A Comparative Investigation on Control for a Three-Phase Shunt Active Power Filter

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Abstract - From the last decade the power electronic converter identified with DC energy source came into focus with the increasing worldwide interest in the electronic gadgets. Power quality has turned in to a major research topic in power distribution systems due to a significant increase of harmonic pollution caused by proliferation of nonlinear loads for example, diode rectifiers, exchanging power provided and different sorts of line associated power converters and so forth. A suitable voltage regulator is required for the power supply of these electronics devices. These power electronic loads inject harmonic currents and reactive power into the supply grid having significant impact on voltage and power quality, thus polluting the electric distribution network and also effect the operation of power electronic interface. The shunt APF is perceived as a practical answer for consonant compensation in low and medium power systems. This work present an extensive literature survey on power control and harmonic suppression using three phase active power filter.

Index- Terms: Power control , Power Filters, Active power filter, Harmonic Suppression, Power quality control.

I. INTRODUCTION

The presence of harmonics due to widespread use of power electronic loads results in an increased deterioration of the power systems voltage and current waveforms, because of line impedance, the voltage at the point of common coupling (PCC) is no longer remains sinusoidal [6]. Figure 1.1 shows the impact of non-linear loads on distribution power system. With a network then dominated by nonlinear components (power electronics coupling for generators and loads), non-sinusoidal regimes will be a common situation. It will be then the task of the power electronics interfaces to provide for the control features that can achieve an acceptable level of power quality required by the system operator or standards (given sensitive loads connected to the system).

Among the features requested, sinusoidal currents, constant power supply, minimum current or minimum reactive power flow and load unbalance compensation will be the most demanding ones. But this work is concentrated on harmonics and unbalance compensation under unbalanced and distorted regimes.

The harmonics disturbances in the power supply are caused by the nonlinear characteristic of the power electronic non-linear components that are used at the interface facility between DRS and main power grid and at the load end as well. Due to the advantages in efficiency and controllability of power electronic devices, their applications can be found in almost all power levels [7]. Hence, power harmonics has become a serious problem.

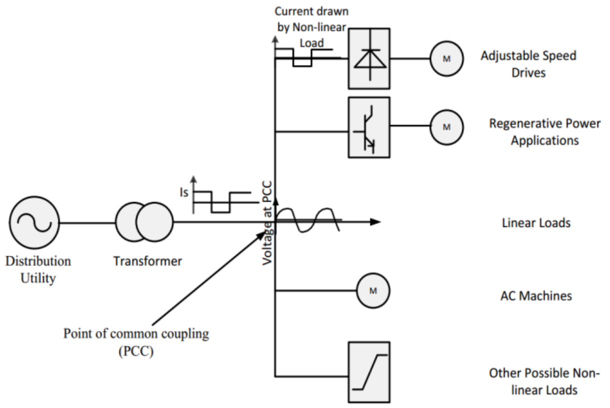

Figure 1.1 Voltage at PCC due to non- linear loads.

Generally Shunt APF is designed to eliminate the majority of the harmonic current orders. As is defined in IEEE 519-1992, harmonic voltage is created when harmonic current travels through the impedance of the electrical system toward the lowest impedance point [2]. This study has been focused on improvement of harmonic compensations for single phase system with battery charger as a load. The APF consists of voltage source inverter (VSI) with DC capacitor as an energy storage device. The DC bus capacitor voltage should be controlled to supply the power losses of filter on the system, providing that more effective filtering and reactive power compensation obtained [3]. Hysteresis current control has been used to generate switching signals for the inverter. Hysteresis control technique is used in Shunt APF applications.

The main objective of a power system is to deliver reliable power to loads with good power quality, e.g. to provide sinusoidal voltage at a fairly constant magnitude throughout the system. Important power quality issues include regulating power factor and current harmonics which result from nonlinear or inductive loads.

II. SHUNT ACTIVE POWER FILTER

The main purpose of the APF installation by individual consumers is to compensate current harmonics or current imbalance as well as power factor improvements of their own harmonic-producing loads. Besides that, the purpose of the APF installation by the utilities is to compensate for voltage harmonics, voltage imbalance or provide harmonic damping factor to the power distribution systems The basic principle of APF is to produce specific currents components that cancel the harmonic components draw by the nonlinear load. The APF act as a harmonic source which is same in magnitude but opposite in direction to the harmonic caused by the nonlinear load. Reactive power required by the load also provided by APF and thus improve the power factor of the system. APF consists of an inverter with switching control circuit. The inverter of the APF will generate the desired compensating harmonics based on the switching gates provided by the controller. This connection is most widely used in active filtering applications. It consists of a voltage or current source configurations. The voltage source inverter (VSI) based shunt APF is the most common type used today due to its well-known topology and straight forward installation procedure. Figure 2.1 show a configuration of a VSI based shunt APF. It consists of a interfacing inductors (L_f) and VSI which is combination of a DC-bus capacitor (Cf) and power electronic switches. Shunt APF acts as a current source, compensating the harmonic currents due to nonlinear loads. The operation of shunt APF is based on injection of compensation current which is equals to the distorted current, thus eliminating the original distorted current.

Coming to the unbalanced load issue, the presence of fundamental negative sequence component in the load currents can affect the APF system performance. This negative sequence, if not blocked by the APF current reference generator, will produce a fundamental negative sequence component in the APF currents due to the proportional gain of the current controller.

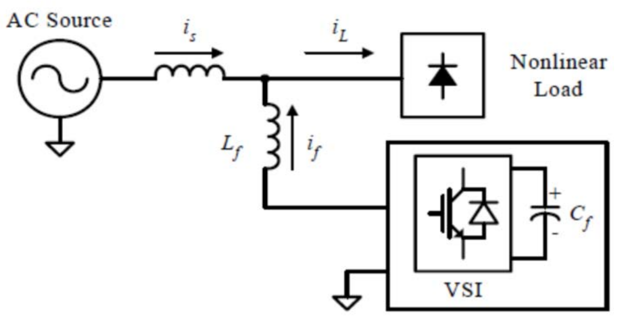

Figure 2.1 Configuration of a VSI based Shunt APF [8].

That will produce a 2nd order ripple in the DC-link voltage, which will generate harmonic distortion in the source currents. Therefore, if the unbalanced load compensation is not required, the circulation of the fundamental negative sequence currents in the APF must be completely blocked to avoid distortion of the source currents.

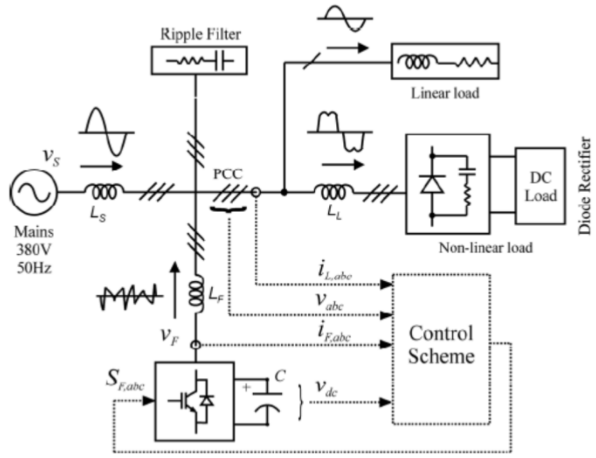

Figure 2.2 Basic current harmonic compensation scheme of an unbalanced load using a shunt APF [9].

III. LITERATURE REVIEW

R. Guzman, L. G. de Vicuña, J. Morales, M. Castilla and J. Miret,[1] This exploration presents a robust model-based control in natural frame for a three-phase shunt active power filter. For the proposed control method, a linear converter model is deduced. Then, this model is used in a Kalman filter (KF) to estimate the system state-space variables. Even though the states estimation do not match the variables of the real system, it has allowed to design three sliding-mode controllers providing the following features to the closed-loop system: 1) robustness due to the fact that control specifications are met independently of any variation in the system parameters; 2) noise immunity, since a KF is applied; 3) a lower total harmonic distortion (THD) of the current delivered by the grid compared with the standard solution using measured variables; 4) the fundamental component of the voltage at the point of common coupling is estimated even in the case of a distorted grid; and 5) a reduction in the number of sensors. Thanks to this solution, the sliding surfaces for each controller are independent. This decoupling property of the three controllers allows using a fixed switching-frequency algorithm that ensures a perfect current control. Finally, experimental results validate the proposed control strategy and illustrate all its interesting features.

A. Farooq and A. H. Bhat, [2] This exploration deals with the performance evaluation of a three-phase, Shunt Active Power Filter for Power Quality Improvement. Power Quality problems can be addressed using Shunt Active Power Filters. A simulation model based on mathematical model of a three-phase, Shunt Active Power Filter has been developed. The results show an inherent power quality improvement in terms of reduced Total Harmonic Distortion (THD) of source current. It also exhibits Power Factor Correction (PFC) properties to a large extent as the source current and source voltage are in phase.

M. Haddad, S. Ktata, S. Rahmani and K. Al-Haddad,[3] A nonlinear control for a three-phase seven-level Neutral Point Clamped (NPC) inverter based Shunt Active Power Filter (SAPF) is proposed in this exploration. The aim of this system is to mitigate the undesired reactive power and current harmonics created by nonlinear loads. The model of the Multilevel Shunt Active Power Filter (MSAPF) is divided into two subsystems including a Multi-Input Multi-Output (MIMO) subsystem defined by two current dynamics inner loop and a Single-Input Single-Output (SISO) subsystem defined by the DC capacitors voltage dynamic outer loop. The exact feedback linearization approach is applied to decouple the current dynamics. A proportional-integral controller is used to ensure DC bus voltage regulatio. An extensive simulation study using the "Power system Blockset" is tested to prove the viability of the nonlinear control.

Table 1: Summary of Literature Review

SR. NO.	TITLE	AUTHOR	YEAR	APPROACH
1	Model-Based Control for a Three-Phase Shunt Active Power Filter,	R. Guzman, L. G. de Vicuña, J. Morales, M. Castilla and J. Miret,	2016	A robust model-based control in natural frame for a three-phase shunt active power filter.
2	Performance evaluation of a three phase shunt active power filter for power quality improvement,	A. Farooq and A. H. Bhat,	2015	A three-phase, Shunt Active Power Filter for Power Quality Improvement
3	A nonlinear control strategy for three-phase seven-level Shunt Active Power Filter,	M. Haddad, S. Ktata, S. Rahmani and K. Al-Haddad,	2015	A three-phase seven-level Neutral Point Clamped (NPC) inverter based Shunt Active Power Filter (SAPF)
4	Instantaneous reactive power theory for real time control of three-phase shunt Active Power Filter (SAPF),	N. M. Chamat, V. S. Bhandare, S. P. Diwan and S. Jamadade,	2014	SAPF is found to be effective in reducing total harmonic distortion (THD)
5	A new topology and control strategy for extraction of reference current using single phase SOGI-PLL for three-phase four-wire Shunt Active Power Filter,	H. K. Yada and M. S. R. Murthy,	2014	Single-phase SOGI-PLL for a three - phase four-wire system.
6	An enhanced current control strategy for three-phase shunt active power filters with repetitive controllers,	Q. N. Trinh and H. H. Lee,	2013	An enhanced current controller for three-phase shunt active power filters (SAPFs)
7	An Advanced Current Control Strategy for Three-Phase Shunt Active Power Filters	Q. N. Trinh and H. H. Lee,	2013	Advanced control strategy to enhance performance of shunt active power filter (APF).

N. M. Chamat, V. S. Bhandare, S. P. Diwan and S. Jamadade,[4] Now-a-days use of nonlinear loads in industries has been increased tremendously which are the source of harmonic currents to be injected in supply system. These harmonics creates power quality issue. The most popular solution to eliminate these harmonics is Shunt Active Power Filter (SAPF) because SAPF can eliminate harmonics easily, overcome voltage sag and improves power factor. SAPF is found to be effective in reducing total harmonic distortion (THD) to acceptable level. Reference current generation is the heart of APF In this exploration reference current generation using instantaneous reactive power (IRP) theory is presented. IRP theory is widely used to control active power filters (APFs). Modeling of this technique is implemented in MATLAB/simulink. The system is experimentally implemented using DS1104 card of dSPACE system.

H. K. Yada and M. S. R. Murthy,[5] This exploration describes an advanced controller to enhance the performance of SHAPF (Shunt Active Power Filter) to improve power quality based on single-phase SOGI-PLL for a three - phase four-wire system. The SHAPF performs various functions such as harmonics elimination, reactive power and neutral current compensation and load balancing under distorted load conditions with self supporting DC bus voltage. This control algorithm is used to extract the fundamental values of active and reactive components of load currents for estimating of reference currents based on three single-phase SOGI-PLLs. The main reason to adopt SOGI-PLL is its capability of current tracking for compensation. The control algorithm is tested and performed using MATLAB/Simulink with load unbalancing and its performance is found satisfactory.

Q. N. Trinh and H. H. Lee,[6] This exploration proposes an enhanced current controller for three-phase shunt active power filters (SAPFs). The proposed current controller is composed of a proportional-integral (PI) controller and two repetitive controllers (RCs) where the RCs are designed with a delay time of one sixth of the fundamental period (T/6). With the combination of these RCs, the SAPF can offer a good harmonic compensation performance under various types of nonlinear loads (three-phase or single-phase nonlinear loads). As consequence, the supply current is effectively compensated to be sinusoidal despite the nonlinear load current. In addition, the proposed SAPF also can provide a fast dynamic response under load variations to maintain the supply current sinusoidal. The effectiveness of the proposed controller is verified through simulation results.

Q. N. Trinh and H. H. Lee,[7] This exploration proposes an advanced control strategy to enhance performance of shunt active power filter (APF). The proposed control scheme requires only two current sensors at the supply side and does not need a harmonic detector. In order to make the supply currents sinusoidal, an effective harmonic compensation method is developed with the aid of a conventional proportional-integral (PI) and vector PI controllers. The absence of the harmonic detector not only simplifies the control scheme but also significantly improves the accuracy of the APF, since the control performance is no longer affected by the performance of the harmonic tracking process. Furthermore, the total cost to implement the proposed APF becomes lower, owing to the minimized current sensors and the use of a four-switch three-phase inverter. Despite the simplified hardware, the performance of the APF is improved significantly compared to the traditional control scheme, thanks to the effectiveness of the proposed compensation scheme. The proposed control scheme is theoretically analyzed, and a 1.5-kVA APF is built in the laboratory to validate the feasibility of the proposed control strategy.

IV. PROBLEM STATEMENT

The impact of harmonics on the power system can be categorized into two group; short term effects and long term effects. The short term effects are usually noticeable and are related to excessive voltage distortion such as nuisance tripping of sensitive loads or overheating of transformer. However, the long term effects will show the impact after certain period and it is undetected. This long term effects are usually related to increased resistive losses or voltage stress. Capacitors in power systems might fail or capacitor fuses may blow due to the overvoltage stress on dielectric. The existence of harmonics in power system can cause overheating of conductor and increase losses [8]. Besides this, harmonics can cause low power factor and lead to higher losses in power system. Moreover, the high cost caused by the poor power quality is also an important issue [9]. A useful approximation has been adopted to reduce the computational time needed for the KF implementation, reducing the total time employed for the control algorithm. In addition, a fixed switching-frequency algorithm has been used to improve the switching spectrum of the controllers [1].

V. CONCLUSION

Among the reasons for the poor power quality,, the harmonics are incorporated as the reason which contributes the larger part of power failure. For this situation, numerous efforts have been proposed to solve the harmonics problem. Various control schemes has been investigated in this work for power control and power quality improvement. The three phase shunt active filter with controller based on instantaneous active and reactive power. Shunt active filters are normally implemented with PWM voltage source inverter (VSC) as it has high efficiency, low initial cost, and smaller physical size which make it better over PWM current source converter (CSC) . The performance of the active filter heavily relies upon the designed qualities of the current controller, the method implemented to generate the gating signals for the VSI. Mostly PWM strategies are employed in active filter controller to modulation the current controller.

REFERENCES

[1] R. Guzman, L. G. de Vicuña, J. Morales, M. Castilla and J. Miret, "Model-Based Control for a Three-Phase Shunt Active Power Filter," in IEEE Transactions on Industrial Electronics, vol. 63, no. 7, pp. 3998-4007, July 2016.

[2] A. Farooq and A. H. Bhat, "Performance evaluation of a three phase shunt active power filter for power quality improvement," 2015 International Conference on Recent Developments in Control, Automation and Power Engineering (RDCAPE), Noida, 2015, pp. 214-219.

[3] M. Haddad, S. Ktata, S. Rahmani and K. Al-Haddad, "A nonlinear control strategy for three-phase seven-level Shunt Active Power Filter," 2015 16th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA), Monastir, 2015, pp. 576-581.

[4] N. M. Chamat, V. S. Bhandare, S. P. Diwan and S. Jamadade, "Instantaneous reactive power theory for real time control of three-phase shunt Active Power Filter (SAPF)," 2014 International Conference on Circuits, Power and Computing Technologies [ICCPCT-2014], Nagercoil, 2014, pp. 792-796.

[5] H. K. Yada and M. S. R. Murthy, "A new topology and control strategy for extraction of reference current using single phase SOGI-PLL for three-phase four-wire Shunt Active Power Filter," 2014 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), Mumbai, 2014, pp. 1-6.

[6] Q. N. Trinh and H. H. Lee, "An enhanced current control strategy for three-phase shunt active power filters with repetitive controllers," 2013 International Conference on Electrical Machines and Systems (ICEMS), Busan, 2013, pp. 1543-1548.

[7] Q. N. Trinh and H. H. Lee, "An Advanced Current Control Strategy for Three-Phase Shunt Active Power Filters," in IEEE Transactions on Industrial Electronics, vol. 60, no. 12, pp. 5400-5410, Dec. 2013.

[8] Mohd Izhar Bin A Bakar, "Active Power Filter with Automatic Control Circuit for Neutral Current Harmonic Minimization Technique", june 2007.

[9] L.R. Limongi, D. Roiu, R. Bojoi, A. Tenconi, ''Analysis of active power filters operating with unbalanced loads'', IEEE Transactions on Power Electronics, Sep.2009, pp: 584 – 591.

[10] C.-J. Wu, J.-C. Chiang, S.-S. Yen, C.-J. Liao, J.-S. Yang, and T.-Y. Guo, "Investigation and mitigation of harmonic amplification problems caused by single-tuned filters," IEEE Trans. Power Del., vol. 13, no. 3, pp. 800– 806, Jul. 1998.

[11] S. Rahmani, A. Hamadi, and K. Al-Haddad, "A Lyapunov-function-based control for a three-phase shunt hybrid active filter," IEEE Trans. Ind. Electron., vol. 59, no. 3, pp. 1418–1429, Mar. 2012.

[12] S. Mariethoz and A. Rufer, "Open loop and closed loop spectral fre- quency active filtering," IEEE Trans. Power Electron., vol. 17, no. 4, pp. 564–573, Jul. 2002.

[13] V. Corasaniti, M. Barbieri, P. Arnera, and M. Valla, "Hybrid active filter for reactive and harmonics compensation in a distribution network," IEEE Trans. Ind. Electron., vol. 56, no. 3, pp. 670–677, Mar. 2009.

[14] J. Miret, M. Castilla, J. Matas, J. Guerrero, and J. Vasquez, "Selective harmonic-compensation control for single-phase active power filter with high harmonic rejection," IEEE Trans. Ind. Electron., vol. 56, no. 8, pp. 3117–3127, Aug. 2009.