



A Presage Mathematical Framework to Leverage Power Quality in Power Electronics

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ABSTRACT

With the increasing attention towards conserving power, the existing trends towards distributive power generation system are much focused on investigating on renewable resources. One of the prime advantages of adoption of renewable resources is minimized cost of operation owing to reduced maintains as compared to the conventional power generators. Hence, the area of power electronics is also found to be inclined towards adoption of various forms of renewable resources. However, with the existing of non-linearity of the existing loads owing to the usage of modern electronic devices that runs of renewable resources, it generates potential amounts of harmonics, which should be control by using power filters. Hence, this paper introduces a technique for predictive control scheme using 4 leg voltage inverter for the addressing the problem of harmonic suppression. The core contribution of the paper is to presents a mathematical model and evaluates the presented scheme under various control state as well as operating situation.

Keywords

Active Power Filter, Power Quality, Power Electronic, harmonic Suppression.

1. INTRODUCTION

The futuristic energy distribution grid will be composed of heterogeneous renewable power generation system such as solar power generation plants, wind power generation plants etc. There is huge non-uniformity and nonlinearity in availability of these resources as well as production efficiency, thus the system becomes highly non-uniform and dynamic which severely affect the power quality [1]. At present, the electric utilities and end users of power demands more electrical energy. Almost all global energy is supplied by burning of fuels. At the same time, increases air pollution, diminishing fossil fuels and their increasing cost look towards renewable sources for future energy solutions. From the last decade year, there is an interest in many countries on renewable energy sources for power generation. This concept is very interesting, when various types of energy resources are available namely, fuel cells, wind turbines and photovoltaic panels. The voltage regulation and distortion in power system is directly related to the nature of power generation. This scheme of power distribution systems have to be dealt with more advanced compensation methods. In power system architecture, the non-linear load current harmonics results in voltage harmonics create serious problems. To overcome these load current harmonics Active power Filter (APF) are used at distribution level. These cause extra hardware cost. In

addition with it includes the feature of APF and the main idea is maximum usage of inverter, which is many times underutilize due to intermittent nature of renewable energy sources. Owing to extensive usage of modern electronic devices like computers, printers, Uninterrupted Power Supply (UPS), the generation of non-linear loads has significantly increased. This problem may pose significant challenges in future which should rely on renewable energies. Renewable energy sources are connected to distribution architecture to utilize more power electronic converters. So, a novel method is used to achieve more benefits from grid-interfacing inverters, by using 3-phase 4-leg systems. Three-phase four-Leg Voltage Source Inverter (4L-VSI) of Active Power Filter implementation is provided in the technical literature [2]-[6]. The paper has discussed a predictive control algorithm and testing particularly for this application. Conventional active power filters are controlled using controllers like PI- type or adaptive in nature. In comparison to conventional method [7], it is expected that adoption of renewable resources will have advantage of effectiveness in harmonic reduction, shorter response time and control online. Output of the conventional PI controller can be controlled by providing load feedback value to a control system [9]. Predictive control algorithm can improve the performance of active power filter especially by obtaining a precise model during transient operation as it quickly follows the current-reference signal constant DC-voltage is maintained. Predictive control implemented in power converters is advantageous because of its applicability to discrete system and fast response. The paper is arranged as follows: Section II describes the some of the significant existing work, while Section III describes the problem identification for current controlled grid-interfacing inverter. Section IV discusses about the proposed method for converter model. Section V illustrates the research methodology by explaining the concepts of predictive current control technique with mathematical representation. Section VI describes the concepts of current reference generation models using DQ transformation technique. A digital simulation study is presented in Section VII. Finally, concluding remarks are discussed in Section VII.

2. RELATED WORK

Zeng et al. [8] implemented a multi-port DC-DC converter for continuous power management for multiple renewable energy sources. It can be different types and capacities and it uses minimum controllable switch. It is applied for continuous Maximum Power Point Tracking (MPPT) control of wind and solar hydride systems. The obtained results to validate the effective using of proposed converter to achieve efficient



point of MPPT. Dai et al. [9] have explained the Pulse Width (PW) modulator that can be control by 3-leg central-split voltage source inverters (VSIs) and 4-leg VSIs from 2-level to multiple level topologies. FPGA is used to develop the PW modulator, because its fast prototyping, simple hardware and software design. It can also apply to active power filter to show its validity. To deal with nonlinear loads/unbalanced loads in high power system, the author Kim et al. [10] suggests a different level 4-leg pulse width modulation (PWM) Voltage-Source Inverter (VSI) as techniques for high power applications. The proposed method was based on DSP and tested using 3-level 4-leg VSI and it was verified by spectral analysis, simulation and experimental results. Ozdemir et al. [11] have studied the balanced / unbalanced and linear / non-linear current control in 3-phase 4-leg VSI and carried out using advanced p-q-r techniques, digital proportional integral derivative (PID) control rule and three-dimensional (3D) space vector pulse width modulation. Here, 3-phase 4-leg and PWM are designed separately. The study shows that even though voltage is not symmetrical, the presented algorithm leads to measuring and to generate the harmonic and reactive components of load current. Authors have also demonstrated both by means of simulation and real-time applications. Zhang et al. [12] have presented a scheme to reduce common mode noise in 3-phase 4-leg VSI. This system is based on classical 3-D SVM (Support Vector Machine) and found to produce greater DC-link, reduced harmonic content and low switching loss compare to sinusoidal PWM. Theory, simulation and results gives the details about near-state three-dimensional space-vector modulation switching scheme works under different balanced load conditions. Kim et al. [13] proposed a carried based PWM method for different level-leg PWM VSI with novel offset voltage. This offset voltage is used for switching sequence of all the legs for optimizing the harmonic distortion of output voltages. This method is implemented and tested using 3-level 4-leg VSI and it is verified by spectral analysis, simulation with experimental results.

To achieve more benefits from grid-interfacing inverters using 3-phase 4-wire distribution systems are explained by the Singh et al. [14]. Here authors have demonstrated and simulated using Matlab / Simulink and it is validated through DSP processor based results. The study has also used various ACF function to perform and evaluate many functional devices. Chau et al. [15] have presented a novel algorithm to control technique with time delay for Hybrid Active Power Filter (HAPF) injection circuits. Here a π -Smith predictive compensator is designed to current time delay and makes a 180o delay in between output current and load harmonic current. This method is compared with conventional PI control techniques and analysed, and it shows shorter time response with reducing harmonics. Mortazavi et al. [16] have presented a new control method to improve dynamic behaviour of shunt active power filter under different loads. This method is tested and compared for large range of different load current and found to be satisfactory to mitigate harmonics for non linear loads. A detailed consolidated survey work findings has been presented in our publication where different suppression techniques were discussed for enhancing the power quality [17].

3. PROBLEM IDENTIFICATION

Adoption of Active Power Filter in the area of renewable resources in power electronic is the less researched topic. Generally, usage of such filters calls for design of predictive

control scheme. However, till date all the schemes that have been introduced in the literature have significant pitfalls pertaining to frequency in terms of oscillation as well as unsteadiness factor generated from the load of uncertain attributes. Such situation leads to generation of load current harmonics and unfortunately, such schemes results in significant loss of power quality. Generally, the source of the renewable power is connected at the level of distribution in power generation process and such architecture of distributive power generation will call for various technical issues associated with regulation of voltage, issues related to stability, and degraded quality of power. Hence, it is required that power generation system using renewable resources are required to adhere to standard framework of regulation for efficient distribution of power. Although with the modernization of harmonic suppression scheme to enhance power quality, there are various issues related to it. Majority of the schemes introduced till date is inclined towards PQ theory, where the inverter is found to be operating as the active actor on a specific oscillation for the purpose of absorbing the unwanted harmonic current. However, the appropriate estimation of the inductance factor over the network is quite challenging and possibly leads to degrade the performance of the power electronic devices. Hence, the problem identifications of the proposed study are as follows:

- Degradation of quality of current for designing an effective power generation system using renewable resources.
- Existence of unbalanced current in the electronic devices for renewable sources leading to generation of harmonics.
- Difficulty in analyzing the compensation techniques for harmonic current using renewable resources.

Active power filter are more flexible and very fast control response compare to conventional control methods. Active Power Filters (APF) is extensively used to compensate the current harmonics and load Unbalance. Shunt Active Power Filter (SAPF) that is capable of simultaneously compensating problems like current unbalance, current harmonics and also of injecting the energy generated by renewable energy source. Hence, the proposed scheme has identified the problems clearly and introduces a mechanism to enhancing the quality of the power using active power filter. The proposed system will take a case study of renewable energy sources to evaluate the issues of harmonic suppression.

4. PROPOSED SYSTEM

In this section architecture of a schematic power distribution system with Hybrid of (ac-ac and dc-ac) power generation system with an active shunt power filter is discussed in Fig.1. It contains different power generation units like, type-1, type-2 (are called nature power generation stations like, wind, river, sunlight), etc., along with variable types of load impedances. Renewable sources like sunlight, wind, ocean etc. are generally used to generate electricity for different applications such as residence, small industries, schools and computer tuitions etc. A hybrid power generation uses AC-AC and DC-DC static pulse width modulation conversion for voltage conversion and more energy storage battery banks. To acquire, maximum energy from wind and sunlight, etc., the converters like type-1 and type-2 are used. The behavior of electrical energy is random and not predictable, so it may be non-linear, unbalance and 3-phase. An active power filter is

used shunt in common coupling to maintain current harmonics unbalance current and reactive power and it consists of an electrolytic capacitor, Proposed PWM converter and 1st order

ripple filter output shown in Fig.2. The nomenclature of the variables used in the study of proposed system is tabulated in Table 1.

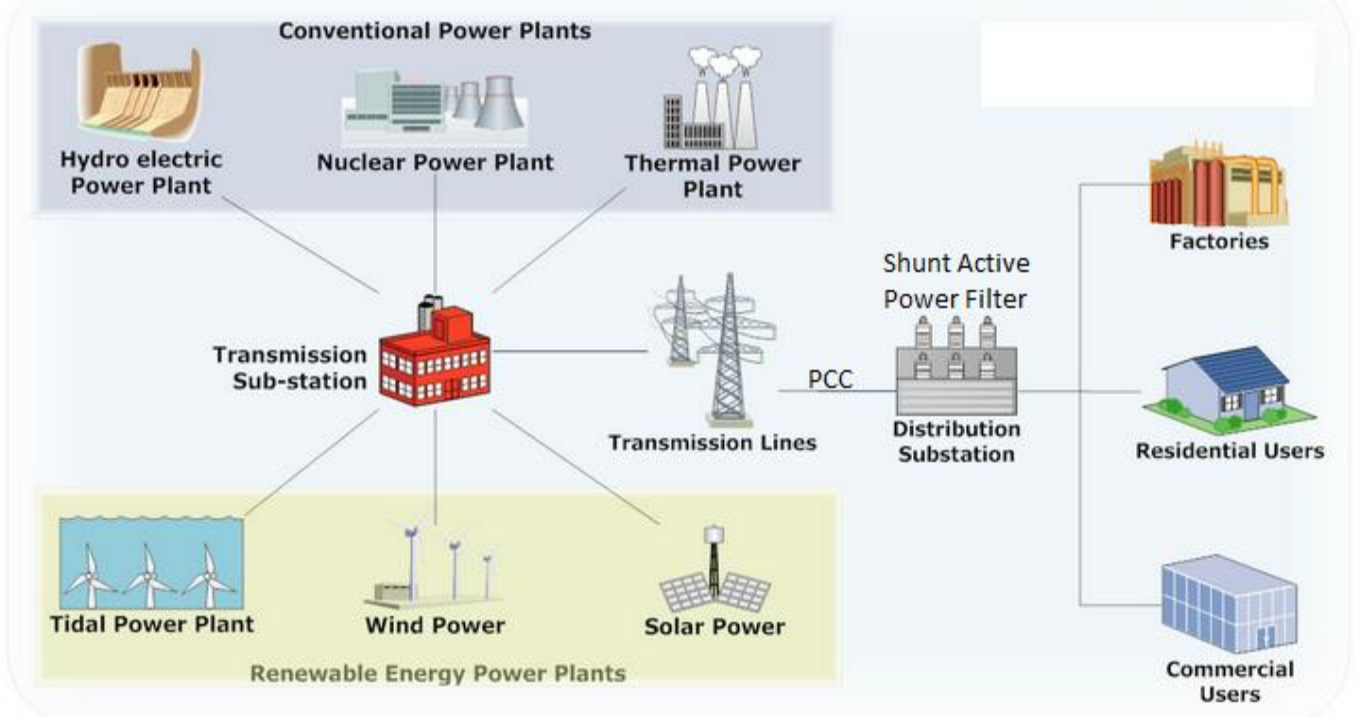


Fig 1: Schema of Renewable Power Generation

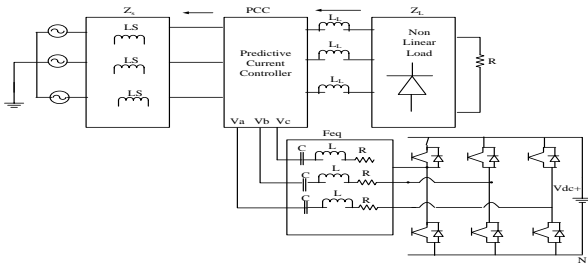


Fig 2: Proposed 3-phase shunt active power filter

This scheme consists of the power system equivalent impedance Z_{Seq} , the ripple filter impedance Z_{filter} and load impedance Z_{load} . A 2-level 4-leg PWM-VSI topology is shown in Fig.2. This topology converts the traditional 3-phase converter with fourth leg added to neutral bus of the system. It will increase the switching state from 8 to 16 and it improves control quality of the output voltage along with flexibility of control. The expression of switching state is given as,

$$V_{uN} = X_u - X_N V_{DC}, u = i, j, k, N \quad (1)$$

Where x indicates the voltage leg, n is the neutral point and the mathematical modeling of filter is obtained from an equivalent circuit shown in figure. 2 and it results,

$$V_{Ovv} = V_{uN} - R_{eq} I_{Ocv} - L_{eq} \frac{d(I_{Ocv})}{dt} \quad (2)$$

Where R_{eq} and L_{eq} are output parameters and these are expressed by using Thevenins impedance (Z_{eq}). So it is obtained by multiplying of Z_{Seq} and Z_{load} to the addition of Z_{Seq} and Z_{load} . Then the overall added with Z_{filter} it gives final Z_{eq} .

Therefore, mathematical representation of stabilized impedance can be given as,

$$Z_{eq} = \frac{Z_{Seq} Z_{load}}{Z_{Seq} + Z_{load}} + Z_{filter} \approx Z_{Seq} + Z_{filter} \quad (3)$$

In this model, it consider that $Z_{load} \gg Z_{Seq}$, i.e., the resistive part of the equivalent impedance neglected, and the reactance is in between the range 3-7% power unit it is acceptable to the real system. Finally in eq (2), $R_{eq} = R_{filter}$ and

$$L_{eq} = L_{sys} + L_{filter}$$

Table 1: Nomenclature

| | |
|-----------|--|
| ac | Alternating Current |
| DC | Direct Current |
| PWM | Pulse Width Modulation |
| PCC | Predictive Current Control |
| PLL | Phase Locked Loop |
| V_{DC} | DC Voltage |
| V_{Svv} | System Voltage Vector $[V_{Si}, V_{Sj}, V_{Sk}]^T$ |
| I_{Scv} | System Current Vector $[I_{Si}, I_{Sj}, I_{Sk}]^T$ |
| I_{Lcv} | Load Current Vector $[I_{Li}, I_{Lj}, I_{Lk}]^T$ |
| V_{Ovv} | VSI Output Voltage Vector $[V_{Oj}, V_{Oj}, V_{Ok}]^T$ |

| | |
|--------------|---|
| I_{Ocv} | VSI Output Current Vector $[I_{O_i}, I_{O_j}, I_{O_k}]^T$ |
| I_{Orcv}^* | Reference Current Vector $[I_{O_{ri}}^*, I_{O_{rj}}^*, I_{O_{rk}}^*]^T$ |
| I_N | Neutral Current |
| L_{filter} | Filter Inductance |
| R_{filter} | Filter Resistance |
| Z_{seq} | System Equivalent Impedance |
| Z_{filter} | Output ripple filter Impedance |
| Z_{load} | Load Impedance |

5. RESEARCH METHODOLOGY

A simplified structure of the proposed digital predictive current control shown in Fig.3. This scheme is purely Optimization algorithms. Thus it has to be implemented digitally using microprocessor based hardware. The aim of the controller is to determine the inverter voltage V_{k+1} required to achieve the set point current $V_{k=1}$ on each cycle. A Proposed novel predictive current control scheme is depends on the optimization algorithm, and it is to be developed in a microprocessor is as shown in Fig.3. The analysis of the PCC gives an additional restriction like delays time and approximate. The characteristic of this controller is to predict, the behavior of variable system models. By using this information, the system model selects optimum switching state and it will be applicable to power converter, as the standards of optimization theory. The PC algorithms are to implemented and understand and it can be design with 3 main blocks as shown in fig 3.

5.1 Current Reference Generator:

A current reference generator is a basic building blocks in analogy circuit design as a bias source for oscillators, amplifiers, PLL'S and etc., all mentioned applications makes extensive use of current reference and their accuracy is strong related to the temperature and process stability of these reference. In the voltage mode can implement a band gap circuit to ensure current biases over a large LANGE of temperature range. V_{Sv} and I_{load} are considered as input parameters and I_{Ocv} is the output parameter. Here it will measure a voltage and load current with dc-voltage controller's. This circuit is used to obtain the reference current I_{Ocv} and it is used to compensate with I_{load} .

5.2 Prediction Model

It is used to predict output current, because it operates in discrete time. So, both must be indicated in digital time domain. This model contains a recursive matrix equation with prediction system i.e. the sampling time T_s , is convert the control variable at instants of time xT_s , and it is also predict the next state of time $[x+1] T_s$ from equation (1) and (2), derived a first order equation is given as,

$$\frac{du}{dt} \approx \frac{u[x+1] - u[x]}{T_s} \quad (4)$$

The outputs are obtained from predicated value and it can be generated from eq (2) and (4) are,

$$I_{Ocv}[x+1] = \frac{T_s}{L_{eq}} (V_{uN}[x] - V_{Ovu}[x]) + \left(1 - \frac{R_{eq} T_s}{L_{eq}}\right) I_{Ocv}[x] \quad (5)$$

as eq (5) shows that in order to obtain the output current I_{Ocv} , at a time $(x+1)$, the value of V_{Ovv} and the value of output voltage (V_{uN}) required.

5.3 Cost Function Optimization

Cost function is a optimize model parameters (design variables), it will evaluate the cost and constraint values for the design variables values for an iterations. It can also be used for global sensitivity analysis. Optimization means minimize a cost (objective function) or maximize a cost (objective function). To get optimal switching state, must be applying to the power converter. The predicted values are generated for $I_{Ocv}[x+1]$ and it is compared with reference cost function (g), and is given as,

$$g[x+1] = (I_{O_{ri}}^*[x+1] - I_{O_i}[x+1])^2 + (I_{O_{rj}}^*[x+1] - I_{O_j}[x+1])^2 + (I_{O_{rk}}^*[x+1] - I_{O_k}[x+1])^2 + (I_{O_{rN}}^*[x+1] - I_{O_N}[x+1])^2 \quad (6)$$

$$\text{When, } g = 0, I_{Ocv} = I_{Ocv}^*$$

Therefore, the cost function achieves a (g) value near to zero. Minimized cost function is applied to the next sampling state. During this state, the switching state creates the less value of g and selected from possible values. This technique selects and produces minimum values and applied it to the converter, when the time is $(x+1)$.

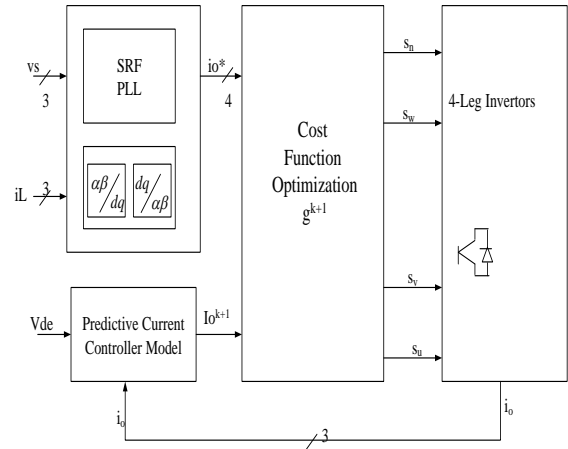


Fig 3: Proposed Predictive Control Scheme

6. DQ-TRANSFORMATION SCHEME

The current reference generator subjected to the quality has to measure and analyse in order to get current reference signal of the shunt active filter system, here we have 3 types of strategies: 1. Load current detection, 2. Supply current detection, 3. Voltage detection. In harmonic detection mainly 2 types of control strategies for analyzing and voltage and current harmonics from distorted waveforms. In synchronous reference PI controller, integrator is used to remove the steady state error of DC components of the 0-d-q coordinate reference signals. With this 0-d-q frame theory, current harmonics represented as components within the corresponding reference frame and integrators removes the steady state error of harmonics components. By the usage of Park transformation, reference signal are first converted into 0 -α -β stationery frame. The PI control eliminated steady state error, achieve a good. This algorithm further explained,

where voltage reference frame signal in 0-d-q rotation frames. And it is converted back to a-b-c stationary frame, there are 0-drotating frame convert back to q-b-c items.

A dq-based current generator method is used to produce an active power filter current signal. This method shows a fast and exact signal tracking capability. This avoids fluctuations in voltage and current and reference signal affect compensating performance and it is obtained from I_{load} (load current) shown in fig.4. To calculate this, the reference current required to the converter to compensate reactive power, current harmonics and imbalanced current. The displacement power factor and maximum total harmonic distortion of the load defined as,

$$\frac{X_{APF}}{X_L} = \frac{\sqrt{\sin(\phi)_{(L)} + MTHD_{(L)}^2}}{\sqrt{1 + MTHD_{(L)}^2}} \quad (7)$$

Where $MTHD_{(L)}$ indicates maximum harmonic current and f_s indicates sampling frequency. The frequency of maximum current components is equal to half of the converter switching frequency.

SRF transformation is similar to phase detector, it is working based on the principle relies on regulating to zero of the rotation frame. It is especially helpful in weak 3-phase systems, where we require very fast and robust phase detection to inverter synchronization, but it may be more difficult to achieve due to varying frequency. It must be trade off noise rejection with fast tracking capabilities. This scheme operates in rotating reference frame. Therefore the contents should be multiply by $\cos(\omega t)$, $\sin(\omega t)$ components. By the application of dq-transformation, the d-current is synchronized with the phase-to-neutral system voltage, and then q current is phase-shifted by 90° . The reference signals like $\sin(\omega t)$ and $\cos(\omega t)$ are produced from a Synchronous-reference frame phase-locked loop (SRF-PLL) and it generated a pure sinusoidal waveform, when the voltage is distorted. The measured error along with non-linear loads are set to cause voltage unbalancing, harmonics. These are avoided by designing of SRF-PLL. Eq (8) Indicates relationship between real current $I_{load}(t)$ ($u = i, j, k$) and associated d_p components (I_d and I_q).

$$\begin{bmatrix} I_d \\ I_q \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \sin(\omega t) & \cos(\omega t) \\ -\cos(\omega t) & \sin(\omega t) \end{bmatrix} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_{Li} \\ I_{Lj} \\ I_{Lk} \end{bmatrix} \quad (8)$$

Here, the Low pass filter is used to extract the constant dc component of I_d (phase Current) and to generate harmonic reference current I_d . Then, the original i_d current is added with the low pass filter current to generate reference harmonic current I_d . The reactive reference component current (I_q^*) is also obtained by phase shifting the reactive current component (I_q) by 180° . Then by adding the modified active power reference signal (I_e) to the d-components to keep a DC-voltage as constant. Then they obtained resulting signals namely, I_d^* and I_q^* sent back to 3- ϕ system by applying the inverse Park and Clark transformation[11] is given in eq (9).

$$\begin{bmatrix} I_{Ori}^* \\ I_{Orj}^* \\ I_{Ork}^* \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \sqrt{\frac{2}{3}} \frac{1}{\sqrt{2}} & -\frac{1}{2} & \sqrt{\frac{3}{2}} \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & -\sqrt{\frac{3}{2}} \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \sin(\omega t) & -\cos(\omega t) \\ 0 & \cos(\omega t) & \sin(\omega t) \end{bmatrix} \begin{bmatrix} I_{Ocv} \\ I_{rd}^* \\ I_{rq}^* \end{bmatrix} \quad (9)$$

The current that flows through (I_{OrN}^*) (neutral current load) of the load is obtained as given eq (10) and it is phase shifted by 180° .

$$I_{OrN}^* = -(I_{Li} + I_{Lj} + I_{Lk}) \quad (10)$$

The main advantage of the Park and Clark transform scheme is that it permits to develop a linear controller in dc-voltage control loop. The disadvantage of this transform is that it uses a 2nd order harmonic component to generate i_d and i_q under unbalanced operating conditions, because the 2nd order harmonics cannot be removed from i_d and i_q .

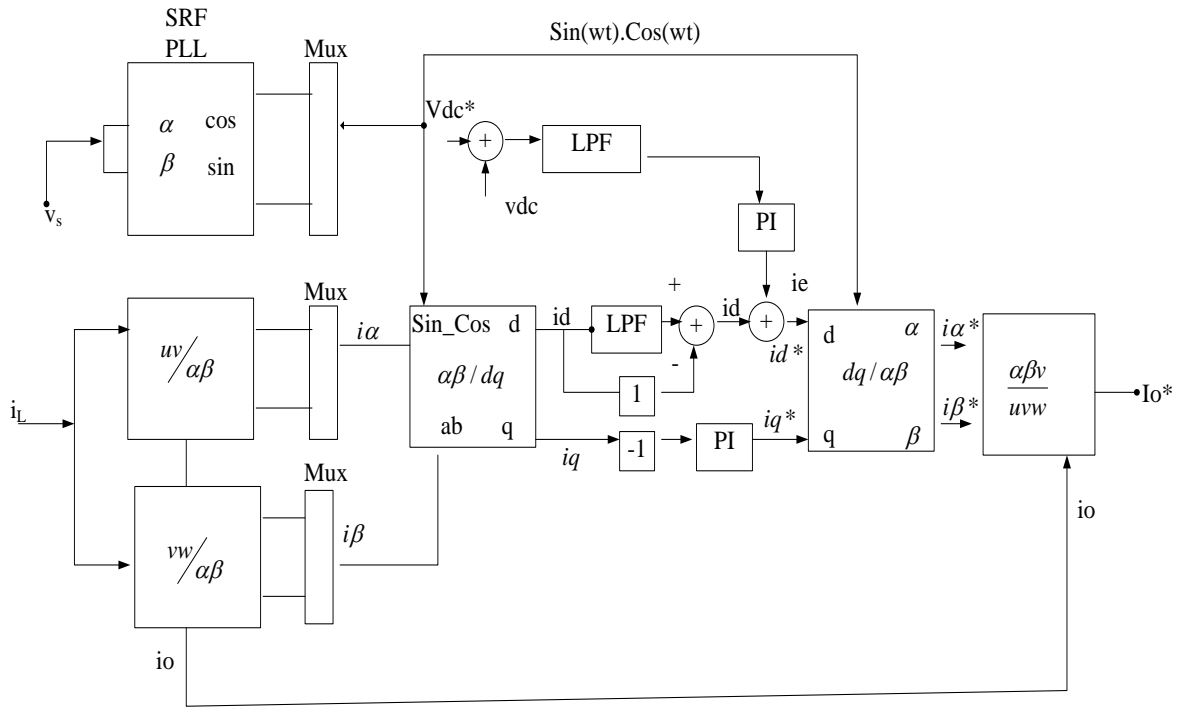


Fig.4: Reference Current generator diagram using dq-based transformation

It from Fig (7) $H(s)$ is the closed loop transfer function, $G(s)$ is first-order system (DC-Voltage transfer function) V_{DC}^* is reference voltage generated from shunt active power filter. Above Fig.(7) deals with the DC-Voltage converter and it is controlled with a PI controller followed by LPF. In this system the cost function is developed based on only current reference to avoid weighting factors. In different operating conditions the weighting factors are not defined. In addition, the dynamic response of voltage across the capacitor will not affect the transient current response, because of this reason PI controller are used in dc-voltage control. In this Fig.4, the DC-voltage V_{DC} is compared with a constant reference value V_{DC}^* . The error signal(e) is processed by a Low pass filter and PI controller with gain factor K_p and T_i . These are calculated based on dynamic requirements. The dc-voltage transform is represented by a first order system is given in eq (11).

$$G(S) = \frac{V_{DC}}{I_e} = \frac{3}{2} \left(\frac{K_p V_{Svv} \sqrt{2}}{C_{DC} V_{DC}^*} \right) \quad (11)$$

The closed-loop Transfer Function ($H(s)$) is given in eq (12) and (13)

A. Predictive DC-Voltage Control:

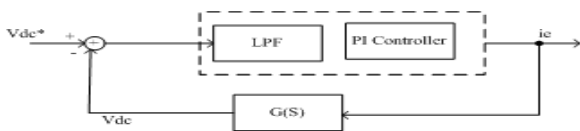


Fig.5:Block diagram of PDC voltage controller

$$H(s) = K_p \left[1 + \frac{1}{T_i \cdot s} \right] \quad (12)$$

$$\frac{V_{DC}}{I_e} = \frac{w_n^2 \cdot (s + a)}{s^2 + 2\xi w_n \cdot s + w_n^2} \quad (13)$$

Where, $\xi \rightarrow$ damping ratio and $\xi = 1$

$w_n \rightarrow$ natural frequency and $w_n = 2\pi \cdot 100$ red/sec

$a \rightarrow$ constant value.

Here, by the application of natural frequency w_n , critically damped outputs are obtained with less voltage oscillations. and T_i (Integer time) is given as,

$$T_i = \frac{1}{a}$$

The proportional gain constant (K_p) is calculated as,

$$\xi = \sqrt{\frac{3}{8} \left(\frac{K_p V_{Svv} \sqrt{2} T_i}{C_{DC} V_{DC}^*} \right)} \quad (14)$$

and

$$w_n = DC \sqrt{\frac{3}{2} \left(\frac{K_p V_{Svv} \sqrt{2}}{C_{DC} V_{DC}^* T_i} \right)} \quad (15)$$

7. SIMULATION RESULTS

Figure.5 shows the simulation model for 3-phase 4-leg PWM converter. It has been This work is carried out using MATLAB/SIMULINK 2014 software. The main objective is to verify the current harmonics components of the novel control system under different operating conditions. The proposed predictive current control algorithm was programmed and it is implemented in real time interface. It contains input sources V_{Svv} , $I_{ref_Isource}$ and Load current(I_{load})

and output is V_{DC} . It uses a non-linear load and predictive control algorithm. This converter has 3-leg connected to natural bus of the system. It improves control flexibility and quality of the output and is suitable for current unbalanced compensation.

Above Fig.2 indicates the input source voltage (phase to natural source voltage), given to the 3-phase 4-leg PWM converter. The above waveform shows 3 different ac input. It contains 3 different voltages of 35kv(p-p) shown in Fig.6. This input signal is given to predictive current control block through source impedance (Z_{Seq}). The simulated results shows that the proposed current control scheme, it effectively removes the unbalanced currents, the above

Fig.7(a)(b)(c).indicates the $I_{ref_Isource}$, gain of $I_{ref_Isource}$ and I_{source_Iload} (Load current) respectively. The signal $I_{ref_Isource}$ is a reference current source is obtained from shunt active harmonic filter. This signal is given to predictive current control model as a reference current. In predictive current control the frequency is taken as 60Hz. i.e., $f=60\text{Hz}$. The load current(I_{load}) also a current signal generated from Non-linear loads and it is given to Predictive current control model. $I_{ref_Isource}$ current signal generated form shunt active harmonic filters. The above Fig.8 indicates output for simulation model for the 3-phase 4-leg PWM converter. This simulation results shows that the proposed predictive current control algorithms effectively eliminates unbalanced currents.

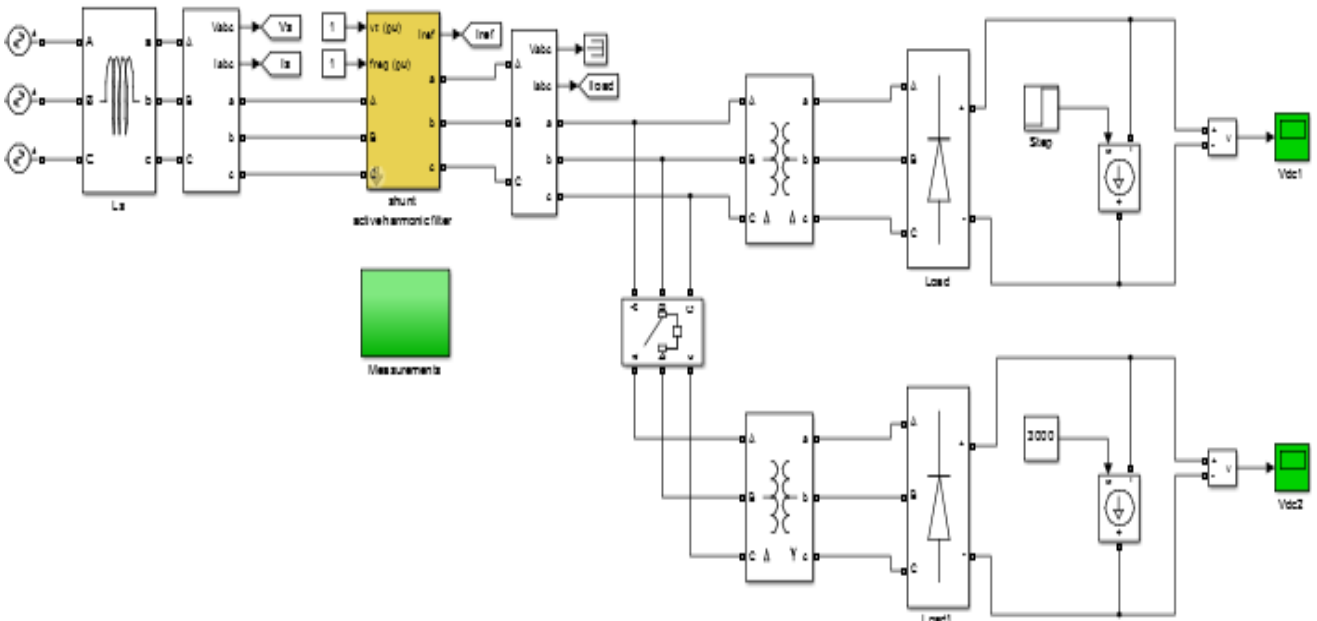


Fig 5: A Schematic diagram of proposed 3-phase shunt active power filter.

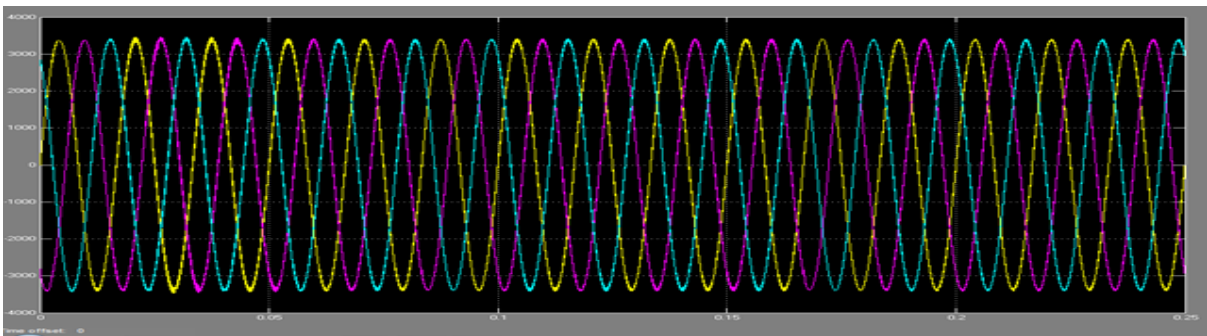


Fig 6: Input Source Voltage (V_{Sw})

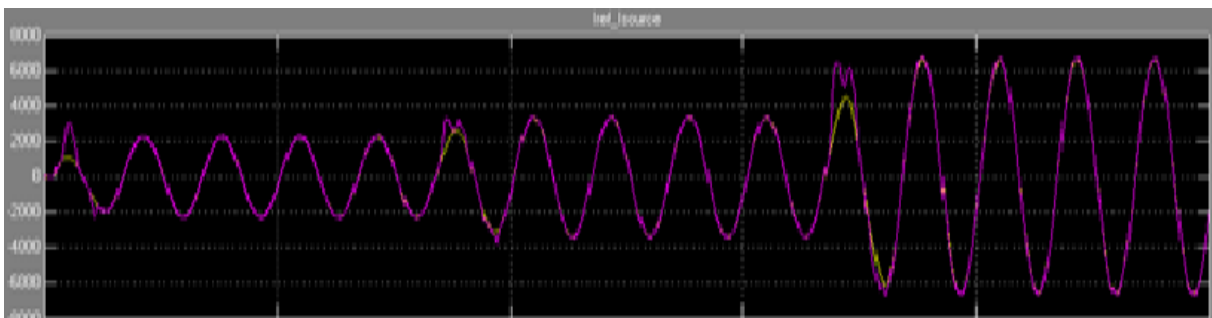


Fig 7:(a). reference input current source ($I_{ref_Isource}$)

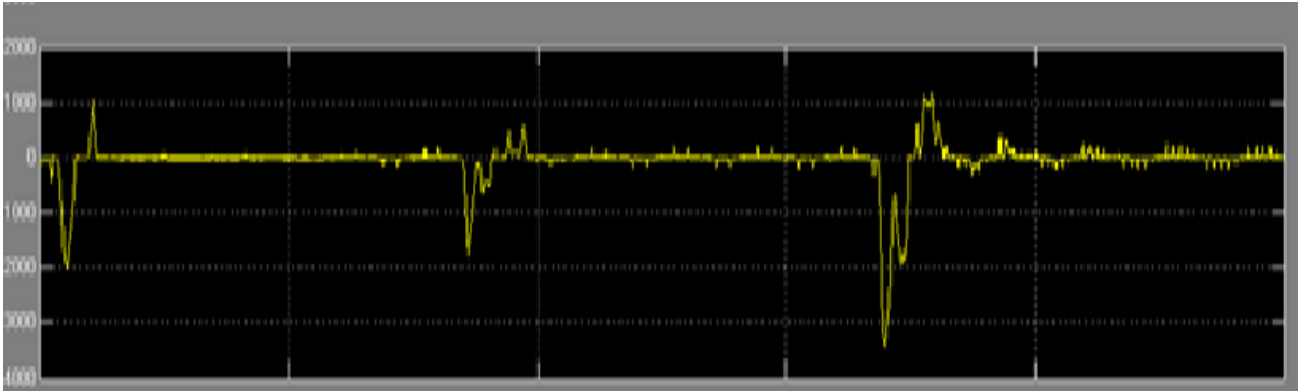


Fig 7: (b). Gain of ($I_{ref-Isource}$)

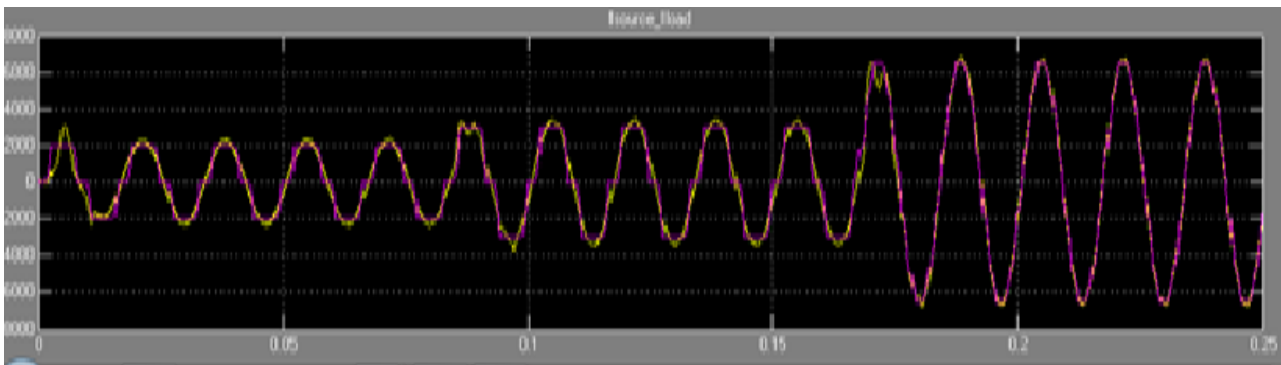


Fig 7: (c). Load Current ($I_{source-Iload}$)

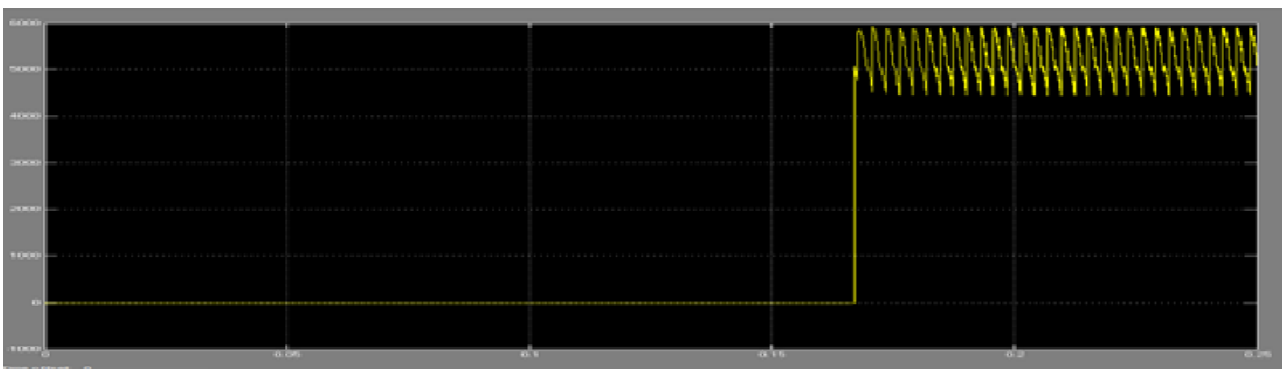


Fig 8: Ooutput Voltage (VDC)

Fig.8 indicates DC-Voltage is stable throughout the process of whole shunt active power filter operations. The simulation results for 3- ϕ shunt power active Filter-I has been developed using Matlab-Simulink model. Here, V_{Svv} , load current, $I_{ref-Isource}$ are used as input signals and V_{DC} is the output signal. This converter has 3-leg connected to neutral bus of the system. It improves control flexibility and quality of the output and is suitable for current unbalance compensation. In this simulation V_{Svv} waveform indicates source voltage. It contains 3 voltage of amplitude 35 kV (p-p) as shown in figure (1). In Fig.6 different colour waveform indicates 3 different input sources. The next signal $I_{ref-Isource}$ is a References current source is obtained from shunt active harmonic filter. This signal is given to the Predictive current control (PCC) model as a reference current. In Predictive current control, the frequency is taken as 60Hz. References current source is obtained from shunt active harmonic filter. This signal is given to the Predictive current control (PCC)

model as a reference current. In Predictive current control, the frequency is taken as 60Hz. Load Current (I_{load}) also a current signal generated from Non-linear loads and it is send to PCC model. Then, the next signal gives gain of $I_{ref-Isource}$ current signal generated from shunt active harmonics filters. V_{DC} is the output voltage signal obtained from 3- ϕ shunt active power filter.

7.1 Performance Analysis

For the purpose of the performance analysis, the outcomes of the proposed study can be compared to any existing study that a bear the similar resembles on the objectives. Hence, we found that recent study conducted by Kouara et al. [4] bears potential similarity. The authors have used shunt active power filter (just like the proposed study) to accomplish better harmonic suppression and enhanced power quality. However, the authors have accomplished the objective using Fuzzy-based approach on the bus voltage control using three phase



four wire approach of harmonic suppression. Hence, we choose to theoretically consider the outcomes of the study presented in [4] and analyze the comparison for the proposed study. The outcomes of the theoretical comparative analysis for study [4] with the proposed systems are as follows:

- **Enhancement in Supply Current:** The work of [4] shows the supply current within the range of -2000 to 2000 A with respect to the time in seconds, where the proposed study supports the supply current of nearly 6000-8000 A. A closer analysis of this outcomes shows that work of [4] is found with the outcomes of supply current within the range of -500-500A, whereas the proposed system is found with double of it.
- **Higher Degree of Reduced Harmonics:** The work presented in [4] is found with total harmonic distortion of around 2.5-2.8%, however, the proposed system has successfully accomplishment of total harmonic distortion of only 1.5-1.8% in maximum scenarios of the load.
- **Enhanced Computational Speed:** It is strongly believed that efficiency of any algorithm can be measured with time complexity. The proposed system takes only 1.622 seconds to generate the waveforms with suppressed harmonics using active power filter, however, there was no such discussion of it in work presented by [4].

8. CONCLUSION

In the recent development of semi conductor devices in power electronics and control circuits, a new generation of equipment for power quality, namely active power filters was developed. Its more advantages over existing methods means, are more flexible and very fast control output. The shunt active power filter comprises 2 parts: the reference current computation and the current control. Here we have 2 basic for generating reference current; based on the pq theory. This paper gives by presenting the principle of active filtering and basic power theory. As for the distorted or unsymmetrical load voltage system, the p-q theory has shows limitations and calculates reference current methods.

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