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ANN Based Active Power Filter to Reduce Harmonics in a Micro Grid

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ABSTRACT

Now a day's Renewable energy generation system being the emerging new revolution in generating department, but to interface it with the Grid we required high power static PWM converters which are one of the cause for disturbance in power quality in our system. So, In this paper we are proposing a new control technique which is based on artificial neural network theory used in active power filter by using this the renewable sources are not only synchronized with the grid but also improves power quality by compensating the current harmonics and unbalanced current generated by sudden disturbance in load. The topology which is used for active power filter is four-leg voltage source converter. The ANN controller is not only improves the power quality; it also improves the total harmonic distortion in current by suppressing the harmonics. The mathematical modeling of the proposed system is explained in the paper. The active power filter is simulated with two control technique such as PI controller and ANN controller. The simulation results and the tabular form show the superiority of ANN controller over PI controller. The proposed circuit is tested under different operating condition through simulation in MATLAB/ SIMULINK and the results shows the potency of the system.

KEYWORDS: *Active Power Filter, Four-Leg Converters, PI Controller, ANN Controller, THD, Renewable Generation System.*

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I. Introduction

Presently a-days the substantial number of PCs and other touchy electrical burdens associated with the power lattice are straightforwardly influenced by control quality issues [1]. A standout amongst the most critical issues is identified with current music created by the expanding number of non direct loads associated with the power framework, for example, diode and thyristor frontend rectifiers. As an outcome, these music can cause voltage contortions, extra misfortunes in the influence framework, and breakdown of delicate electronic hardware. Hence, symphonious limitation gauges, for example, IEEE 519 [2], have been prescribed to confine the consonant streams infused into the framework by non direct loads. Shunt inactive channels, comprising of tuned LC channels and high pass channels, have been customarily utilized as a straightforward and minimal effort answer for remunerate current sounds. All things considered, their execution unequivocally relies upon the matrix impedance and can cause the undesirable parallel reverberation marvels with the network. In the most recent decades, the expanding unwavering quality of energy semiconductor gadgets has spurred the improvement of energy hardware answers for the issue of consonant flow into the lattice. The shunt dynamic power channel (APF), comprising essentially of a voltage source inverter (VSI) with a substantial capacitor on its dc interface, is viewed as a settled answer for lessen the present sounds to the suggested guidelines limits [3]– [13]. The non-uniform nature of energy age straightforwardly influences voltage direction and makes voltage twisting in control frameworks. This new situation in control appropriation frameworks will require more modern remuneration systems. Albeit dynamic power channels executed with three-stage four-leg voltage-source inverters (4L-VSI) have just been displayed in the specialized writing, the essential commitment of this paper is a prescient control calculation planned and actualized particularly for this application.

Generally, dynamic power channels have been controlled utilizing pre tuned controllers, for example, PI-sort or versatile, for the present and in addition for the DC-voltage circles. PI controllers must be outlined in view of the equal direct model, while prescient controllers utilize the non straight model, which is nearer to genuine working conditions. An exact model got utilizing prescient controllers enhances the execution of the dynamic power channel, particularly amid transient working conditions, since it can rapidly take after the present reference flag while keeping up steady DCvoltage. Up until now, usage of prescient control in control converters have been utilized for the most part in acceptance engine drives. On account of engine drive applications, prescient control speaks to an extremely instinctive control plot that handles multi variable attributes, disentangles the treatment of dead-time pay, and allows beat width modulator substitution. In any case, these sorts of uses show detriments identified with motions and unsteadiness made from obscure load parameters. One preferred standpoint of the proposed calculation is that it fits well in dynamic power channel applications, since the power converter yield parameters are notable. These yield parameters are acquired from the converter yield swell channel and the power framework identical impedance. The paper is sorted out as takes after: The proposed framework topology is clarified in part II. The entire depiction of the chose current reference generator executed in the dynamic power channel is introduced in section III. The Control Scheme of DC transport voltage control and ANN control calculation is depicted in part IV. At long last, the proposed dynamic power channel and the viability of the related control plot remuneration are shown through reenactment brings about part

II. Proposed System Topology

The configuration of a common place power dispersion framework with inexhaustible power age is appeared in Fig.1. It comprises of different sorts of energy age units and diverse sorts of burdens. Inexhaustible sources, for example, wind and daylight, are ordinarily used to create power for private clients and little ventures. The two sorts of energy age utilize air conditioning/air conditioning and dc/air conditioning static PWM converters for voltage change and battery banks for long haul vitality stockpiling. These converters perform most extreme power direct following toward separate the greatest vitality conceivable from wind and sun. A dynamic power channel is associated in shunt at the purpose of regular coupling to repay current music, current unbalance, and responsive power. It is formed by an electrolytic capacitor, a four-leg PWM converter, and a firstorder yield swell channel, as appeared in Fig. 2. This circuit considers the power framework comparable impedance Zs, the converter yield swell channel impedance Zf, and the heap impedance ZL. The four-leg PWM converter topology is appeared in Fig. 3. This converter topology is like the ordinary three-stage converter with the fourth leg associated with the nonpartisan transport of the framework. The fourth leg builds changing states from 8 (23) to16 (24), enhancing control adaptability and yield voltage quality, and is appropriate for current unequal pay.

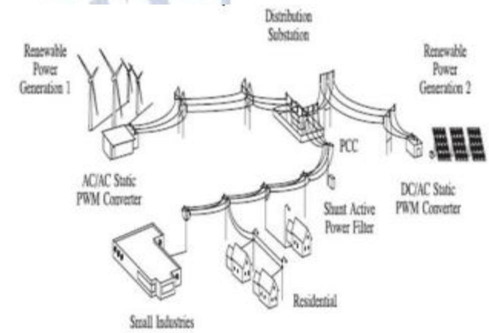

Fig 1. Hybrid power generation system with a shunt active power filter

The voltage in any leg x of the converter, measured from the neutral point (n), can be expressed in terms of switching states, as follows:

$$v_{xn} = S_x - S_n \, v_{dc}, \quad x = u,\ v,\ w,\ n. \tag{1}$$

$$\mathbf{v_o} = v_{xn} - R_{eq}\, \mathbf{i_o} - L_{eq} \frac{d\, \mathbf{i_o}}{dt} \tag{2}$$

Where Req and Leq are the 4L-VSI output parameters expressed as Thevenin impedances at the converter output terminals Zeq.

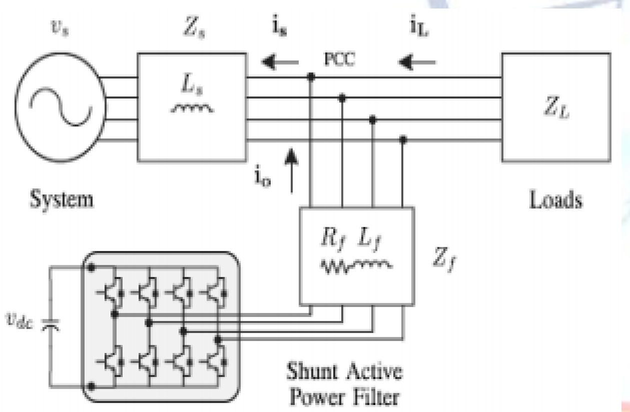

Fig 2. Three-phase equivalent circuit of the proposed shunt active power filter.

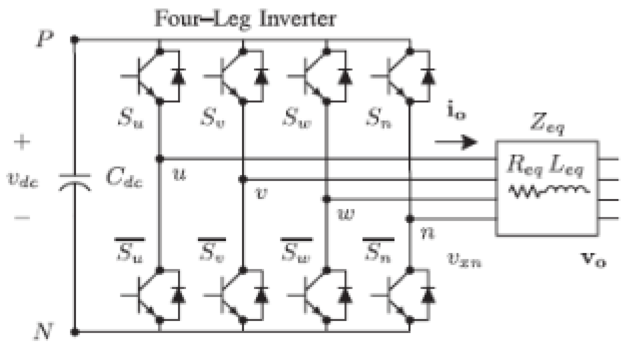

Fig 3. Two-level four-leg PWM-VSI topology.

Therefore, the Thevenin equivalent impedance is determined by a series connection of the ripple filter impedance Zfand a parallel arrangement between the system equivalent impedance Zs and the load impedance ZL

$$Z_{eq} = \frac{Z_s Z_L}{Z_s + Z_L} + Z_f \approx Z_s + Z_f. \tag{3}$$

For this model, it is assumed that ZL>>Zs, that the resistive part of the system's equivalent impedance is neglected, and that the series reactance is in the range of 3– 7% p.u., which is an acceptable approximation of the real system. Finally, in (2) Req = Rfand Leq = Ls+ Lf.

III. Current Reference Generation

A dq-based current reference generator scheme is used to obtain the active power filter current reference signals. The current reference signals are obtained from the corresponding load currents as shown in Fig. 5. This module calculates the reference signal currents required by the converter to compensate reactive power, current harmonic and current imbalance. The displacement power factor (sin φ(L)) and the maximum total harmonic distortion of the load (THD(L)) defines the relationships between the apparent power required by the active power filter, with respect to the load, as shown

$$\frac{S_{APF}}{S_L} = \frac{\sqrt{\sin\phi_{(L)} + \mathrm{THD}_{(L)}{}^2}}{\sqrt{1 + \mathrm{THD}_{(L)}{}^2}} \tag{4}$$

Where the value of THD (L) includes the maximum compensable harmonic current, defined as double the sampling frequency fs. The frequency of the maximum current harmonic component that can be compensated is equal to one half of the converter switching frequency. The dqbased scheme operates in a rotating reference frame; therefore, the measured currents must be multiplied by the sin(wt) and cos(wt) signals. By using dq-transformation, the current component is synchronized with the corresponding phase-to-neutral system voltage, and the q current component is phase-shifted by 90◦. The sin(wt) and cos(wt) synchronized reference signals are obtained from a synchronous reference frame (SRF) PLL. The SRF-PLL generates a pure sinusoidal waveform even when the system voltage is severely distorted. Tracking errors are eliminated, since SRF-PLLs are designed to avoid phase voltage unbalancing, harmonics (i.e., less than 5% and 3% in fifth and seventh, respectively), and offset caused by the nonlinear load conditions and measurement errors. Equation (8) shows the relationship between the real currents iLx(t) (x=u,v,w) and the associated dq components(id and iq)

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \sin\omega t & \cos\omega t \\ -\cos\omega t & \sin\omega t \end{bmatrix} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{Lu} \\ i_{Lv} \\ i_{Lw} \end{bmatrix}. \tag{5}$$

A low-pass filter (LFP) extracts the dc component of the phase currents id to generate the harmonic reference components −_id. The reactive reference components of the phase-currents are obtained by phase-shifting the corresponding ac and dc components of iq by 180◦. In order to keep the dc-voltage constant, the amplitude of the converter reference current must be modified by adding an active power reference signal i.e with the d-component, as will be explained in Section IV-A. The resulting signals i∗d and i∗qare transformed back to a three-phase system by applying the inverse Park and Clark transformation, as shown in (6). The cut off frequency of the LPF used in this paper is 20 Hz.

$$\begin{bmatrix} i^*_{ou} \\ i^*_{ov} \\ i^*_{ow} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \times \begin{bmatrix} 1 & 0 & 0 \\ 0 & \sin\omega t & -\cos\omega t \\ 0 & \cos\omega t & \sin\omega t \end{bmatrix} \begin{bmatrix} i_0 \\ i^*_d \\ i^*_q \end{bmatrix}. \quad (6)$$

The current that flows through the neutral of the load is compensated by injecting the same instantaneous value obtained from the phase-currents, phase-shifted by 180◦, as shown next

$$i^*_{on} = -\left(i_{Lu} + i_{Lv} + i_{Lw}\right). \quad (7)$$

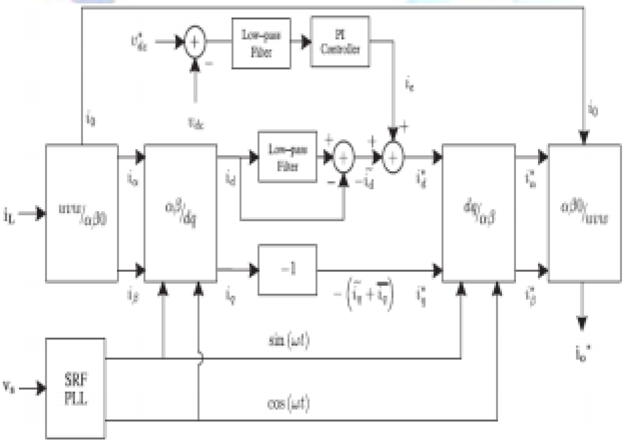

Fig4.dq-based current reference generator block diagram.

One of the major advantages of the dq-based current reference generator scheme is that it allows the implementation of a linear controller in the dc-voltage control loop. However, one important disadvantage of the dq-based current reference frame algorithm used to generate the current reference is that a second order harmonic component is generated in id and iq under unbalanced operating conditions. The amplitude of this harmonic depends on the percent of unbalanced load current (expressed as the relationship between the negative sequence current iL,2 and the positive sequence current iL,1). The second-order harmonic cannot be removed from id and iq, and therefore generates a third harmonic in the reference current when it is converted back to abc frame. Fig. 6 shows the percent of system current imbalance and the percent of third harmonic system current, in function of the percent of load current imbalance. Since the load current does not have a third harmonic, the one generated by the active power filter flows to the power system.

IV. DC-Voltage Control

The dc-voltage converter is controlled with a traditional PI controller. This is an important issue in the evaluation, since the cost function (6) is designed using only current references, in order to avoid the use of weighting factors. Generally, these weighting factors are obtained experimentally, and they are not well defined when different operating conditions are required. Additionally, the slow dynamic response of the voltage across the electrolytic capacitor does not affect the current transient response. For this reason, the PI controller represents a simple and effective alternative for the dc-voltage control. √The dc-voltage remains constant (with a minimum value of6 vs(rms)) until the active power absorbed by the converter decreases to a level where it is unable to compensate for its losses.

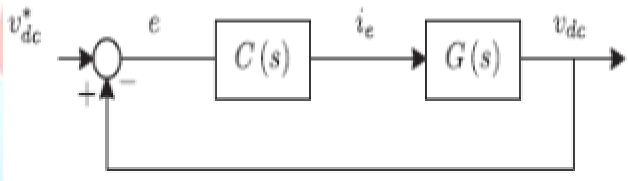

Fig 5. DC-voltage control block diagram.

The active power absorbed by the converter is controlled by adjusting the amplitude of the active power reference signal i.e., which is in phase with each phase voltage. In the block diagram shown in Fig. 4, the DC-voltage vdc is measured and then compared with a constant reference value v∗dc. The error(e) is processed by a PI controller, with two gains, Kp and Ti. Both gains are calculated according to the dynamic response requirement. Fig. 7 shows that the output of the PI controller is fed to the dc-voltage transfer function Gs, which is represented by a first-order system. The equivalent closedloop transfer function of the given system with a PI controller (12) is shown in (13)

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

$$\frac{v_{dc}}{i_e} = \frac{\frac{\omega_n^2}{a}\cdot(s+a)}{s^2 + 2\zeta\omega_n \cdot s + \omega_n^2}. \quad (13)$$

Since the time response of the dc-voltage control loop does not need to be fast, a damping factor ζ = 1and a natural angular speed ωn= 2π ·100 rad/s are used to obtain a critically damped response with minimal voltage oscillation. The corresponding integral time Ti = 1/a (13) and proportional gain Kp can be calculated Zieglonichol as method.

V. ANN CONTROLLER

Artificial Neural Networks are relatively crude electronic models based on the neural structure of the brain. The brain basically learns from experienceIt is regular confirmation that a few issues that are past the extent of current PCs are to be sure resolvable by little vitality productive bundles. This cerebrum displaying likewise guarantees a less specialized approach to create machine arrangements. This new way to deal with registering likewise gives a more effortless debasement amid framework over-burden than its more conventional partners. These naturally motivated strategies for figuring are believed to be the following significant headway in the registering business. Indeed, even straightforward creature brains are equipped for capacities that are at present outlandish for PCs. Presently, propels in organic research guarantee an underlying comprehension of the common intuition component. This examination demonstrates that brains store data as examples. Some of these examples are exceptionally convoluted and permit us the capacity to perceive singular appearances from a wide range of edges. This procedure of putting away data as examples, using those examples, and afterward taking care of issues incorporates another field in registering. This field, as said some time recently, does not use customary programming but rather includes the production of hugely parallel systems and the preparation of those systems to take care of particular issues. This field likewise uses words altogether different from conventional registering, words like carry on, respond, self arrange, learn, sum up, and overlook.

A. Working of ANN

As of now, neural systems are the straightforward bunching of the primitive counterfeit neurons. This grouping happens by making layers which are then associated with each other. How these layers interface is the other piece of the "workmanship" of designing systems to determine true issues. Fundamentally, all counterfeit neural systems have a comparable structure or topology as appeared in Figure1. In that structure a portion of the neurons interface to this present reality to get its information sources. Different neurons furnish this present reality with the system's yields. This yield may be the specific character that the system conceives that it has checked or the specific picture it supposes is being seen. All the rest of the neurons are hidden from view.

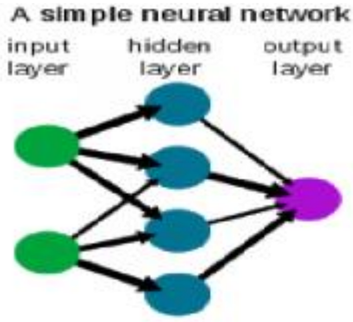

Fig 6.Topology of neural network

B. Training of ANN

Once a system has been organized for a specific application, that system is prepared to be prepared. To begin this procedure the underlying weights are picked haphazardly. At that point, the preparation, or learning, starts. There are two ways to deal with preparing - managed and unsupervised. Directed preparing includes an instrument of giving the system the coveted yield either by physically "evaluating" the system's execution or by furnishing the coveted yields with the information sources. Unsupervised preparing is the place the system needs to comprehend the contributions without outside help.

1.Supervised Training -In supervised training, both the inputs and the outputs are provided The system at that point forms the data sources and thinks about its subsequent yields against the coveted yields. Mistakes are then spread back through the framework, making the framework alter the weights which control the system. This procedure happens again and again as the weights are persistently changed. The arrangement of information which empowers the preparation is known as the "preparation set." During the preparation of a system a similar arrangement of information is handled ordinarily as the association weights are ever refined. The present business arrange advancement bundles give instruments to screen how well a manufactured neural system is focalizing on the capacity to foresee the correct answer.

2. Un supervised, or Adaptive Training: The other type of training is called unsupervised training. In unsupervised training, the network is provided with inputs but not with desired outputs. The framework itself should then choose what highlights it will use to amass the info information. This is regularly alluded to as self association or selection Here we are utilizing the administered

preparing ANN controller. The compensator yield relies upon info and its advancement. The picked design has seven information sources three each for reference stack voltage and source current individually, and one for yield of error (PI) controller. The neural system prepared for yielding key reference streams. The signals thus obtained are compared in a hysteresis band current controller to give switching signals.

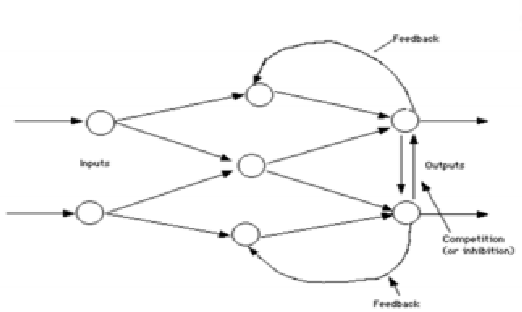

Fig 7. Simple Network with feedback and competition.

Training is given as follows:-

```
 net=newff(minmax(P),[7,21,3],
 {„tansig‟,‟tansig‟,‟purelin‟},‟trainlm‟);
 net.trainParam.show =50;
 net.trainParam.lr = .05;
 net.trainParam.mc = 0.95;
net.trainParam.lr_inc = 1.9;
net.trainParam.lr_dec = 0.15;
 net.trainParam.epochs = 1000;
net.trainParam.goal = 1e-6;
 [net,tr]=train(net,P,T);
 a=sim(net,P);
gensim(net,-1);
```

VI. Simulation Results

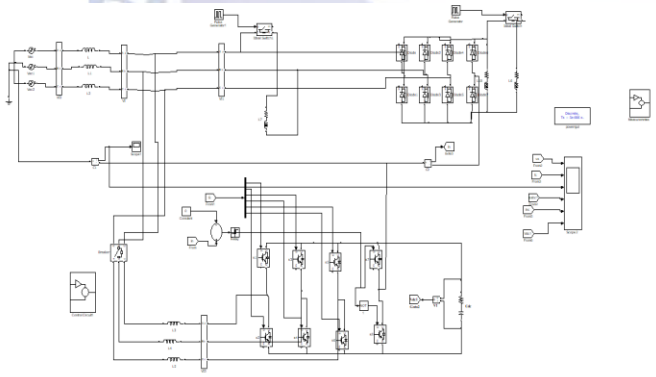

Fig.8.Proposed model in simulink.

In Circuit diagram main three phase voltage will be applied input side and output side three phase converters using to convert three phase to DC voltage and here we are using DC to three phase inverter with high accuracy.

The compensation effectiveness of the active power filter is corroborated in a 2 kVA experimental setup. A six-pulse rectifier was selected as a nonlinear load in order to verify the effectiveness of the current harmonic compensation. A step load change was applied to evaluate the transient response of the dc voltage loop. Finally, an unbalanced load was used to validate the performance of the neutral current compensation.

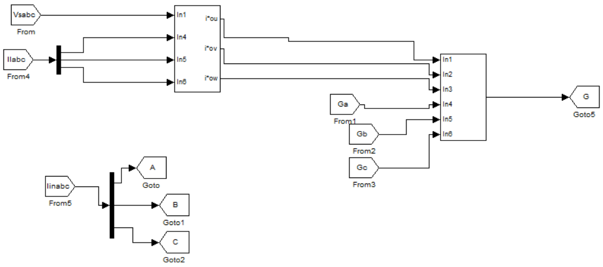

Fig.9. Controller circuit.

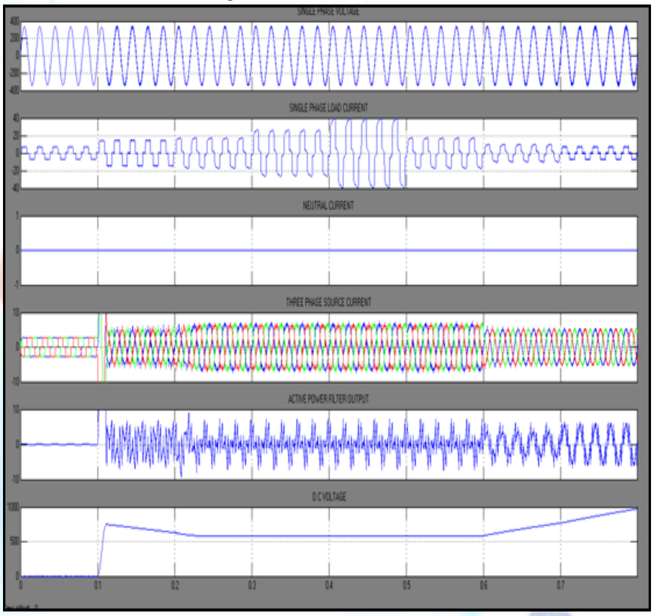

Fig.10. Simulation results.

Fig.10. the transient response of the compensation scheme. Fig. 10 shows that the line current becomes sinusoidal when the active power filter starts compensation, and the dc-voltage behaves as expected.

Extension circuit with ANN controller:

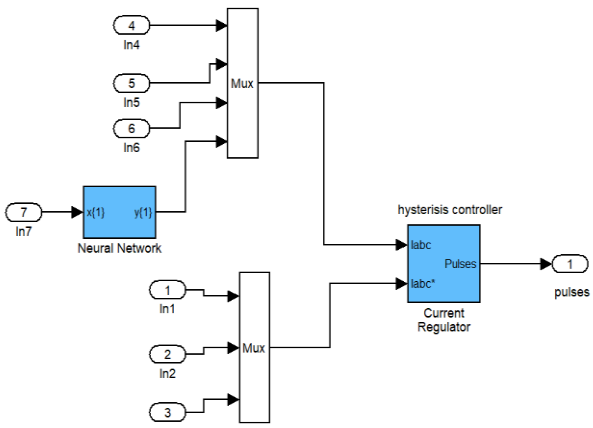

Fig.11. ANN controller circuit.

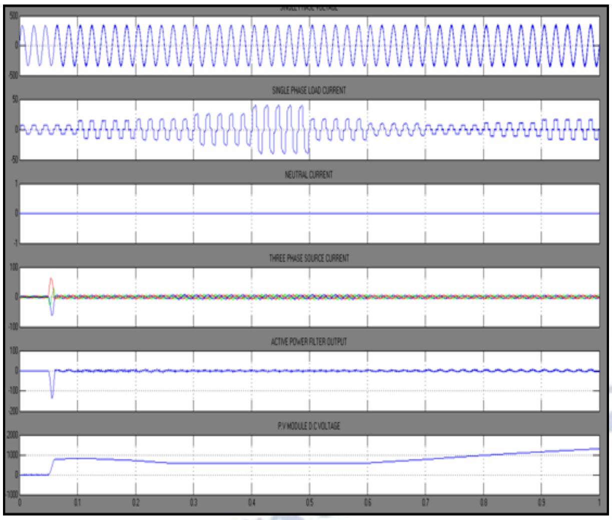

Fig.12. Output results across the with APF.

This is a consequence of the good tracking characteristic of the current references, as shown in Fig. 12. In Fig.12. the transient response of the active power filter under a step load change is shown.

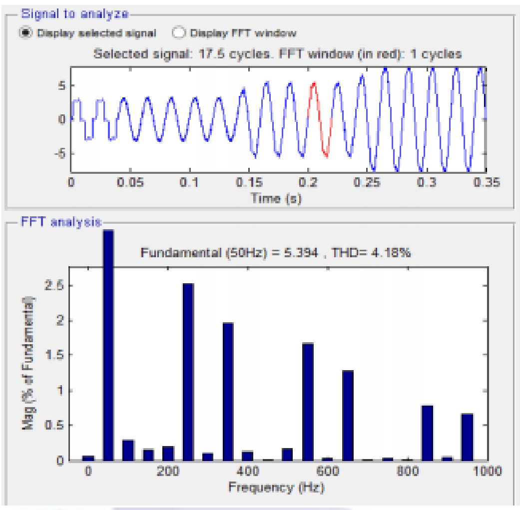

Fig 13. %THD using PI controller.

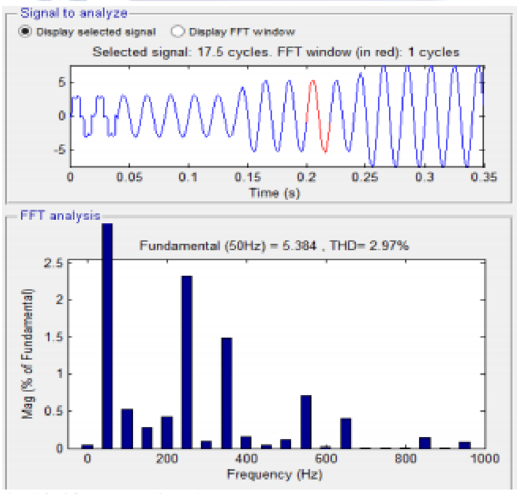

Fig 14. % THD using ANN controller.

VII. Conclusion

The free forward ANN controller based dynamic power channel has been actualized in MATLAB/Simulink. The many outcomes are displayed to demonstrate the capable of the planned ANN controller. The THD of source current for dynamic power channel utilizing PI controller is 4.18%, though THD for it utilizing ANN controller is 2.97%. The execution of composed ANN controller for dynamic power channel is tried under various nonlinear load conditions and it numerical outcomes are listed in table. The dynamic power channel enhances the power nature of appropriation framework by dismissing sounds and receptive power remuneration of non-straight load.Hence, from the recreation comes about, it can infer that ANN controller is more viable than PI controller.

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