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Comparative Study for Optimum Performance of Series Active Power Filter

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Abstract: - Harmonics and reactive power have been a key concern in power systems owing to the extensive usage of power electronic converters during varied levels of its working. This increase will suppress the quality of the power of the system and there will be contaminate in the power system leading to lesser efficiency and outturn. An active power filter when connected in series to the power system will help out in diminishing the harmonics within the system and serve the matter of reactive power throughout. Here, in the paper a neural network controller which is based on Kalman filter is connected to the active power filter to reduce the Total Harmonic Distortion [THD] to 3.61% and after that again a PI controller is added to it to observe that betterment is achieved in THD again to about 1.11%.

Key Words—*Series Active Power Filter (APF), PI Controller, Kalman filter, Total harmonic distortion (THD), Neural network.*

I. INTRODUCTION

In contemporary years, the notion of power superiority has evicted to be further problematic in the electrical business. Stable voltage and fixed ac frequency near to the rated assessment or balanced voltage waveform or improved power factor are the physiognomies of worthy power quality. The occurrence of harmonics in power system can amend the voltage and current waveform and are able to furthermore alteration occurs in the rated ac frequency [3].

Harmonics denote to numeral multiples of the ultimate frequency and are instigated by non-linear loads similar to SMPS, Direct Current Converter, VFD, fluorescent tubes, inverters, etc. This chore taken up purified on the harmonic reduction in Variable Frequency Drive (VFD) which is engaged in practically all businesses as an electro-mechanical energy scheme. The inverter yields in the variable frequency drive trail make sense of harmonic currents. The vital frequency of generated harmonics is never from the frequency of applied power instead it is from the functioning frequency of inverter. Harmonics can pick up harsh mishap in power system which may include excessive heat energy dissipation in the electrical devices, wrong identification meter output leading to inappropriate hike in customer bills, creating torque thumps in motor based equipment, interloping with phone trails and low-slung power factor [8].

A controller is a contrivance intended to pursue the alleviation of the gap amid the real value of a scheme, of course of the process feature, and the anticipated outcome from the implementation, which is what expected from the system. When coming to control engineering segment, controllers are the most crucial gadgets for getting the most complicated controlling done [2].

Proportional Integral Controller (PI Controller) is an arrangement of a proportional and an integral organizer where the output, precisely called as the actuating signal, similar to the outline of proportional and integral of the error pointer. When the proportion coefficient gets more, the yielding power will be lessened for the identical regulator fault. While considering the integration coefficient, its escalation will slow down the hoarded integration coefficient [2].

II. SYSTEM DESIGN

The implementation here has taken its path to escalate the mitigation of the harmonics and problem of reactive power done by Active Power filter by using a neural network which is based on Kalman filter and later a PI controller is added to the same system of circuit. The entire three scenarios are being simulated in Matlab/Simulink to compare and conclude on possible betterments available with the approach [1], [2].

A. Series Active Power Filter

While considering a series Active Power Filter, there will be serialized link among the load and the AP filter. Only a reduced occupying area is necessary for obliging a series AP filter. The budget value and affluence of execution also styles

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it a pertinent selection. It is predominantly made use of in alleviating voltage harmonics and further more to shield subtle load from voltage falsifications [7]. A three phase inverter connected to a three phase transformer organizes the circuit of a three phase series APF; the recompense of voltage harmonics by means of series APF is completed by constructing harmonic voltage of indistinguishable scale and reverse phase, ensuing in sinusoidal voltage/current waveforms at the yielding point. Because of the inoculation of voltage factor, the filter can be pronounced as a meticulous voltage provider. Consequently, the series APF conditions the voltage/current waveform those which were depreciated by the non-linear load and correspondingly normalizes the terminal load voltage. This conformation of series active power filter is named technically as a dynamic voltage restorer [1].

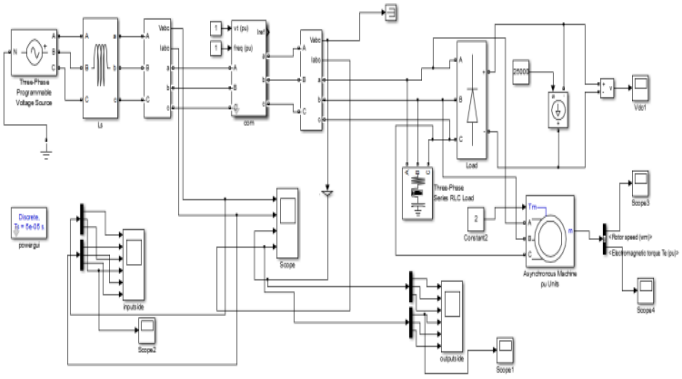

Fig.1. Full Model with Grid Injection

B. Kalman Filter Design

Kalman filtering is a procedure intended for providing guesstimates of a few unidentified variables by considering the available dimensions perceived during a period of time. Kalman filters can be seen to be establishing its practicality in numerous solicitations and have comparatively guileless practice and necessitate minor computational clout. By linear prototypes with stabilizer Gaussian noises, the Kalman filter delivers ideal approximations while the protracted Kalman filter is employed for nonlinear complications like bearing-angle target chasing or Terrain- Referenced Navigation (TRN) [9]. Kalman filters which are made use of for estimating states depending upon linear dynamical systems in state space layout.

C. Neural Network Controller

The elementary structure of a feed forward neural network with dual layers, specifically a hidden layer and an output layer made use of in this execution is delineate below as figure 2; the feeds are multiplied with weights, Wi and added up to the biases, bi .In this effort, the neural network is fed with the state vector figured by means of Kalman filter. The neural network output layer will hold any of the binary values, i.e., 0 or 1. The neural network is educated expending the back propagation procedure. The hidden layer encompasses of ten neurons through sigmoid activation function.

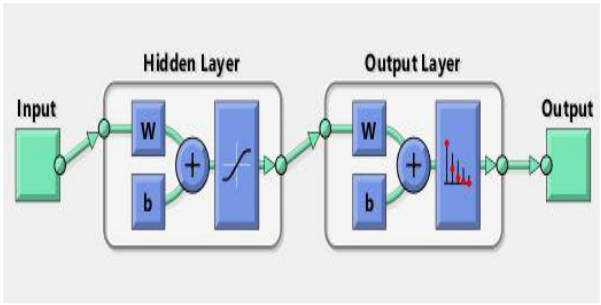

Fig.2. Double Layer Neural Network

The neural network yield part is attached to a pulse width modulation (PWM) generator use to regulates the swapping of power transistors within the structure of series active power filter and after that the voltage is produced to recompense the harmonic constituents [5], [6].

D. Proportional Integral [PI] Controller

A PI Controller is a feedback regulating hoop that gauges an error waveform after taking the difference among the output of a scheme, which in this circumstance is the power that is taken from the power source (battery) and the set point [10].

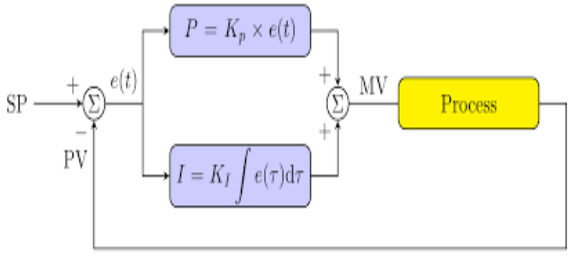

Fig.3. PI Control Loop [10]

The set point is the part at which from where the system is getting its feed and idyllically the executed scheme has taken its working nigh to a max power (990W) deprived of instigating the controller to involve. The figure depicted above has illustrated the loop structure of a PI controller; set

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point is seen and an error is fed to both the blocks to reach the system [10].

III. System Implementation

A method for controlling an active power filter using neural networks is presented which is based on Kalman filter and an additional PI controller is added for additional escalation in enactment efficiency. A number of researches shows, it is visibly evident that an increase of voltage and current harmonics in power systems is triggered by nonlinear loads; the active power filters (APFs) are made use of to recompense the spawned harmonics and to resolve the load power factor [1], [4].

While implementing the simulation of circuit without any recompense attached, the following graphical values of Total Harmonic Distortions [THD] was figured out.

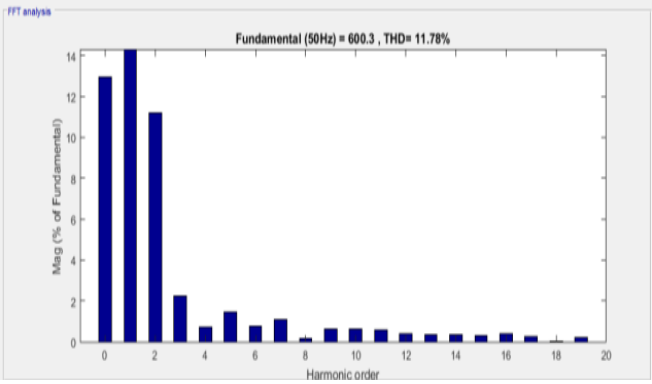

Fig.4. FFT analysis of load current without Compensation

But after attaching an active filter with neural network which is dependent on Kalman Filter a considerable difference is seen in THD, which represented graphically below.

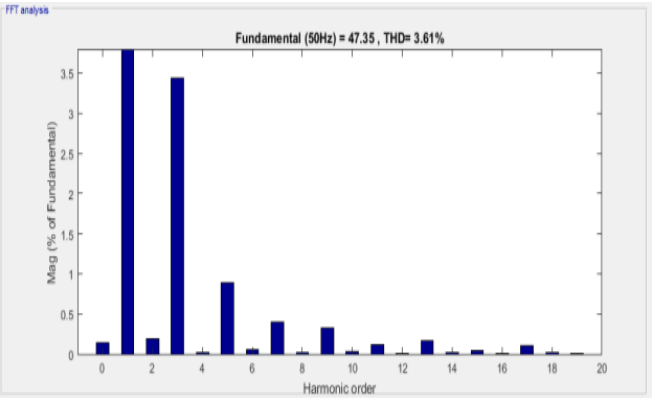

Fig.5. FFT analysis of load current with ANN

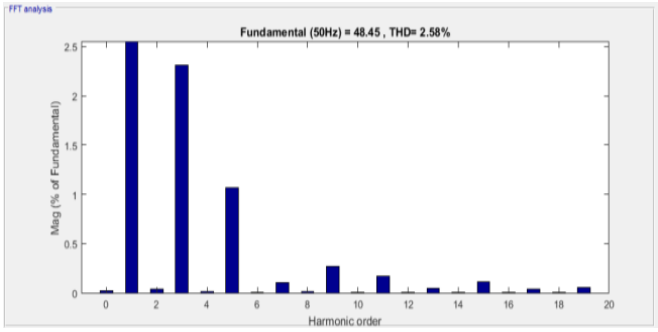

Fig.6. FFT analysis of load current with NN + PI

Figure.6. shows the simulated result of THD from the circuit having serially connected Active Power Filter with both neural network and PI controller

IV. Results and Discussion

The implemented scheme had its output with identified betterment figures in terms of THD determined when compensation factors were added in two levels; the percentage values obtained are kept in the table below. The tabular info below gives a significant support to the capability of Active Power Filter attached in series with the circuit along with Kalman Filter based neural network by reducing THD by 8.17% [1]. And when an additional PI controller was introduced to the system an additional 1.03% reduction was obtained in THD.

On the basis of results, the system with series APF based on ANN with PI controller are well implemented because it produces the minimal of THD and the optimum performance.

Table.1. Total Harmonic Distortion (THD) Values

Name of controller	THD in %
Without APF	11.78
With ANN without PI Controller	3.61
With both ANN and PI Controller	2.58

V. Conclusion

The harmonics created by a non-linear load was evidently diminished to a very low value in comparison to its situation where no recompensing part was attached. By utilizing a series Active Power Filter (APF) harmonics came under control and the addition of controlling feedback to APF through a Kalman dependent neural network, superiority of power percentage of harmonics reached as low as 3.61% from

11.78%. When the PI controller was attached to the system, additional betterment was apparent with the least harmonic distortion recorded as 2.58%. Subsequently, line current turns out to be sinusoidal, stable and in phase with the relevant source voltage and condenses the THD of the basis current lower than 5% limit. It is agreed from simulation sequel that the transient validation of the source current and DC part of capacitor voltage is enhanced for the PI controller with respect of the setting time and % augment in DC link voltage.

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