New Approach to Universal Active Power Filter for Harmonics Elimination

Lavleen Dhalla
Dept. of Electrical Engineering,
G.H. Raisoni Institute of Engineering &
Technology for Women
Nagpur, India
lavleen1812@gmail.com

Sandeep S. Mahajan
Asst.Prof.,
Department of Electrical Engineering
G.H. Raisoni Institute of Engineering &
Technology for Women
Nagpur, India
sandeep.mahajan@raisoni.net

Abstract— The intent of this paper is to give information about a filter which is a collaboration of series and shunt active power filters for achieving the eminence quality of power without transformer. The obtained model emphasizes on controlling the circulating current in the system.

The proposed method utilizes the flexible and adaptive conditioning to normalize all the distortion, hence boosting and upgrading the quality of power made available to the end consumers. With the help of pulse width modulation proficiency it is proved that the enhanced structure has an improved total harmonics distortion than the previous one.

Keywords- *Universal Active Power Filter (UAPF), Total Harmonic Distortion(THD)*

*****

I. INTRODUCTION

Quality and reliability are the two very crucial issues of power transmission and distribution systems. The consumers are slowly depriving of both reliability and quality of power with the advancements in the technologies used by them. Because of the continuous growth of electronic equipment either for industrial or commercial use, there are several serious downfalls of increasing amount of distorted current into the transmission systems [1]. As these electronic appliances also known as “non-linear loads”, draws current rich in harmonic content has engaged the interest of many power electronics engineers. As a repercussion to these harmonic rich currents the supply voltage gets distorted at the intersection point [3].

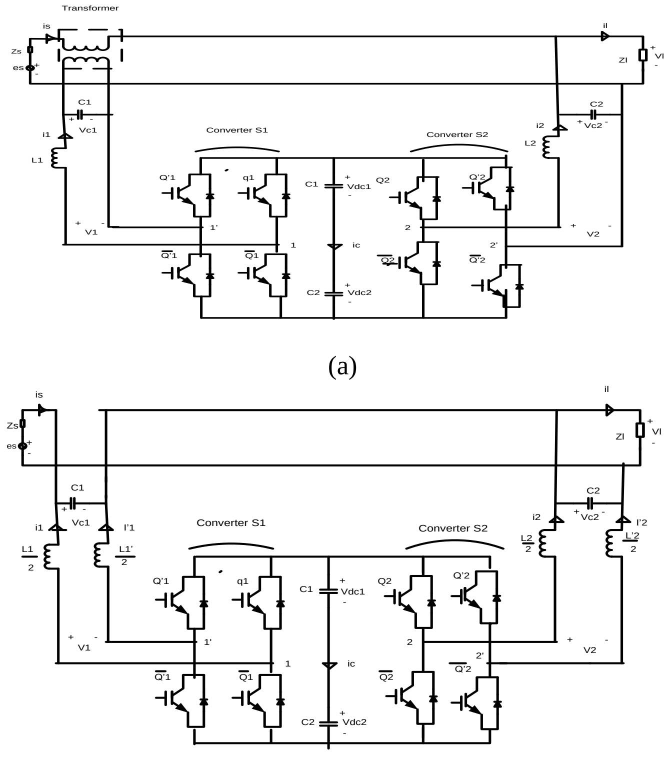
Also leading to acute problems like reactive power imbalance, drawing of uncontrolled neutral currents, less efficient networks, poor power factor, at the same time endangering other users at the end by interfering in their telecommunication web [4], also compelling the use of switching devices of higher ratings.

Therefore to overpower these problems IEC 1000-3-2 standards have been brought up [5].Hence keeping in view about preserving the quality of power and after the IEC standards it is mandatory that consumers must be made available with standard quality of waveforms of voltage and current. This can be achieved by having a voltage filtering system [6]. There are various methods available to combat these harmonic and phase distortions. Formerly compensation of these harmonic currents was provided with the help of L-C passive filters. But due to their limited nature and unfavorable properties like resonance, fixed compensation characteristics, large size, various tuning problems etc., they failed to cope up with the increasing disturbances in the transmission systems [5, 6]. After the failure of passive filters, experiments were done with the active filters. An active power filter for load harmonic compensation distinguishes the harmonics and infuses a compensating current to smooth out the harmonic currents flowing in the system. Hence, tackling the harmonics with help of active power filter proved out to be the better option since past few decades [7, 8]. The disturbances related to load voltage are abolished with the aid of series active filter. All the

Inconveniences in providing the sinusoidal currents are eliminated by the use of shunt active power filter. i.e. it extracts out the harmonic rich current, counterbalances the reactive power need, and supervises the dc-link voltages between the two in-phase converters.The collaboration of these narrated filters is collectively called a universal active power filter [9]. The functioning of Universal Active Power Filter has many vital objectives i.e. the current smoothing mode, voltage repairing mode, and power factor correction [2].For conventional layout, a transformer is needed by the series converter for connecting with the transmission line for isolation purpose. The use of transformer makes it inconvenient for the configuration to be used for small-scale environments keeping in view the cost and size related to it. Hence a transformer less Universal Active Power Filter configuration is discussed for single-phase applications.

II. PROPOSED CIRCUIT MODEL

The conventional structure is comprised of the supply system (vs, is), internal grid inductance (ls), load Zl (vl,il), converter 1 and converter 2 with a capacitor bank at the dc-link and the filters Z1 and Z2. Each converter is comprised of four switches as shown in the figure 1(a). In figure 1(b), the transformer used for coupling the converter 1 with the transmission line is removed to fulfill the stated objective.



(a)

(b)

Fig 1 Single –Phase UAPF; (a) conventional structure and (b) proposed transformer less structure.

In the balanced situation, the respective filter inductances are equal i.e. $L_1= L'_1$ and $L_2=L'_2$ .Therefore the circulating current in the above case becomes

$$V_o = V_s + [\left(\frac{r_1}{2}+\frac{r_2}{2}\right)+\left(\frac{l_1}{2}+\frac{l_2}{2}\right)p\,]\,i_o \quad (1)$$

Hence the proposed model is alike to the original filter consisting transformer. So, we can use equation (2) for regulating the load voltage and equation (3) to keep a track of the power factor and harmonics in the supply current(as taken reference from paper 1).

$$V_1 = V_{1o} - V'_{1o} \quad (2)$$

$$V_2 = V_{2o} - V'_{2o} \quad (3)$$

III. CONTROL STRATEGY

Fig. 2 shows the block diagram of the control strategy for the proposed structure. The control block diagram of the system is shown in fig (2).The controller Rc, which is a standard PI type, is used to adjust the voltage across the dc link capacitor i.e. V_{dc}.This controller provides the amplitude of the reference current I^*_s. The reference current i^*_s must be synchronized with θs for harmonic and power factor control. This is performed by the block GEN-g from a phase-locked loop scheme.

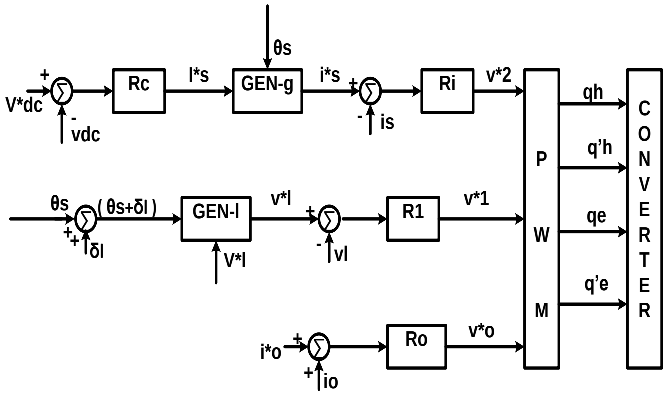


Fig.2. Control Block Diagram

The current i^*_s is generated as the result of synchronization with θ_s and the amplitude I^*_s. The controller indicated by the block R_i is used to implement the current controller which the input reference voltage v^*_2 used to compose the PWM strategies for compensating grid current.

The rated optimized angle δ_l plus the information θ_s and the defined load amplitude V^*_l, the instantaneous reference load voltage v^*_l can be determined. The block GEN-l uses the input information to generate the desired reference load voltage v^*_l. In order to compensate for the load voltage, the difference between the voltages v_{*l} and v_l is applied to the control block named R1 which generates the reference voltage signal V^*_1, which is then applied to the PWM strategies.

The controller Ro is used to control the homopolar current io, that determines voltage V^*_o responsible to minimize the effect of the circulating current io. All these reference voltages v^*_2 ,v^*_o ,v^*_1 are applied to the PWM block to determine the conduction state of the converter's switches.

IV. PWM STRATEGY

$V^{*'}_{1o}$, V^*_{1o}, $V^{*'}_{2o}$, V^*_{2o} (pole voltages) are used for the calculation of the PWM strategy for both the converters. Let the reference voltages given to the converters be V^*_1, V^*_2 and V^*_o. therefore we get

$$V^*_{1o} - V^{*'}_{1o} = V^*_1 \quad (4)$$

$$V^*_{2o} - V^{*'}_{2o} = V^*_2 \quad (5)$$

$$V^*_{1o} + V^{*'}_{1o} - V^*_{2o} - V^{*'}_{2o} = V^*_{1o} \quad (6)$$

The above equations are not sufficient for determination of the four pole voltages $V^{*'}_{1o}$,V^*_{1o}, $V^{*'}_{2o}$,V^*_{2o} .Hence we need to use an auxiliary variable V^*_a. V^*_a can be chosen equal to V^*_{amax}, V^*_{amin} or $V^*_{aavg}=(V^*_{amax} +V^*_{amin})/2$.

$$\text{Where} \quad V^*_{amax} = V^*_{dc}/2 - V^*_{max} \quad (7)$$

$$V^*_{amin} = -V^*_{dc}/2 - V^*_{min} \quad (8)$$

Where V^*_{dc} is the reference dc-link voltage, V^*_{max}= max v and V^*_{min}= minv with v={ V^*_1, 0, $V^*_1/2 + V^*_2/2 - V^*_o/2$, $V^*_1/2 - V^*_2/2 - V^*_o/2$ }.With the help of $V^*_{dc}/2$ maximum and minimum $-V^*_{dc}/2$ and the above equations, we can calculate the reference voltage V^*_a. After V^*_a is selected, we can calculate all the pole voltages with the help of equations below and choosing $V^{*'}_{1o}=V^*_a$, we get

$$V^*_{1o}= V^*_1+ V^*_a \quad (9)$$

$$V^{*'}_{1o}=V^*_a \quad (10)$$

$$V^*_{2o}= \frac{V*_1}{2} + \frac{V*_2}{2} - \frac{V*_o}{2} + V^*_a \quad (11)$$

$$V^{*'}_{2o}= \frac{V*_1}{2} - \frac{V*_2}{2} - \frac{V*_o}{2} + V^*_a \quad (12)$$

Finally, by comparing the pole voltages with a high-frequency triangular carrier signal we can generate the gating signals.

V. MATLAB SIMULATED RESULTS

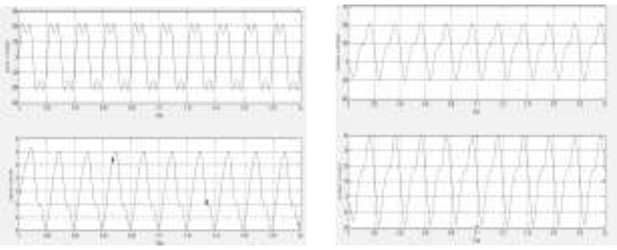
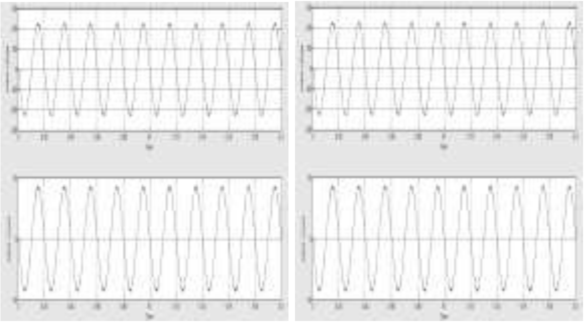
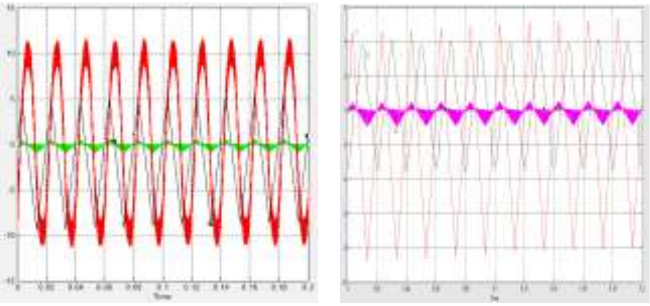

(a) (b)

Fig 3 Simulated results for a linear load ; (a) input voltage and current (b) output voltage and current.


(a) (b)


(c) (d)

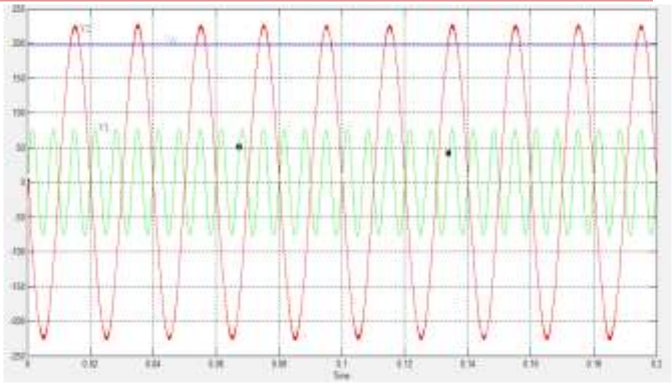
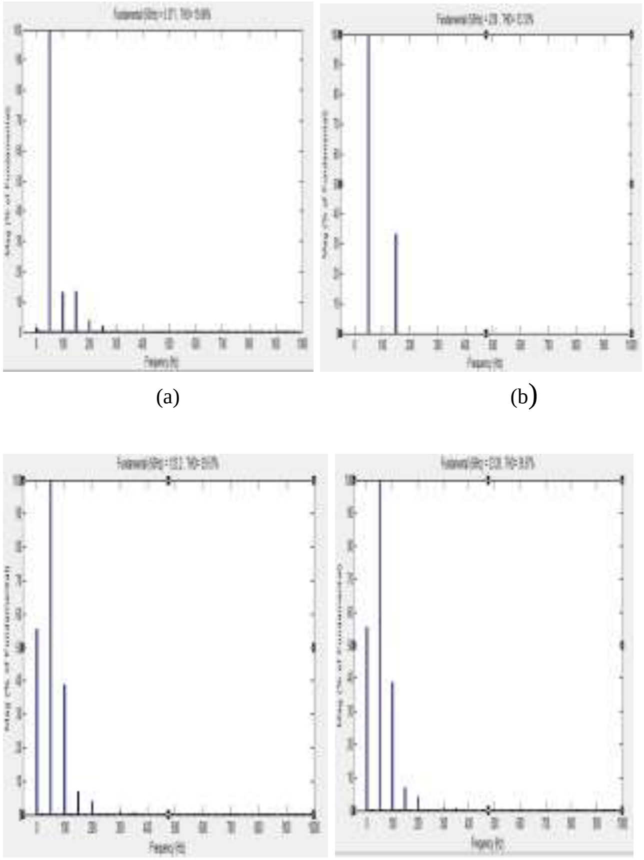

(e)

Fig 4 Simulated results for transformer less structure for linear load; (a) input voltage and current (b) output voltage and current (c) converter 1 currents (i1,i'1,io) (d) converter 2 currents (i2,i'2,io) (e) converter voltages (V1,V2,Vdc).

Both the structures are simulated using MATLAB SIMULINK model .Various results for the two structures are shown using


(a) (b)

(c) (d)

Fig 5 Spectral Analysis for the conventional structures; (a) of the input voltage (b) of the input current (c) of the load voltage (d) of the load current

.

Linear load for demonstrating the feasibility of the proposed Structure. The simulated results for linear loads are shown for conventional structure in fig 3.Fig 3(a) shows the input voltage and current of the grid. The grid the voltage was inserted along with the third harmonics of 33% from fig 3(b) it is shown that the disturbances due to the third harmonics in the supply voltage and current are eliminated but not so effectively.

Similarly, various simulated results for linear load conditions are presented in figure 4.

From presented results, it is noted that even with the presence of third harmonics at the supply side, the load voltage and current are sinusoidal with low harmonics content. Both the converter currents are shown in fig 4(b) and 4(c). Also in fig 4(e) the voltage at the dc-link is shown which must be maintained constant reducing the converter losses.

In addition to the above results the spectral analysis is also shown for both the conditions. As can be seen from the spectral analysis presented above for the conventional structure implies that the structure is not much effective in eliminating the harmonics.

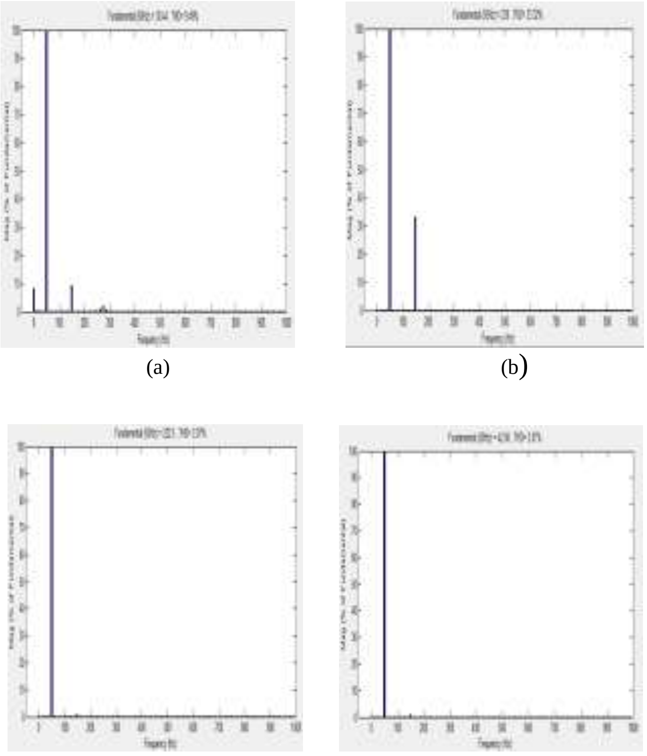

(a) (b)
(c) (d)

Fig 6 Spectral Analysis for the proposed structure; (a) of input voltage (b) of input current (c) f output voltage (d) of output current.

It is clear from the above spectral analysis of the proposed third harmonics have been removed effectively with a low value.

VI. CONCLUSIONS

A suitable control strategy, including the PWM technique has been developed for the proposed UAPF for linear load. In this way, it has been shown that the proposed structure presents low THD in comparison to the traditional structure. Also it has been shown that the circulating current has been minimized and the power factor is also improved.

VII. ACKNOWLEDGEMENT

I am thankful to my guide Prof. S.S.Mahajan for his guidance and support for this paper. I owe a great to my parents, for their continuous encouragement and moral support.

REFERENCES

[1] Welflen Ricardo Nogueira Santos, Edison Roberto Cabral da Silva, Fellow, IEEE, Cursino Brand ˜ao Jacobina, Senior Member, IEEE, Eisenhawer de Moura Fernandes, Alexandre Cunha Oliveira, Rafael Rocha Matias, Dalton Franc¸a Guedes Filho, Otac´ılio M. Almeida, And Patryckson Marinho Santos, " The Transformer less Single-Phase Universal Active Power Filter for Harmonic and Reactive Power Compensation", IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 29, NO. 7, JULY 2014 3563.

[2] R. Strzelecki, H. Tunia, M. Jarnut, G. Meckien, and G. Benysek (2003), "Transformer less 1- Phase active power line conditioners, " in Proc. Power Electron. Spec. Conf., 2003 PESC 2003. IEEE 34th Annu., 2003, vol. 1,pp. 3211–326

[3] P. Salmerón and S. P. Litrán(2010)," Improvement of the Electric Power Quality Using Series Active and Shunt Passive Filters " IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 25, NO. 2, APRIL 2010

[4] B. Singh, K. Al-Haddad , and A. Chandra, "A review of active filters for power quality improvement," IEEE Trans. Ind. Electron., vol. 46, no. 5,pp. 960–971, Oct. 1999.

[5] Mauricio Aredes Klemens Heumann Edson H. Watanabe, "An Universal Active Power Line Conditioner" IEEE Transactions on Power Delivery, Vol. 13, No. 2, April 1998.

[6] H. AKAGI, " Modern active filters and traditional passive filters," Bulletin Of The Polish Academy Of Science Technical Sciences Vol. 54, No. 3, 2006.

[7] Hirofumi Akagi, "New Trends in Active Filters for Power Conditioning," IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL 32, NO 6, NOVEMBERDECEMBER 1996

[8] Ahmed M. A. Haidar, Chellali Benachaiba, Faisal A. F. Ibrahim , Kamarul Hawari, "Parameters Evaluation of Unified Power Quality Conditioner," EIT020.

[9] Saheb Hussain MD 1, K. Satyanarayana2 , B .K .V .Prasad3 , " POWER QUALITY IMPROVEMENT BY USING ACTIVE POWER FILTERS," International Journal Of Engineering Science & Advanced Technology Volume - 1, Issue - 1, 1 – 7.