A Review of Current Control Techniques for Active Power Filter Applications

Babandeep Kaur Bains[1], Arvind Dhingra[2]
[1,2]Department of Electrical Engineering, Guru Nanak Dev Engineering College, Ludhiana, India
[1]babandeep17@gmail.com, [2]arvinddhingra@gmail.com

***Abstract*-In recent years, many reference signal generation techniques and controlling schemes of active power filter have developed for the compensation in an AC electric system, to control current harmonics produced due to non-linear loads. This paper presents a review on the already proven current control techniques for Active power filter. This paper is organized in four sections. Section I presents introduction. Section II presents a comparative analysis of different instantaneous power theories. Section III presents a review of different current techniques. Finally, the paper presents conclusion in section IV.**

Keywords- Power Quality,Active Power Filter (APF), Total Harmonic Distortion(THD), Current Controller.

I. INTRODUCTION

With the emergence of power electronic devices harmonic pollution has come into the picture. Power electronic devices have brought about substantially more productivity and adaptability. However; harmonic pollution has come together with these devices in the electric system. [1] A number of end user's equipment containing power electronic devices pollute the supply system as they draw non sinusoidal current and behave as nonlinear loads. Aside from this there are number of various reasons for the pollution of the electric system such as natural ones like lightening, equipment failure, flashover, faults etc and forced ones such as voltage distortions, notches, flickers etc. so the term electric power quality has acquainted which means to maintain the good quality of power at the level of generation, transmission, distribution and utilization of an ac electrical power. The pollution of AC electric power supply systems is much severe at utilization level. The power quality problems in electric system may result in failure or mal operation of end user's equipments. Power quality problems related to the voltage at the point of common coupling (PCC) are voltage harmonics, surges, spikes, notches, sag/dip, swell, unbalance, fluctuations, glitches, flickers, outages etc. Power quality problems related to the current drawn from ac mains are poor power factor, reactive power burden, harmonic currents, load balancing, unbalance currents etc. [2]

These power quality problem causes failure of capacitor banks, excessive current due to resonance, over voltages, vibrations, increased losses in the distribution system and electric machines, noise, negative sequence currents in generators and motors, voltage instability, leads to unnecessary wastage of power and economy [3], etc. So it is important to study the causes, effects, and mitigation techniques for power quality problems. Hence power systems under unbalanced and non-sinusoidal conditions have to be analyzed, leading to different instantaneous power theories. For taking care of the power quality issue the passive filter are used, yet the weakness of that filter is high cost, rely upon impedance of source and Parallel or series resonance. Filteration of active power is exceptionally well-off and involves numerous parts of control theories, harmonic extraction method and reference current generation methods of filer of active power [4].So, the Active filters have to be used to compensate three phase non-linear loads. As the load harmonics may be complex, change quickly and haphazardly, APF needs to react rapidly with high control precision in current tracking.[5] Therefore, Active filter equipped with current control have used to obtain the compensating current from the ac power source so that it cancels the harmonic current contained in the load current. A voltage source PWM converter, power circuit, for the active filter has considered instead of current source PMW converter. [6] Basic structure of Shunt AF with a three leg VSC is shown in fig 1 and is depicted in [7].

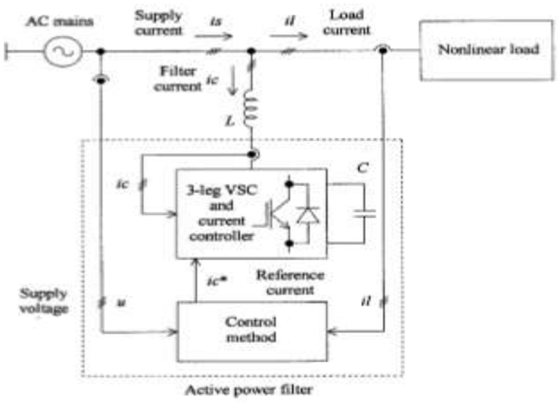

Fig 1. Basic structure of a shunt AF with a three leg VSC

II. INSTANTANEOUS POWER THEORIES

Many researchers have examined various theories in order to compensate three phase non-linear loads by means of an active power filters (APF).The first theory [8] was first introduced by Akagi, Kanazawa and Nabae in 1983 in Japan known as p-q theory or instantaneous reactive power theory or alpha-beta theory. After that different speculations, presented in [9], [10],[11],were also proposed such as time domain correlation techniques or the synchronous reference frame or also called d-q theory, the modified p-q theory or cross product theory, p-q-r theory, Vectorial theory and global control strategy.

Reyes s. Herrera it al. in [9], [10], and [11] presented a comparative evaluation of some of the theories for an unbalanced and non-linear load in a three phase four wire system under three operational conditions:

- Case-I: a balanced sinusoidal supply voltage
- Case-II: an unbalanced sinusoidal supply voltage
- Case-III: a balanced nonsinusoidal supply voltage

All the formulations achieve the target if the supply voltage is balanced and sinusoidal. Comparison between Different Controllers are presented in table I.

III. CURRENT CONTROL TECHNIQUES

Compensation for the distorted current drawn from the utility grid by the rectifier, AFs and its control must have the capability to track high di/dt in the current reference, makes the outline of the controller critical. A variety of current controlled systems have been examined previously. They are classified as linear and non-linear current controllers. The most effective performance in practical applications to the control of active filters are the linear current controller, the digital dead beat controller and hysteresis controller [12]. Basic system diagram of PWM current controller have shown in fig 2 and is described in [13]. Simone Buso in [12] and David M. Brod in [13] showed a comparison between different current controllers. Comparison of different current controllers is shown in Table II as far as the active filter applications are concerned for case II & III cited above.

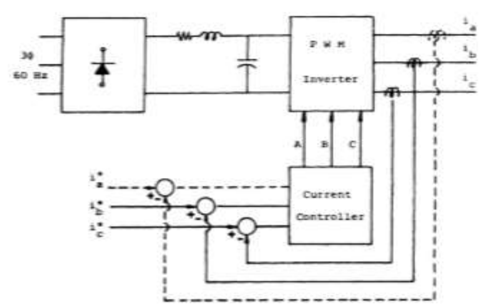

Fig 2. Basic system diagram of PWM current controller

TABLE-I: COMPARISION BETWEEN DIFFERENT CURRENT CONTROL METHODS

S.No.	After compensation	Case-II	Case-III
1	p-q theory	-Less THD compared to modified p-q theory. -Assumes null compensator average power. -Eliminates neutral current. -Not suited for compensation when the supply voltage is unbalanced.	-Less THD compared to modified p-q theory. -Assumes null compensator average power. -Eliminates neutral current. -Not suited when the supply voltage is balanced non sinusoidal.
2	d-q theory	-Less distortion compared to p-q and modified p-q theory. -Requires a compensator average power that is not null. -Eliminates neutral current. -With respect to RMS source current, method using d –q theory has maximum value.	-Requires a compensator average power that is not null. -Eliminates neutral current. -With respect to RMS source current, method using d –q theory has minimum value.
3	Modified p-q theory	-Maximum THD -Does not eliminate the neutral current. -Not suited when the supply voltage is unbalanced. -with respect to RMS source current, method using modified p-q theory is superior to p-q theory.	-Maximum THD -Does not eliminate the neutral current. -Assumes null compensator average power. -Not suited when the supply voltage is balanced non sinusoidal.
4	p-q-r theory	-THD in p-q-r <THD in p-q < THD in modified p-q-r<10% -Eliminates neutral current - Assumes null compensator average power.	-THD in p-q-r <THD in p-q < THD in modified p-q-r<10% -Eliminates neutral current - Assumes null compensator average power.
5	Vectorial theory	- ~Zero THD -Eliminates neutral current. - Assumes null compensator average power. -with respect to RMS source current, method using Vectorial theory is inferior to p-q theory.	- <%10 -Eliminates neutral current - Assumes null compensator average power.
6	Global control	- ~Zero THD -Eliminates neutral current. - Assumes null compensator average power. - concerning RMS source current, method using global control theory is inferior to p-q theory.	-Eliminates neutral current. - Assumes null compensator average power. -only global control strategy obtains balanced and sinusoidal source current after compensation

TABLE II: COMPARISION OF DIFFERENT CURRENT CONTROLLERS

S.No.	Current controller	Advantages	Disadvantages
1	Hysteresis controller: utilizes some sort of hysteresis between the real present and acquired reference current to such an extent that their difference remains inside the hysteresis band.	-simplest to implement -inverter switching frequency can be diminished by adding zero voltages at the appropriate time. -high dynamic response [14] -THD and RMS current error is lowest. -quick voltage controllability[15] -unaffected by the variation in the firing angle alpha.	-high inverter switching frequency -negatively affected by the phase currents interactions (three phase system with neutral)
2	Ramp comparison controller: produces a-synchronous sine triangle PWM with the current error which is considered to be the modulating function.	-limits the maximum inverter switching frequency.	-inherent magnitude and phase error in the line current -requires large gain and compensation to reduce the current error. -lower bandwidth. -multiple crossing of the ramp by the current error when the time rate of change of the current error ends up more noteworthy than that of the ramp.
3	Predictive controller: for each sample period it computes an inverter voltage vector that will make the current to track the current command.	-doesn't provide an inherent instantaneous current limit.	-most complex -require information of the load and extensive hardware results in restricting the dynamic reaction. -controller response is slower.
4	Linear controller: performs a sine triangle PWM voltage modulation of the power converter utilizing as the modulating signal the current error filtered by the Proportional integral (PI) regulator.	-easy to implement	-bandwidth limitation (when high di/dt of the current reference or alpha is not zero)
5	Digital Dead-beat Controller: digital control calculates the phase voltages in order to make the phase current achieve its reference by the end of the following modulation period.	-suitable for fully digital implementation -doesn't require the line voltage measurement in order to generate the current reference	-inherent calculation delay -slow response

IV. CONCLUSION

Utilization of power electronic devices has presented numerous power quality issues in the ac electric system. Active power filters are used for the compensation of current harmonics under non sinusoidal and harmonically unbalanced system using different, theories and current control strategies. The global control strategy using hysteresis controller gives the balanced and sinusoidal current in all the conditions of the supply voltage.

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