RESEARCH ARTICLE OPEN ACCESS

Improve Total Harmonic Distortion Factor and Mitigation Reactive Power in AC Railway Systems by Using Shunt Active Filter

Rashwan Ammon [1], Mohsen Daod [2]
Postgraduate student [1], Professor [2]
Department of Mechatronic
Faculty of Mechanical and Electrical Engineering
Tishreen University
Lattakia – Syria

ABSTRACT

The nonlinear load characteristics of electric trains produce high reactive power and harmonic currents, so that the total power factor becomes adversely affected. These power quality problems in the AC railway system can constrain the amount of power delivered to the locomotive and have a negative effect on themselves as well as on the public grid .In this research, we have been working to reduce reactive energy and harmonic distortion factor by using shunt active filter. A model of a single-phase electric train system was designed, and a model of a shunt active filter based on the d-q synchronous frame theory also was designed by using matlab\simulink .when testing the model it was found that the reactive power has decreased significantly and the harmonic distoration factor has become a standard permissible value. Therefore, we recognize the importance of using the effective filter when building of feeder lines for railways.

Keywords:- Shunt active filter , reactive power , harmonics , Synchronous Reference Frame Theory Control , total harmonic distortion factor**.**

I. INTRODUCTION

Development of modern populated cities makes public transportation an inevitable matter. Among all the transportation vehicles, electric railways having advantages such as high-speed transportation, safety, environment sustainability and production of no pollution have been developed increasingly. active filters are widely used to control harmonic distortion in power systems. They use power electronics converters in order to inject harmonic components to the electrical network that cancel out the harmonics in the source currents caused by non-linear loads . This paper presents a control system using active filters for harmonic current mitigation and reactive power compensation and follow the generated reference current quickly without any error. All the simulation work has been done on Matlab/Simulink [1].

II. CLASSIFICATION FILTER

Harmonic (voltage or current distortion) in distribution system increases with the increase of high rating nonlinear load. The filter design is becoming more and more essential for industrial distribution systems. This work examines the probability of manipulating the filtersize in such a way that the total investment cost, in which undesirable voltage profile must be corrected and harmonic, must be condensed within

the tolerable maximal value. Filter can be classified as passive filter and active filter [2].

A. Passive Filter

A passive filter is a kind of electronic filter that is made only from passive elements -- in contrast to an active filter, it does not require an external power source (beyond the signal). Since most filters are linear, in most cases, passive filters are composed of just the four basic linear elements -- resistors, capacitors, inductors, and transformers. More complex passive filters may involve nonlinear elements, or more complex linear elements, such as transmission lines[2,3,4].

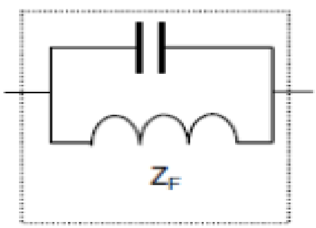


Fig.1 Series passive filter

B. Active Filter

Fig.2 shows the basic compensation principle of shunt active power filter. A voltage
source inverter (VSI) is used as the shunt active power filter. This is controlled so as to draw or supply a compensating current Ic from or to the utility, such that it cancels current harmonics on the AC side i.e. this active power filter (APF) generates the nonlinearities opposite to the load nonlinearities. This is the basic principle of shunt active power filter to eliminate the current harmonics and to compensate the reactive power. [2,4,5].

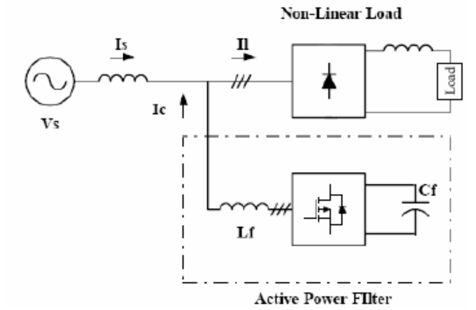


Fig.2 Active filter and Basic compensation principle

There are two main kinds of active filters. Shunt Active Filter is most widely used to eliminate current harmonics, reactive power compensation and balancing unbalanced currents. Only the control scheme makes difference either it work as an SAF or STATCOM. And this filter is used in this study (see figure 3) [1,2,6].

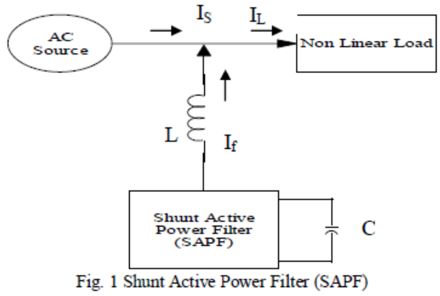


Fig.3 Shunt active filter

Series Active Filter is connected before the load in series with the main using matching transformer. In this filter is act as a controllable voltage source (see figure 4)[2,6,7].

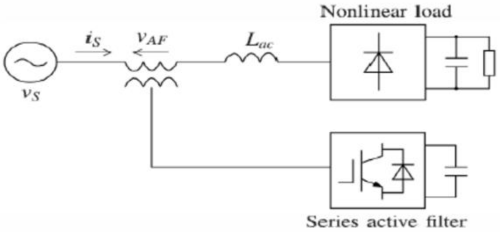


Fig.4 Series active filter

III. METHODS

A. Modeling of Overhead Line System (Catenary System)

The traction system considered in this thesis is 25KV AC single phase electrified railway system. The distribution circuit associated with this system is considered to constitute lumped circuits. The feeder line is represented by the circuit consisting of three π sections of resistance, R, in series with an inductance, L, and a parallel capacitance C [8,9].This feeder is modeled as three pi sections, each having a longitudinal impedance of 0.130081+j0.39238 Ω/km at 50 HZ and shunt capacitance of 0.011 µF/km feed from a substation step down (see figure5).

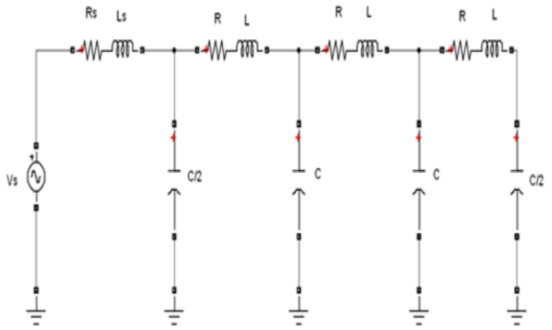


Fig.5 Modeling of the AC electrified railways system feeder line

B. Locomotive Load Modeling

In this study the load block is represented by a single phase bridge rectifier with RL-load, which generates the harmonic currents and the reactive power demand. The parameter values of bridge rectifier with RL-load is taken from reference [10] as R=20Ω and L=10mH [10]. Finally simulation will be done in several load conditions and different position of the locomotive .

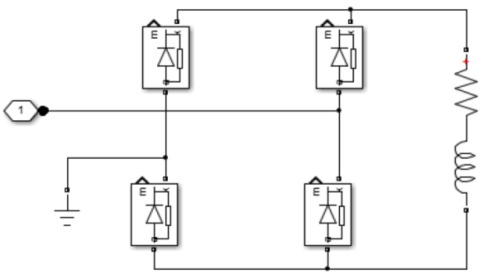


Fig.6 AC locomotive load

C. Modeling Control System

The design of the control system is based on the principle of the d-q synchronous reference frame theory.

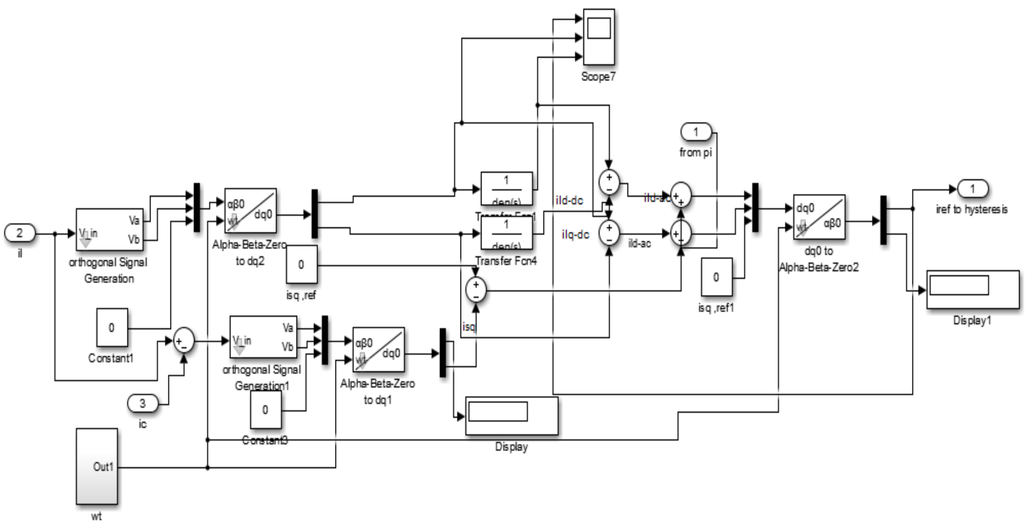


fig.7 Simulink model for the control system for the active filter

D. Modeling of Electric Traction System Without Installation of Active Filter

TABLE 1. System parameters for simulation without SAPF.

Voltage source	Nominal voltage	25KV
	Rated frequency	50Hz
Source impedance	LS	23.4mH
	RS	100Ω
Catenary line (double track)	Longitudinal impedance	0.13008+j0.392Ω/km
	Shunt capacitance	0.011µf/km
Locomotive load	Inductor	10mH
	Resistor	20Ω

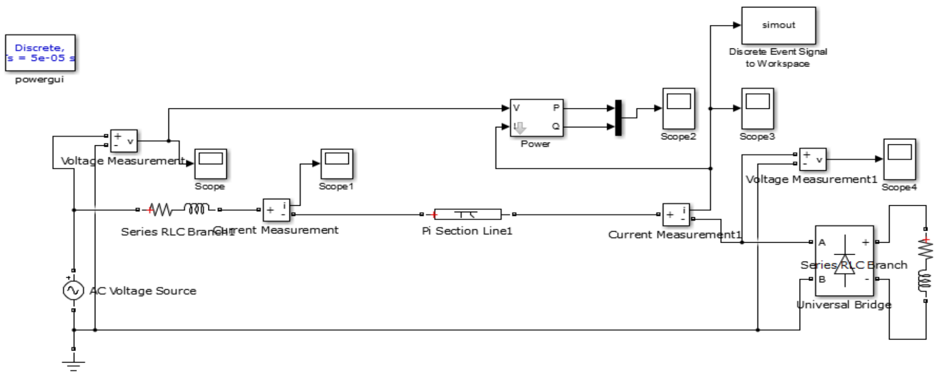


Fig.8 Simulink model of electric traction system without shunt APF

E. Modeling of Electric Traction System After Installation the Active Filter

TABLE 1. System parameters for simulation with SAPF

SAPF parameters	DC-link capacitor	Cdc = 2000µf
	Interfacing inductor	Lf =5mH
	DC-link reference voltage	VDC,ref =72kV
	PI-controller gain	KP =3, KI =2

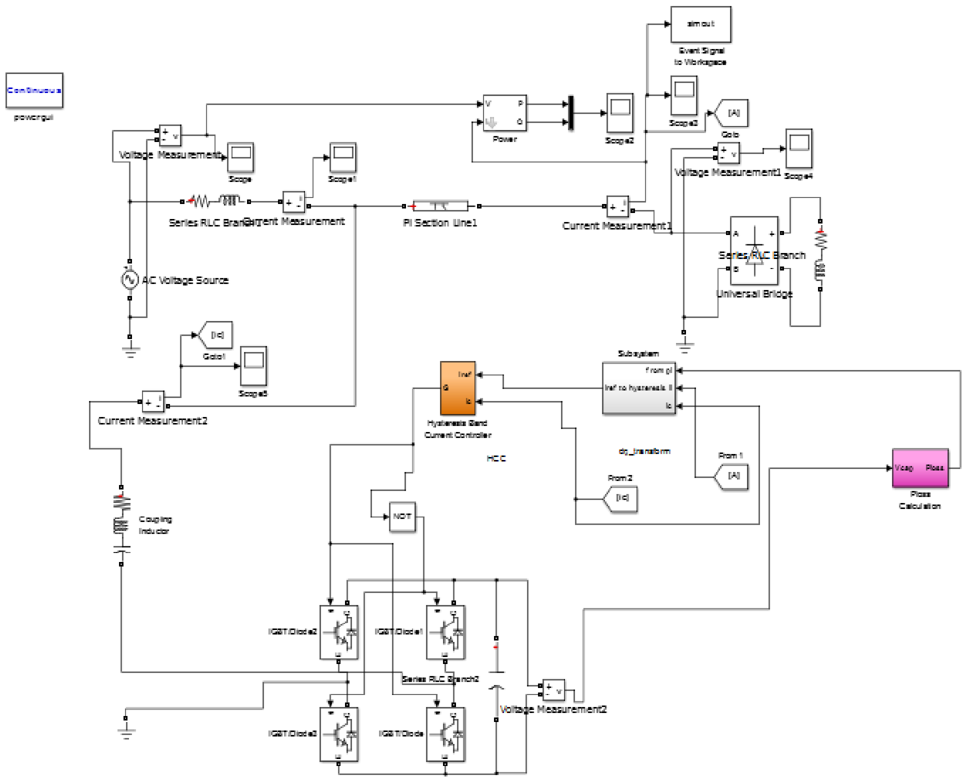
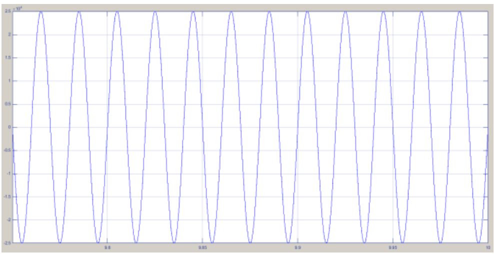


Fig.9 Matlab simulation model of electric traction system with shunt active filter

IV. RESULTS

Assuming a single train in the sector, where the train is located 10km away from the substation. The simulation results for voltage and current and for the active and reactive energy of the train and the content of the harmonic distortion without any type of compensation are shown below.



Figu.10 The source voltage without active filter system

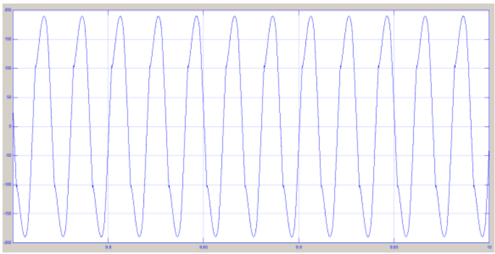


Fig.11 The source current without active filter system

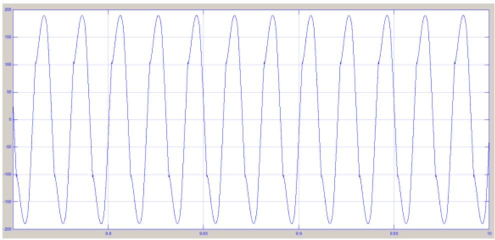


Fig.12 The load current without active filter system

The load current without the installation of shunt active filter system has a large amount of harmonics content (see figure 12).

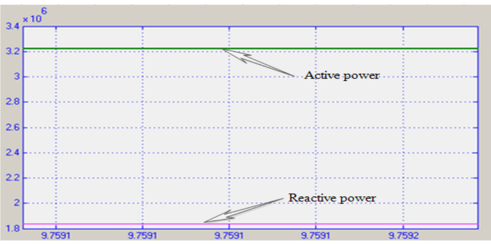


Fig13. Active and reactive energy supplied from the source without shunt active filter system

To illustrate the harmonic distortion in the current signal, we applied the FFT to the source signal without shunt active filter system

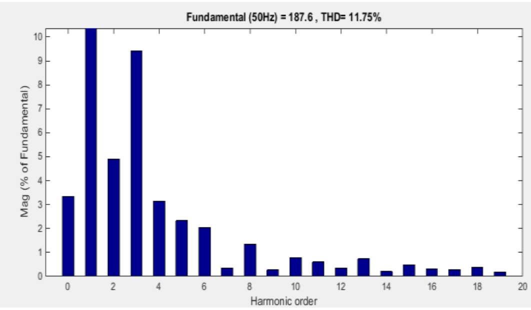


Fig.14 FFT Spectrum analysis of the source current without SAPF

When the SAPF is not installed the source current has large amount of the harmonic contents and is approximately 11.75% (see figure 14).

when shunt active filter system is installed:

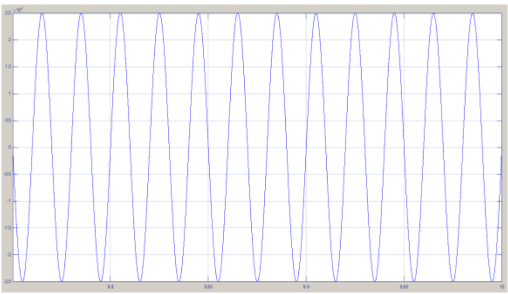


Fig.15 Source voltage after installation of shunt active filter system

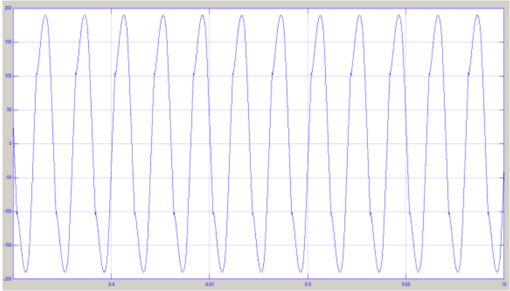


Fig.16 Source current after installation of shunt active filter system

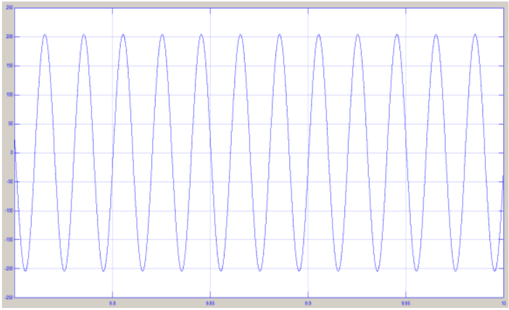


Fig.17 Load current after installation of shunt active filter system

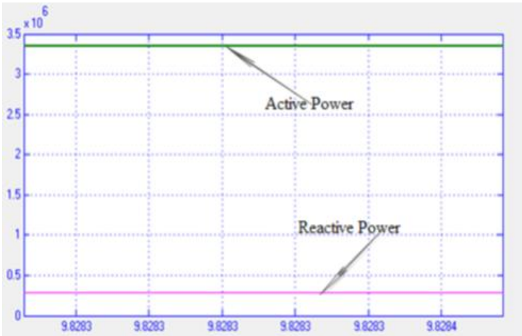


Fig.18 Active and reactive energy supplied from the source with shunt active filter system

The reactive energy was reduced because the active filter compensated it and improved the result (see figure 18).

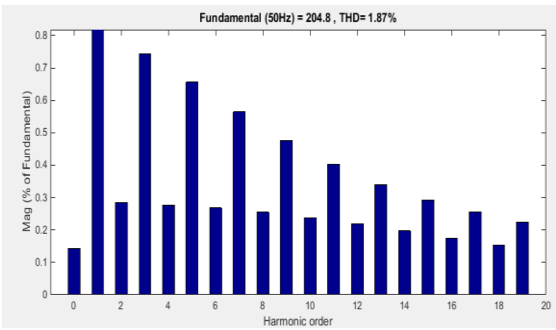


Fig.19 FFT spectrum analysis of the source current with SAPF

The value of the THD is equal to 1.87% and is within the standard permissible value (see figure19).

V. CONCLUSIONS AND RECOMMENDATION

- Using shunt active filter improvesTotal Harmonic Distortion factor.

- Using shunt active filterreduces reactive energy and improves energy quality.

- Importance of using shunt active filter When building feeding lines of electric trains.

REFERENCES

[1] Yousefi, s., Biyouki, M.M., and et al., *"Harmonic elimination of 25kv ac electric railways utilizing a new hybrid filter structure "*, AUT journal of electrical engineering, 49, 1, 2017, pp. 3-10.

[2] Chauhan, A., and Thakur, R., *" Power quality improvement using passive & active filters "* , International journal of engineering trends and technology, 36, 3, 2016, pp. 130-136.

[3] Dai, N.Y., Lao, K. W., and Wong, M.C.*A.*, *"Hybrid railway power conditioner for traction power supply system"*.Science and technology for power electronics J, 13, 2013, pp. 56-63 .

[4] Ghanizadeh, A. J., Hosseinian, S. H., and Gharehpetian, G. B., *"Harmonic disturbance compensating and monitoring in electric traction system"*, An international journal electrical and electronics engineering, 2, 3, 2013, pp. 47-59 .

[5] Natesan, P., and Madhusudanan, G., *"Compensation of power quality problems in traction power system using direct power compensator"*, International journal of innovative research in science, engineering and technology, 3, 3, 2014, pp. 62-78 .

[6] Thomas, R ., and et al., *"Reactive power compensation in railways using active impedance concepts"* IOSR journal of electrical and electronics engineering, 4, 1, 2013, pp. 7-23 .

[7] Sharma, S., and Patel, D., *"Modelling and simulation of FC-TCR for reactive power compensation using the matlab/simulink"*, International journal of advances in engineering & technolog , 1, 2015, pp. 102-116 .

[8] Jain, N ., and Gupta, A., *"Comparison between two compensation current control methods of shunt active power filter"*, International journal of engineering research and general science , 2, 5, 2014, pp. 113-124 .

[9] Arulkumar, A., and et al., *"PI controller based shunt active power filter with cascaded multilevel inverter"*, International journal of innovative research in science engineering and technology, 3, 3, 2014, pp. 33-40 .

[10] Ramya, M;., Sathyapriya, M., Hajira, A., and Kumar, P., *"Mitigation of line current harmonics using shunt active filter with instantaneous real and reactive power theory"*, IOSR journal of electrical and electronics engineering, 9, 2, 2014, pp. 156-172