# Reduction Of Current Harmonics In 11 KV Distribution System Using Active Power Filter And Discrete Wavelet Transform

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***Abstract*—Current harmonic is a generally known pollution in power system as it reduces the efficiency of the system drastically and degrades the system's operability. Many mitigating techniques such as passive filters, active filters and adaline based decomposer and discrete wavelet transform (DWT) have been suggested to reduce current harmonics in power system. This paper presents the reduction of current harmonics in 11 kV distribution system using a hybrid of active power filter and discrete wavelet transform. An 11kV distribution system model was generated and modelled in Simulink, where the effect of current harmonics on the power system was analysed. The reduction of the current harmonics was achieved using a hybrid of the active power filter and DWT. The measure used as a factor in determining the magnitude of current harmonics in the power system is the total harmonic distortion (THD). The simulation results showed that the THD of the system before filtering is 20.4% and the THD after applying the hybrid of active filter and DWT is 0.54%. These results showed that a hybrid of active power filter and discrete wavelet transform is very effective in drastically reducing current harmonics in power systems.**

***Keywords—Current harmonics, Total Harmonics distortion, Active power filter, Discrete wavelet transform, Nonlinear load.***

## I. INTRODUCTION

Electrical equipment were operated mostly on sinusoidal current and voltage waveforms prior to the advent of power electronics. The use of harmonics producing electrical equipment such as uninterrupted power supply, personal computers and other nonlinear devices used in industrial, commercial and residential applications has greatly increased in recent years [1]. This has resulted in severe problems for electrical networks and power quality as supply current and voltage waveforms are no longer sinusoidal [2]. Harmonics are voltages or currents with frequencies that are a multiple of the fundamental frequency of the power system. The presence of harmonics has a notable effect on all sections of power systems such as generation, transmission and distribution [3].

These current harmonics cause operating problems in electrical power distribution systems such as overvoltage, premature ageing of insulation on grid components, heating up of wiring equipment which leads to power system losses [4].Researchers and power system engineers have made effort to provide solution to these harmonics problems in order to comply with the standard of Institute of Electrical and Electronics Engineers (IEEE) 519 – 2014 on the minimum total harmonics distortion (THD) of current and voltage bearable within the power distribution network[5]. Solutions to mitigate harmonics problems involve the use of filters (active and passive filters), magnetic wave shaping and network reconfiguration [6]. Passive and active filters are prominent among the harmonic reduction techniques. The passive filter has limitations such as series and parallel resonances, largeness in size and weight and cancellation of some selective harmonics due to the nonlinear loads [7]. Active power filters has improved on the drawbacks of passive filters, to become more dynamic and viable solution for the compensation of harmonics current drawn by nonlinear loads [8].

## II. REVIEW OF PREVIOUS WORKS

The undesirable effects and power quality problems caused by nonlinear loads was presented by [9]. The power quality with nonlinear load was analysed and total harmonic distortion (THD) in the system calculated by utilizing Fast Fourier Transform (FFT) method. The total harmonic distortion observed in every case was recorded for harmonics present in the current and voltage at the two buses. FFT analysis results with diode bridge rectifier and electric arc furnace shows a THD of 21.68% and 85.41% respectively. The author did not propose any mitigating scheme to reduce the current harmonics in the system [9].

The instantaneous active and reactive power (p-q method) based active filter was applied by [10] to filter current harmonics in three phase distribution system with three phase nonlinear loads. The three phase load voltages and currents of three phase rotating reference frame were transformed into two phase components of orthogonal reference frame by Clarke's transformation. The results obtained showed the THD in the system due to nonlinear load to be 17.37%, which exceeds the IEEE standards. When the active power filter was applied, the current harmonics reduced from 17.37% to 3.79% and the

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source current became almost sinusoidal. Though [10] reduced total harmonics distortion to the level of 3.79%, addition of more nonlinear loads can lead to increase of the THD hence the need to further reduce it to the possible minimum.

## III. METHODOLOGY

An 11kV distribution station model was modelled in Simulink, where the effect of current harmonics on the power system caused by nonlinear loads with emphasis on transformer was analyzed. This was achieved using daubechies four (db4) and level (14) model interface of the DWT model [11]. Current signal of the three phases generated from the power system model was exported to the MATLAB environment where the data was sent to the wavelet transform toolbox. The measure used as a factor in determining the magnitude of disturbance in the power system is the total harmonic distortion (THD) with filtration of the three phases of the distorted current signal performed with a hybrid of active filter and DWT.

The line diagram of the power system with the active filter and DWT filter is shown in Figure 1.

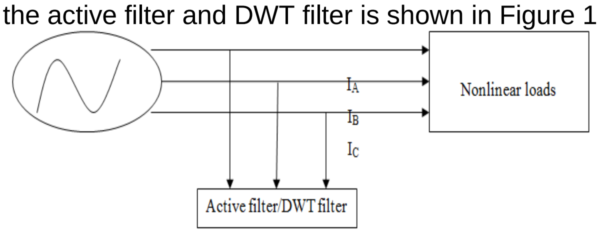


*Fig. 1. Power system with DWT analyzer /filter.*

The current signal contains high harmonics due to the effect of nonlinear loads. As such, an active filter was designed and applied to minimize the effect of the current harmonics. The three phase source voltages $V_a, V_b, V_c$ and the three phase load currents $I_a, I_b, I_c$ is transformed into the stationary frame $d-q$ to make them two phase quantities instead of three phase quantities using the Park's transformation as shown in Equations (1) and (2)respectively in [12].

$$\begin{bmatrix} V_{ds} \\ V_{qs} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} I_{ds} \\ I_{qs} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} \quad (2)$$

The nonlinear load current is transformed from the stationary frame into rotating frame with angle $\omega$ as shown in Equation (3).

$$\begin{bmatrix} I_d \\ I_q \end{bmatrix} = \begin{bmatrix} \cos\omega T & \sin\omega T \\ -\sin\omega T & \cos\omega T \end{bmatrix} \begin{bmatrix} I_{ds} \\ I_{qs} \end{bmatrix} \quad (3)$$

where $\omega$ is the angular frequency.

The synchronous reference current is decomposed into two segments by utilizing a basic low pass filter as shown in Equations (4) and (5) respectively.

$$I_d = I_d^{-} + \hat{I}_d \quad (4)$$
$$I_q = I_q^{-} + \hat{I}_q \quad (5)$$

where $I_d^{-}$ , $I_q^{-}$ are the direct current (DC) parts of $I_d$ and $I_q$ and $\hat{I}_d$ , $\hat{I}_q$ are the oscillating parts $I_d$ and $I_q$respectively.

After filtering, the DC parts ($I_d^{-}$, $I_q^{-}$)are suppressed and the oscillating parts ($\hat{I}_d$ , $\hat{I}_q$) appearing in the output of the extraction system are taken as the active filter reference currents ($I_{cd}^*, I_{cq}^*$).

The reference currents ($I_{ca}^*, I_{cb}^*, I_{cc}^*$) are obtained by applying inverse Park's transformation to the reference currents ($I_{cd}^*, I_{cq}^*$) as shown by Equations (6) and (7)respectively in [13].

$$\begin{bmatrix} I_{cd}^* \\ I_{cq}^* \end{bmatrix} = \begin{bmatrix} \cos\omega T & -\cos\omega T \\ \sin\omega T & \cos\omega T \end{bmatrix} \begin{bmatrix} \hat{I}_d \\ \hat{I}_q \end{bmatrix} \quad (6)$$

$$\begin{bmatrix} I_{ca}^* \\ I_{cb}^* \\ I_{cc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_{cd}^* \\ I_{cq}^* \end{bmatrix} \quad (7)$$

The active filter model is shown in Figure 2.

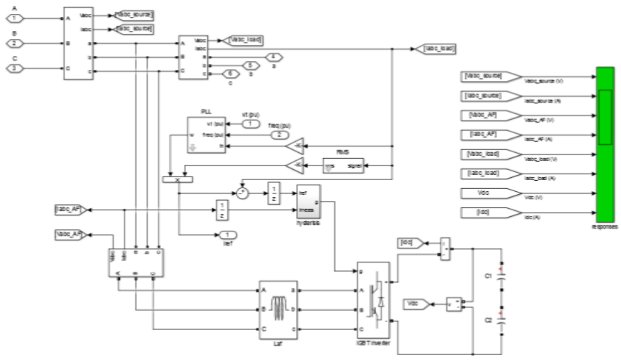

*Fig. 2. Active filter model*

DWT interface was used in analysing and filtering the current signal. The sample structure of the db4 l4 utilized in the filtration process is shown in Figure 3.

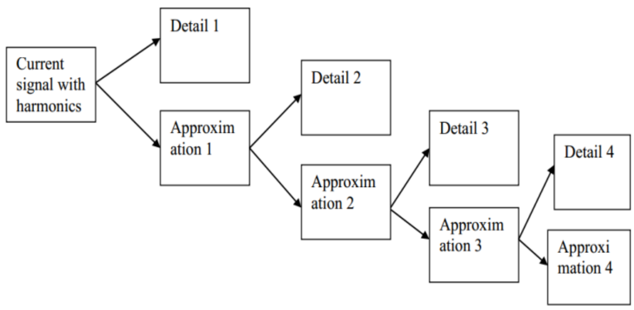


*Fig. 3. Daubechies 4 level 14.*

The current signal sent to the DWT model is being filtered into four levels (eight levels in our actual model) as shown in Figure 3, with the filtered signal being the fourth (eighth) approximation. The equation for the THD with respect to current signal is shown in Equation(8).

$$THD = \frac{I_H}{I_F} \quad (8)$$

where $I_H$ is the root mean square (RMS) of the harmonic current given as $\sqrt{I_2^2 + I_3^2 + \ldots + I_n^2}$ and $I_F$ is the fundamental current [14].

The Simulink model of the distribution system without filter is shown in Figure 4.

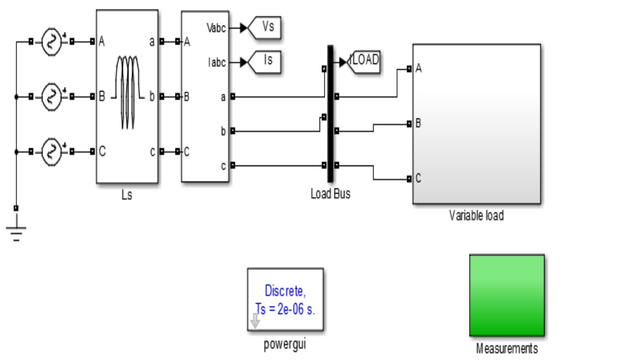


*Fig. 4. Power system feeder without filters.*

The Simulink model of the distribution system with the hybrid of active filter and DWT model is shown in Figure 5.

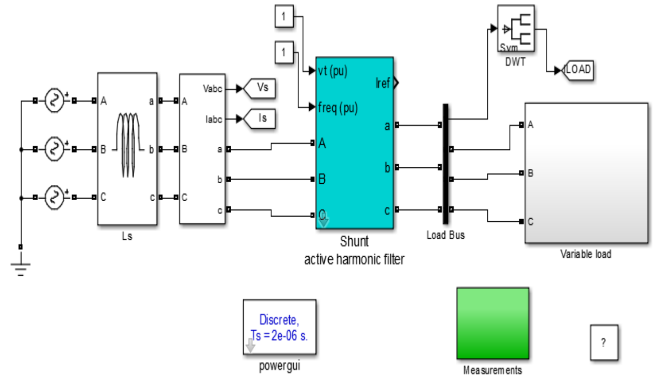


*Fig. 5. Power system model with both Active and DWT filter.*

## IV. RESULTS AND DISCUSSION

The Three – phase current signal of the 11kV power system without nonlinear load is shown in Figure 6.

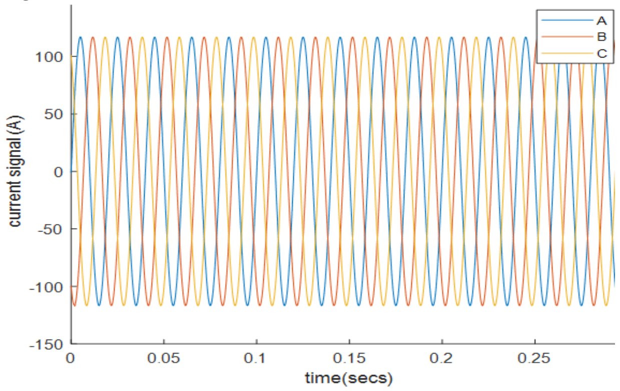


*Fig 6. Current signal of the 11kV power system.*

The 11 kV power system was monitored for 0.3 seconds as shown in Figure 4.4. From the figure, it can be seen that there was no harmonic distortion as the THD for the signal is approximately zero (0.0000953 for each of the phases).

When nonlinear load was added to the system, the three – phase current signal of the system without any filters is shown in Figure 7.

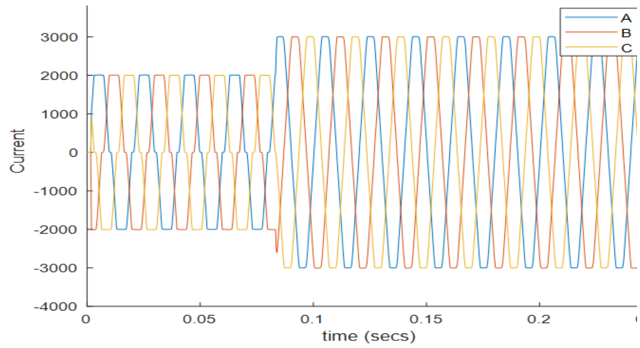


*Fig. 7. Current signal of the power system with filters.*

The THD for the power system without the filters is shown in Figure 8.

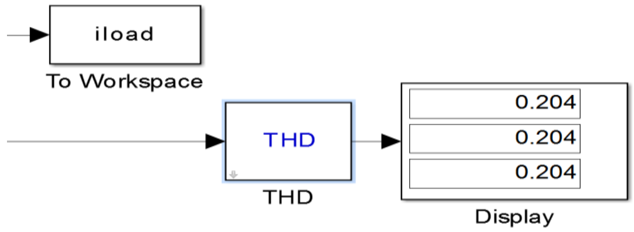


*Fig. 8. Total harmonic distortion for the power system without filter.*

It can be seen from Figure 8 that the power system feeder with the variable load without the any of the filter has THD of 20.4% for the three phases. This is above the IEEE recommendation of less than 5% as such, a harmonic filter is needed.

Figure 9 shows the waveform of the current signal when the hybrid of active filter and DWT was added to the power network.

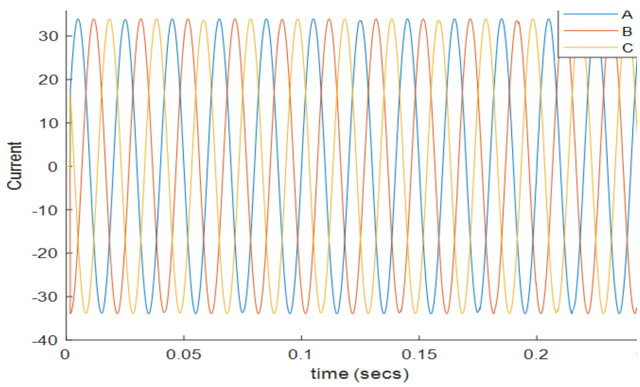


*Fig. 9. Current signal after applying the harmonic filter and DWT.*

Figure 10 shows the THD of the system when the hybrid of active filter and DWT was introduced to the power system feeder network.

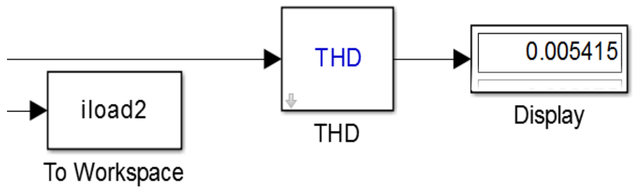


*Fig.10. The THD for the feeder with the hybrid of active filter and DWT.*

In Figure 10, it can be seen that the THD was reduced to 0.005415 (0.54%) with the introduction of db4 l4 DWT model.

## V. CONCLUSION

A power system having a THD of 0.54% implies that the possibility of harmonic distortion on the distribution power system is minute. Initially, without any filters, the system was operating at a THD of 20.4% which corresponds to the presence of high current harmonic in the system, enough to cause damage to the distribution power system network [15]. The application of the proposed hybrid of active filter and DWT achieved the reduction of the THD to 0.54% which falls within the IEEE stipulated threshold range. Hence, ensure safety operation of the power system network.

## REFERENCES

[1] Michaels, K. (1999). Fundamental of harmonics. http://ecmweb.com/mag/electric/ (Retrieved on 10th December, 2018).

[2] Nikunj, S. (2013). Harmonics in Power Systems — Causes, Effects and Control. http://usa.siemens.com/drives (Retrieved on 15th November, 2018).

[3] Lovinskiy, N. (2010). Effects of imbalances and nonlinear loads in electricity distribution system.MSc Dissertation. Lappeenranta University of Technology, Finland,71p.

[4] Rexel (2018). Harmonics in Electric Power Systems: Effects and Prevention. https://thegrid.rexel.com/en-us/knowledge/product (Retrieved on 20th January 2019).

[5] Tolbert, L., Hollis, H. and Hale, P. (1996). Survey of harmonics measurements in electrical distribution systems. Institute of Electrical and Electronic Engineering (IEEE) Annual Meeting held at San Diego, CA from 6th – 10th October 1996, pp. 2333-2339.

[6] Fuchs, E. and Masoum, M. (2008). Power quality of electric machines and power systems. Proceedings of the Eighth IASTED International Conference.

[7] Gabrielson, B. (2004). Basic Active and Passive Filters. https//www.semanticscholar.org (Retrieved on 30th April, 2019).

[8] Shah, A. and Vaghela, N. (2005). Shunt active power filter for power quality improvement in distribution systems. http//www.ijedr.org (Retrieved on January 20, 2019).

[9] Kullarkar, V. T. and Chandraka, V. K. (2017). Power quality analysis in power system with nonlinear load. *International Journal of Electrical Engineering.* 10(1); 33-45.

[10] Kota, K. (2016). Estimation and Filtering of Current Harmonics in Power System. MSc Thesis. National Institute of Technology Rourkela, India, 60p.

[11] Percival, D. and Walden, A. (2000). Wavelet Methods for Time Series Analysis. Cambridge University Press, Cambridge, U.K

[12] Pradhan A. (2011). Estimation and elimination of power system harmonics and implementation of kalman filter algorithm. MSc Dissertation. National Institute of Technology Rourkela, India, 79p.

[13] Sunitha, M. and Kartheek, B. (2013). Elimination of harmonics using active power filter based on dq reference frame theory. *International Journal of Engineering Trends and Technology*. 4(4):781-792.

[14] Radil, T. and Ramos, P. (2011).Methods for estimation of voltage harmonic components. http://www.intechopen.com/books (Retrieved on 25th March, 2019).

[15] Soni, M. and Soni, N. (2014). Review of causes and effect of harmonics on power system. *International Journal of Science, Engineering and Technology Research*, 3(2):1–7.