Research Paper Engineering

Comparative Analysis of Different Harmonics Detection Techniques for Power Quality

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ABSTRACT

In the attempt to minimize the harmonic disturbances created by the non-linear loads there exist many implementations supported by different theories which continuously debate their performances proposing ever better solutions. This paper proposes three different control strategies applied to shunt active power filter based under broad classification of time domain, frequency domain and multiple adaptive.

Generalized integrators and variants strategy in time domain is used for non- continuous signals by deriving the integration by the generalized integrator in time domain as a second order transfer function in Laplace domain.

Multiple adaptive feed forward cancellation method (MAFC) for harmonic reference generation ,this adaptive method is simple and effective in extracting fundamental and harmonic current information for non linear load current .The adaptive law is derived by an SPR (strictly positive real) Lyapunov function. A Hysteresis current controller is used to track the compensated current references.

The conclusions are collected and a comparison is given at the end, which is useful in deciding the future hardware setup implementation. The comparison shows that the choice of numerical filtering is a key factor for obtaining good accuracies and dynamics for an active filter.

Keywords: power system harmonic; harmonic distortion; active filters; harmonics analysis; Discrete Fourier Transform; digital signal processing, signal detection.

INTRODUCTION

Active filters are relatively new types of devices for eliminating harmonics. They are based on sophisticated power electronics and are much more expensive than passive filters. However, they have the distinct advantage that they do not resonate with the system. Active filters can work independently of the system impedance characteristics. Thus, they can be used in very difficult circumstances where passive filters cannot operate successfully because of parallel resonance problems. They can also address more than one harmonic at a time and combat other power quality problems such as flicker. They are particularly useful for large, distorting loads fed from relatively weak points on the power system. The active power filter detects harmonic information in non-linear load currents and actively injects counter harmonic currents to the grid so that the currents at Point of Common Coupling (PCC) approximate sinusoidal waveforms.

Many harmonic detection techniques for active power filters have been studied. In frequency domain, Discrete Fourier Transform (DFT) has been used [3-6-]. The main disadvantage of these techniques is the time delay associated with sampling and computation of Fourier coefficients, which makes them difficult for real-time application on dynamically varying load. In the time domain, a number of methods have been proposed. Notch filters or band pass filters [8-9] were used to extract harmonics but it was difficult to implement the ideal amplitude and phase characteristics of the filters and its performance is also sensitive to power system parameter variation.

The proposed methods are the time domain- generalized integrator variants, frequency domain –discrete Fourier transform & multiple adaptive feed-forward cancellation (MAFC). The comparison done between in different control scheme in active filters that use different harmonic detection methods is not a direct effect of only the performance of the detection block, but also of the quality of the controller. Therefore, this work analyzes the harmonic detection methods decoupled from the entire active filter in order to see its contribution. One-line diagram of a shunt active filter in a feed-forward configuration with an adjustable speed drive as load. The diagram shows the place of the harmonic detection block inside the active filter.

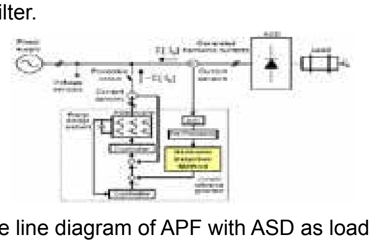


Fig.1 Single line diagram of APF with ASD as load

Following are the different technologies, which are used for harmonic detection in active power filter applications

1. Frequency domain method
1.1. Discrete Fourier Transform (DFT)
1.2. Recursive Discrete Fourier Transform (RDFT)
1.3. Fast Fourier Transform

2. Time domain method
2.1. Synchronous fundamental dq frame
2.2. Synchronous harmonic dq frame
2.3. Instantaneous power theory (pq theory)
2.4. Generalized integrator
3. Multiple adaptive feed forward cancellation

HARMONIC DETECTION METHODS

A) **Generalized Integrator:** This method comes out from the limitation of PI controller in dq-frame which does not have good tracking capability for harmonics so steady state error occurs. This can be overcome by using generalized integrators. A generalized integrators derive the integration as a second order transfer function in Laplace Domain. This gives an infinite gain at the selected resonant frequency. Thus both filtering and the controllers can be implemented in stationary frame instead of rotating frame. The diagram of generalized integrator approach is as shown in Fig. (2). the selectivity and response time of this approach depends on the integral constant K_i.

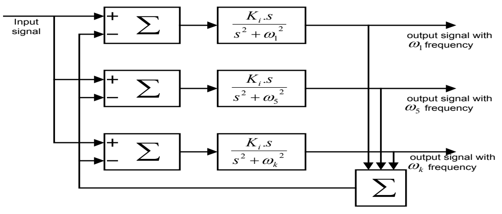


Fig.2 Principle algorithm of generalized integrator method.

B) **Discrete Fourier Transform:** DFT is a mathematical transformation for discrete signals which gives both the amplitude and phase information of the desired harmonic by calculating the following equation.

$$\overline{X}_h = \sum_{n=0}^{N-1} x(n)\cdot\cos\left(\frac{2\pi\cdot h\cdot n}{N}\right) - j\cdot\sum_{n=0}^{N-1} x(n)\cdot\sin\left(\frac{2\pi\cdot h\cdot n}{N}\right)$$

$$\overline{X}_h = X_{hr} + j\cdot X_{hi}$$

$$\left|\overline{X}_h\right| = \sqrt{X^2_{hr} + X^2_{hi}}\,; \qquad \varphi_h = \arctan\left(\frac{X_{hi}}{X_{hr}}\right)$$

where: *N* is the number of samples per fundamental period; *x(n)* is the input signal (voltage or current) at point *n*; X_h is the complex Fourier vector of the h^{th} harmonic of the input signal; X_{hr}

is the real part of X_h; X_{hi} is the imaginary part of X_h; $|X|$ is the amplitude of the vector; Φ_h is the phase of the vector.

Once the harmonics are detected and isolated with above equation it is just a matter of reconstruction back in time-domain to create the compensation signal for the controller [8], [9].

C) Multiple adaptive feed-forward cancellation:

CONTROL SCHEME: The proposed control scheme is illustrated in Fig. 3, which includes three modules: the harmonic cancellation module, the reactive power compensation module, and the DC capacitor voltage control module. The harmonic cancellation module generates harmonic compensating signal and provides the fundamental current information to the reactive power compensation module. The reactive power compensation module calculates reactive power compensating signal. The DC capacitor voltage control module regulates the voltage across the DC capacitor. All compensating signals are summed up at the *abc*-frame to form the reference signal for the hysteresis current controller [9]. Finally, gating signals are generated for the IGBT based switching devices. From above introduction, we can see that the harmonic cancellation and the reactive power compensation modules are used towards the nonlinear load, while the DC voltage control module is used for the active power filter. This is the reason why the signs assigned to the three signals are '+', '+', and '-', respectively as shown in Fig. 2. The algorithms used in three control modules are introduced as follows.

MAFC algorithm has been proposed in [11]. This algorithm does not need voltage information to extract harmonic current, which makes it invulnerable to contaminated voltages. In addition, this harmonic identification method is phase independent. That means it can identify harmonic contents in three-phases independently, even for unbalanced system or single-phase system.

With adaptive laws the proposed method control block is easily derived and is shown in Fig.4

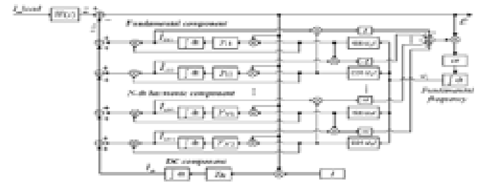


Fig.3 Control block diagram of MAFC

SIMULATION RESULTS

To demonstrate the performance of the proposed control scheme, a power system shown in Fig.5 is simulated in MATLAB/SIMULINK environment.

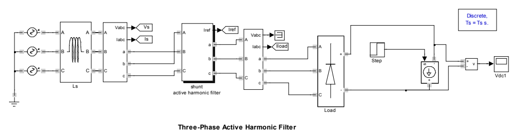


Fig.4. Control diagram of Active power filter

COMPARISON OF HARMONIC COMPARISION OF HARONIC DETECTION METHODS

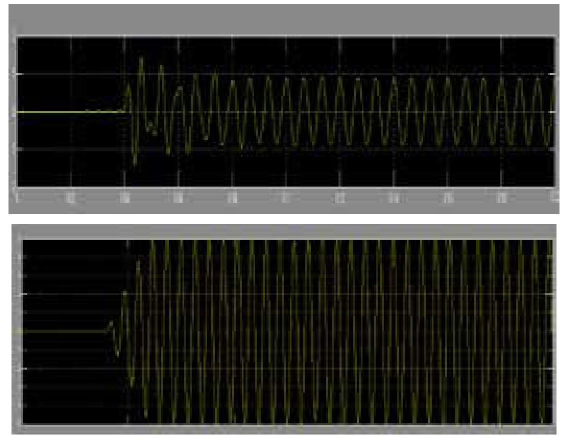


Fig.5. Waveform spectrum for generalized integer and discrete Fourier transform respectively.

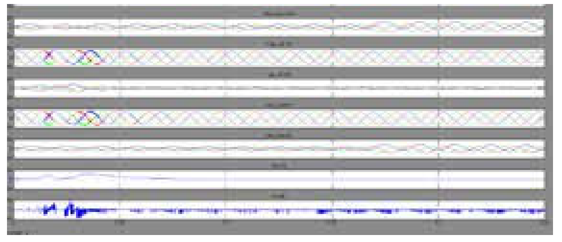
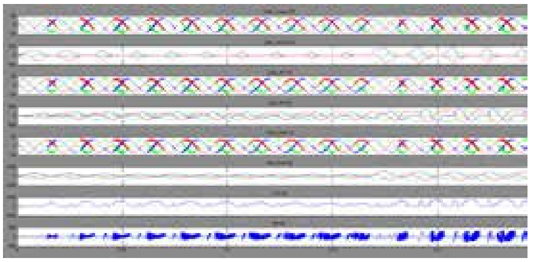


Fig.6. Waveform spectrum for discrete Fourier transform and MAFC technique respectively



Since we have considered the standard harmonic as fifth harmonic and designed all the controllers for comparison we can observe from Fig 6&7 that 5th harmonic is separated from the other higher harmonics between the time-interval of 0.05 s – 0.15 s the output of each method is different and hence comparable in accordance with settling time and all other responses.

CONCLUSION

The generalized integer will give an infinite gain at the selected resonant frequency. And in the case of the DFT methods, the settling time is limited to at least the windowing time (1 fundamental period in this case), and the requirement is that the harmonic should be constant during the windowing interval. A new control scheme is proposed to address harmonic current and reactive power problem in power systems. The proposed control scheme can compensate both harmonic current and reactive power in the system, which greatly improves power quality at the PCC. In the future, it will be investigated how to find optimal control schemes for the cases where harmonic and reactive power compensation requirement exceeds the rating of active filter.

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