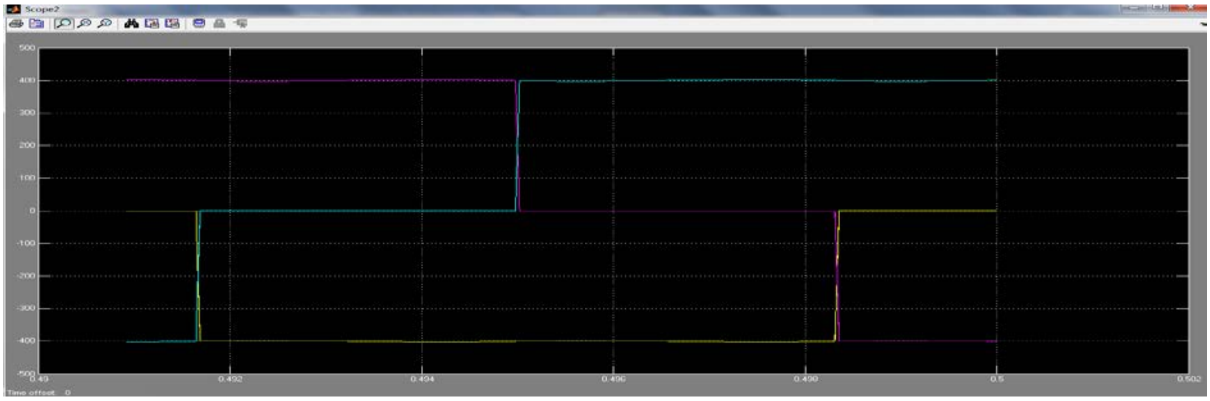

Fig. 4.2 Three Phase Load Current Short Period Waveform

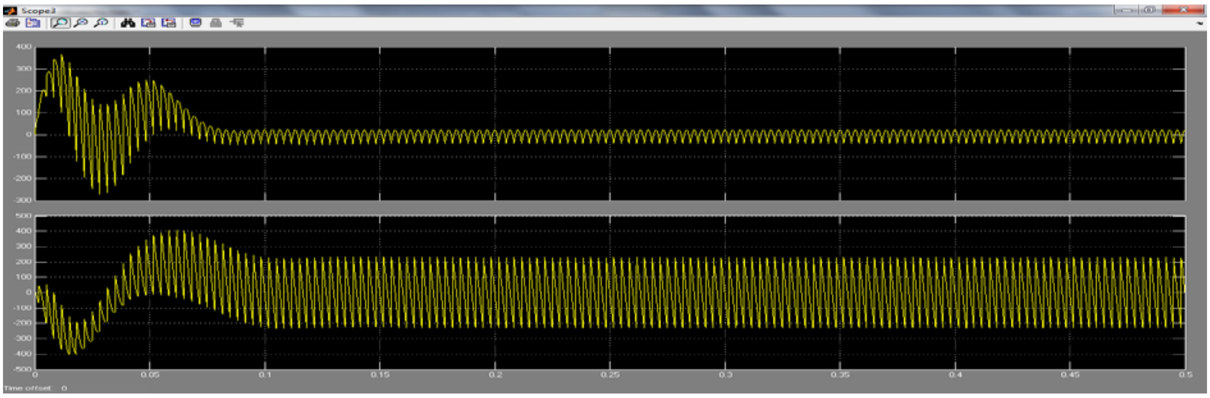

Fig. 4.3 High Pass and Low Pass Filter output(top to bottom)

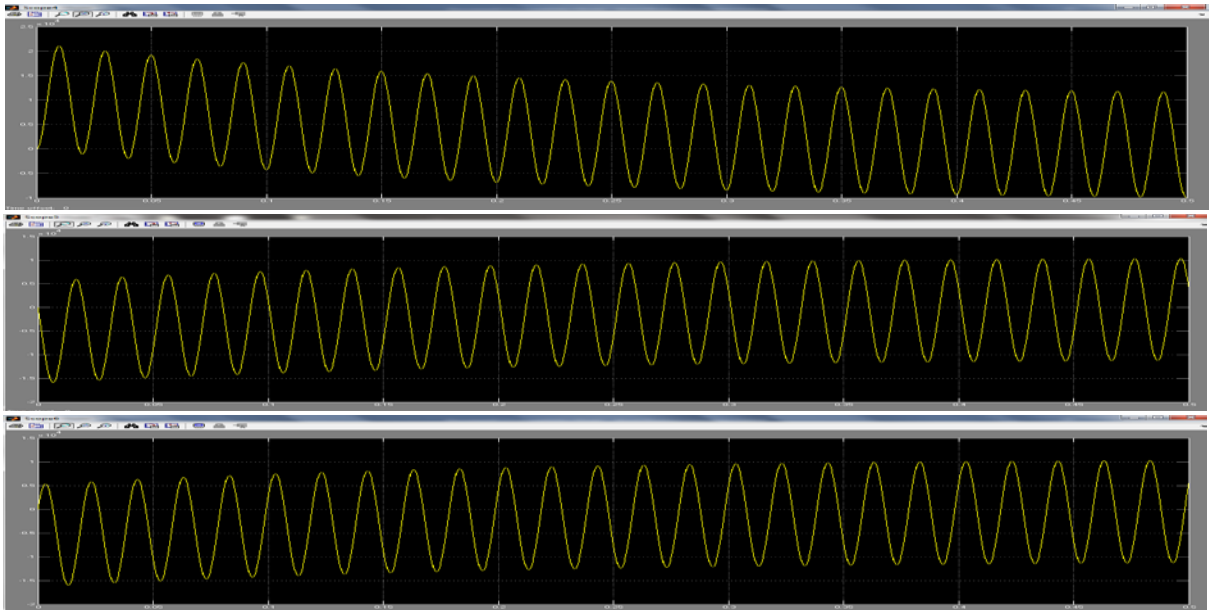

Fig. 4.4 Source Current Phase A, B and C Respectively

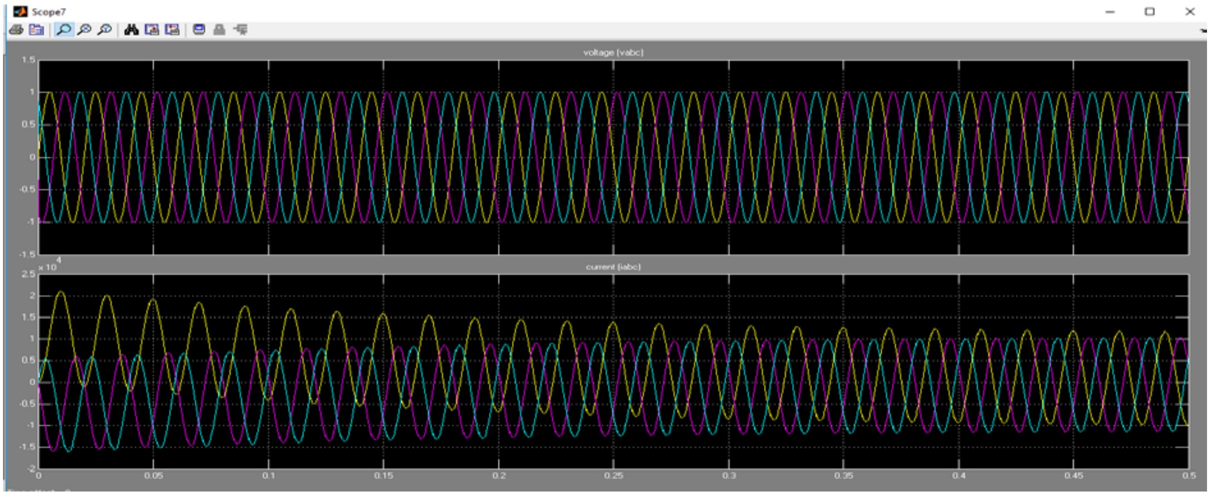

Fig. 4.5 Grid Voltage and Grid Current of Proposed System.

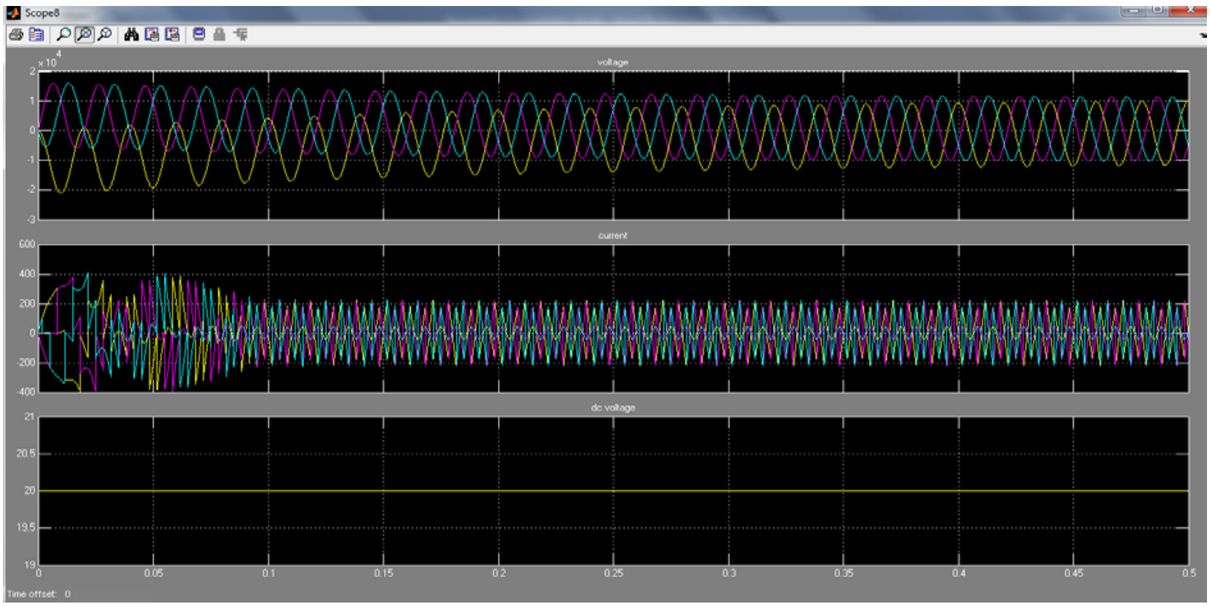

Fig. 4.6 Grid Currents and Control Currents and Output DC Voltage of Proposed System.

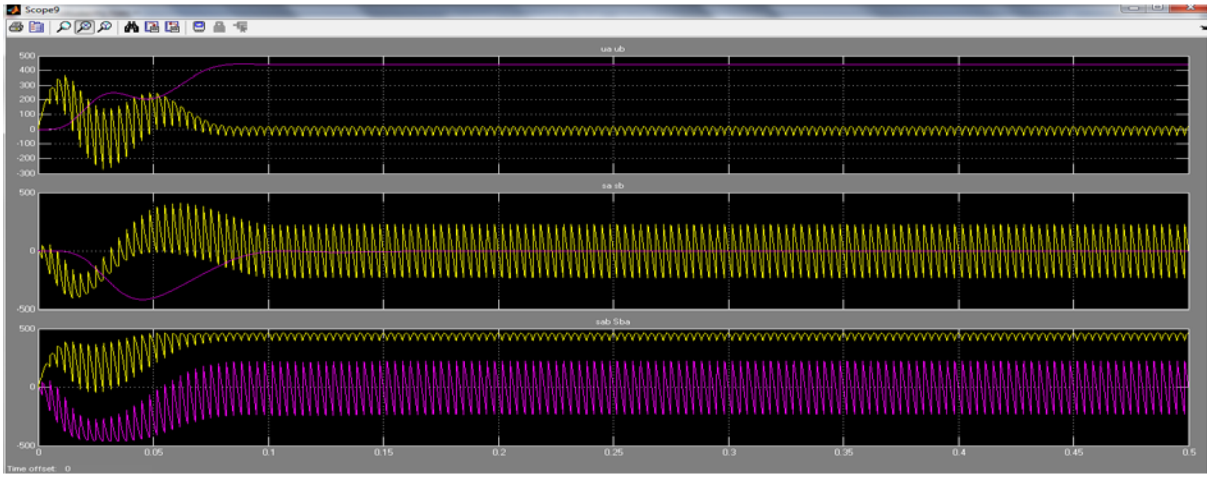

Fig. 4.7 From top to bottom Filter Control Signals u_a, u_b, corresponding sliding surfaces s_a, s_b and s_{ab}, s_{ba} of Proposed System.

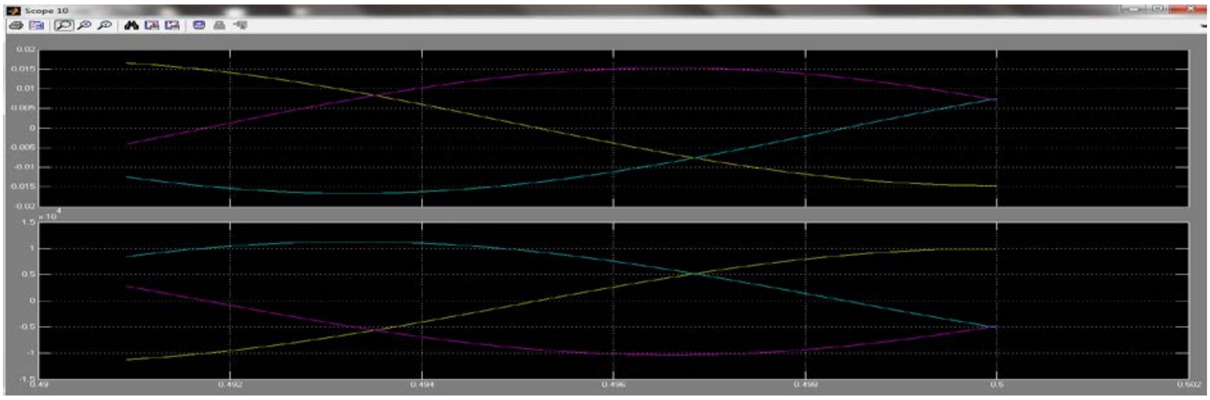

Fig. 4.8 Controlling Voltage and Current Waveforms

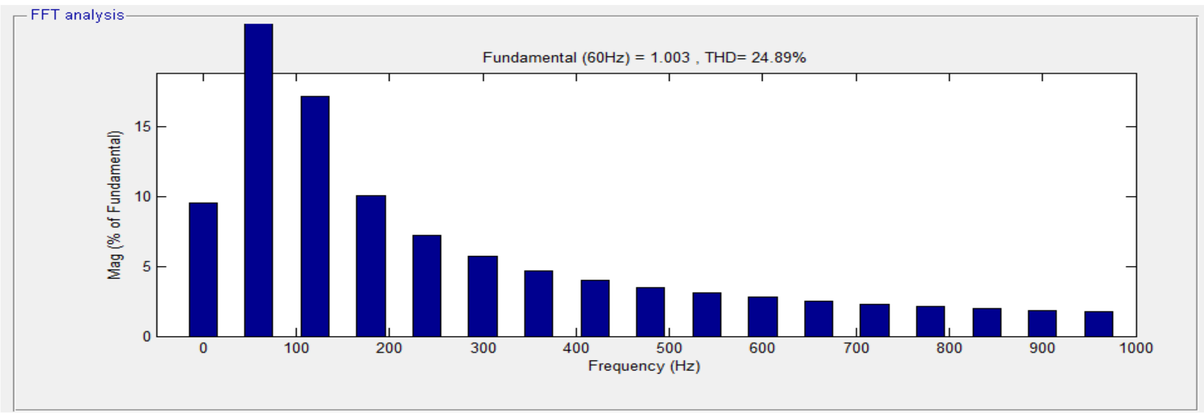

Fig. 4.4 THD of Proposed System Before Compensation is 24%

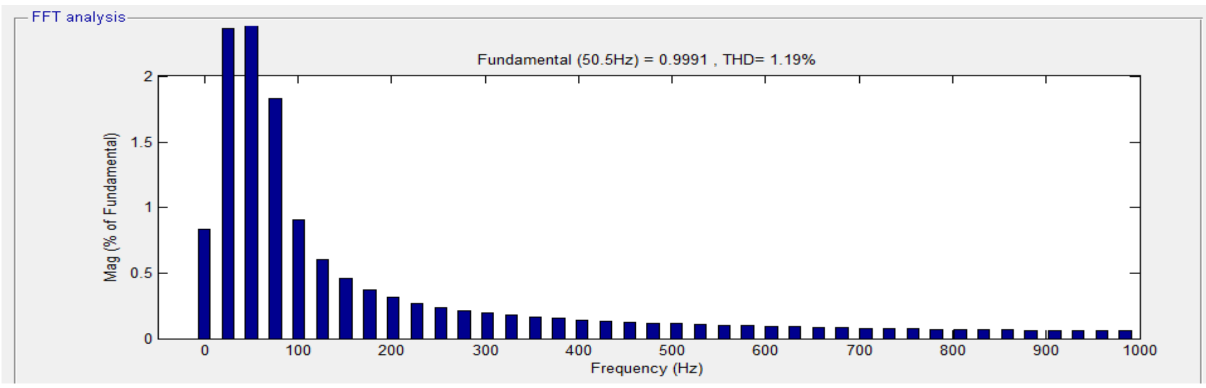

Fig. 4.5 THD of Proposed System After Compensation is 1%

V. CONCLUSION AND FUTURE SCOPES

In this work a model predictive control-based control for a three-phase shunt low & high pass active power filter has been implemented and simulated on Matlab Ra2009. A vital perception is that industrial MPC controllers quite often utilize observational dynamic models recognized from test data. The impact of identification theory on process modelling is perhaps comparable to the impact of optimal control theory on model predictive control. It is probably safe to say that MPC practice is one of the largest application areas of system identification. The simulation result of proposed system has shown the elimination of total harmonic distortion from power supply. It is observed from waveform the total harmonic distortion before the compensation and after compensation the evaluated harmonic after compensation is very small about to 1%. In future Efforts towards integrating identification and control design may bring significant benefits to industrial practice. For example, uncertainty estimates from process identification could be used more directly in robust control design. Cutting edge MPC innovation is probably going to incorporate numerous function goals, an unbounded expectation skyline, nonlinear process models, better utilization of model vulnerability gauges, and better treatment of ill- conditioning.

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