DESIGN OF DFT-BASED CONTROLLER FOR SELECTIVE HARMONIC COMPENSATION IN SHUNT ACTIVE POWER FILTERS

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ABSTRACT

Selective harmonic compensation plays a vital role in power quality evaluation, harmonic compensation, and so on. There are various methods to compensate harmonics in the system one among the technique is, discrete Fourier transform (DFT)-based algorithms has found full and popular applications due to advantages like simplicity and excellent selectively filtering properties. The Discrete Fourier Transform (DFT) is the equivalent of the continuous Fourier Transform for signals known only at N instants separated by sample times T (i.e., a finite sequence of data). In this paper, a Discrete Fourier Transform (DFT) based controller used in active power filters (APF) for selective harmonic elimination. Detailed design consideration is given with a focus on stability analysis and transient behavior of the APF. Atmega328 based reduced rated hardware is developed for verifying the system enhancements.

Keywords: Active power filter; closed-loop; DFT-based controller; selective harmonic compensation.

INTRODUCTION

Active power filters are mainly used to compensate current harmonics in the power system network. Due to the presence of non-linear loads in the power system network, the harmonics are present. APF is also used to control reactive power support, unbalanced loading condition, and peak overshoot. Design and development of Active power filters (APFs) are discussed in several papers [1-7]. Because the control process of APF plays an vital task to compensate for the harmonics present in the system. In [3] there are various filters used to compensate harmonics currents, the EMI filters and APF are discussed briefly. A brief control strategy of APF used in multiple voltage source PWM converters. From the utility side, the main problem is the interference of adjustable speed drive (ASD) with APF. To reduce the current harmonics in the ASD a proper design and implementation, and the parallel filters are used to compensate current harmonics [2]. Before injecting the compensation current in the system, we know the distorted current present in the load. Selective harmonic elimination is a crucial task in the operation of active power filters. The APF is used in many applications to reduce both current-based, and voltage-based harmonics presents in the network. The application issues of APF are discussed in [4]. The application of grid-synchronization connected rectifiers for a motor drive system, charges for electric motor drive. An active shunt filter based on voltage detection for harmonic elimination in a radial power distribution system is proposed in [5]. In [6], a series filter is used in synchronous frame harmonic isolator to eliminate voltage harmonic. In [7] proposed control of strategy for square-wave inverters in high power hybrid active filter systems. The feedback loop is also used to eliminate selective harmonic compensation for active filters [8].

Various harmonics methods are used to detect the selective harmonic elimination for APF applications [9]. In [10] proposed reference current computation methods for active power filters are used. The accuracy assessment in the frequency domain is achieved. Y. W. Li and J. He, they proposed an overview of DG-interface inverters and to compensate the harmonic presents in the distribution system [11]. In [12] proposed a grid fundamental and harmonic component detection method for single-phase systems. The instantaneous reactive power compensators are used in switching devices without energy storage components is discussed in [12]. Detection of grid voltage fundamental and harmonic components using Kalman filter and generalized averaging method is discussed in [13]. There are various references the current generation are produced in both traditional and modern methods. The conventional techniques are based on frequency domain and time domain applications. Time domain represents P-Q theory and SRF theory. Frequency domain the fast Fouriertransforms (FFT), Sliding Discrete Fourier transform (S-DFT), R-DFT, and wavelettransform. Excellent accuracy and fast dynamics are achieved in frequency domain techniques. In modern techniques, the soft computing techniques are reused. Artificial neural networks and adaptive filtering are used. To implements, the DFT based controllers in APF plays a significant role in removing the selective harmonics in the grid. In [14-15] proposed an update to sliding DFT (S-DFT). In [16] an accurate, guaranteed stable, sliding discrete Fourier transform is proposed to give tips and tricks methods to the digital signal processing (DSP). The SVFT-Based control method is discussed in [17]. In [18] proposed a programmable based performance in an AC power source to eliminate low harmonic distortion used in DSP-based repetitive control technique. The internal models for linear multivariable regulators are discussed in [19]. A current-tracking method is used in active filters based on a sinusoidal internal model are discussed in [20]. The comparison between time-domain and frequency-domain control scheme for active shunt
filters is easy to understand in [21]. To understand the drawbacks associated with selecting the harmonics in the system, an improved and DFT-based controller is proposed. The DFT is connected to the current control loop through the PI controller connected in parallel with the circuit. This idea can be implemented to both slow and fast dynamic operations. The working principle of shunt active of power filter is presented and also essential components in shunt APF, reference current generation is discussed in section II. And, to improve the system performance, the proposed DFT-based controller is presented in section III. The reduced rated hardware results are given in section IV. Section VI concludes this paper.

**Shunt Active Power Filter Works**

Schematic diagram of shunt active power filter (SAPF) is shown in Fig. 1. Shows the AC source is directly connected to the load. The non-linear loads are connected in the utility side produced harmonics and draws reactive power from the grid.

![Schematic diagram of Shunt active power filter system](image)

The filters are connected in parallel to the grid to compensate for current-based power quality issues. Thus the active power filters have the following components present in the circuit they are (i) Directive current operational circuit, (ii) Current tracking control circuit, and (iii) the Main circuit. First, we know the distorted current value in the grid for compensation procedure. The directive current operational current block is directly connected to the Point of common coupling (PCC) to detect the distorted current or voltage value. The current tracking control circuit is used to control the compensation current into the circuit. It controls the flow a dynamic operational condition. The river circuit is used for grid-synchronization operation in a microinverter. Thus the compensation current is directly fed to the grid with the help of the main circuit. The main circuit is mainly used as an inverter. The APF is also used to compensate common voltage-based power quality problems.

**Basic Components of SAPF**

Control circuitry: The primary function of the control circuitry is used to control the current-based and voltage-based power quality problems. In this paper, the PI controller is used as a controller to reducing the harmonics in the system. The control circuit may also do the following functions:

1. Voltage control.
2. Current control.
3. Reference current generation.
4. Reactive power support.
5. Harmonic elimination

Firing angle generator: The firing angle is used to produce a gate pulse for operating voltage source inverter (VSC). It is mainly used to control the switches in VSC. Voltage source Inverter: The VSC is used as a pulse width modulation (PWM) for controlling current and voltage waveforms. The performance of VSI depends on the current reference generation, dc bus voltage, and storage devices.

**Reference Current Generation**

The current reference generation is mainly classified into two types. One is traditional, and another one is modern. In conventional control method, the time and frequency domain are initialized. In time domain theory, the P-Q theory and SRF theory is processed. In the frequency domain, the Fourier transform based control is handled. Thus, it can be classified into four major groups (i) FFT, (ii) S-DFT, (iii) R-DFT and (iv) wavelet.

**Discrete Fourier Transform**

The Discrete Fourier Transform (DFT) is the equivalent of the continuous Fourier Transform for signals known only at $N$ instant separated by sample times $T$ (i.e., a finite sequence of data). Let $\tilde{f}(t)$ be the continuous signal, which is the source of the data. Let $N$ samples be denoted The Fourier Transform of the original signal $\tilde{f}(t)$ would be

$$F(j\omega) = \int_{-\infty}^{\infty} f(t)e^{-j\omega t} \, dt$$

![Classification of reference current generator techniques](image)
We could regard each sample $f[k]$ as an impulse having area $f[k]$. Then, since the integrand exits only at the points: We could, in principle, evaluate this for any $\omega$, but with only $N$ data points to start with, only final $N$ outputs will be significant. You may remember that the continuous Fourier transform could be evaluated over the last interval (usually the first period $T_0$) than from $-\infty$ to $+\infty$ if the waveform was periodic. Similarly, since there are only a finite number of input data points, the DFT treats the data as if it were periodic (i.e., $f(N)$ to $f(2N - 1)$ is the same as $f(0)f(N - 1)$).

**Proposed System**

General topology of the shunt active power filter is explained in Fig.3. Thus forward to propose a DFT-controller we know about the general behaviour of the SAPF. The shunt active power filter is connected parallel to the grid system. It compensates the current-based harmonic problems presents in the grid. The inductor $L_f$ is used for smoothing operation because due to some disturbance in the grid, the peak overshoot occurs. The inductor $L_{ac}$ is used for line inductor connected to the non-linear load. This paper proposed a new technique DFT-based controller used in SAPF for selective harmonic elimination. In the proposed DFT-based controller have the following components.

![Fig.3 General topology of the shunt active power filter](image)

They are (i) DFT-based controller, (ii) PI controller, (iii) current control loop, (iv) voltage control loop. To improve the system stability, a DFT-based controller is used for selected frequency compensation, either leading or lagging compensation. A DFT based control structure to achieve an exact tracking in the presence of periodic disturbances However, the proposed solution provides a more efficient and durability.

The complexity of the proposed controller is independent of number of harmonics to be compensated and less sensitivity. The selected harmonics can be chosen as a discrete form using DFT. The reduced rated hardware experimental results verify the performance of the proposed solution. The proposed controller is based on sliding DFT to reduce the calculation burden and easy to select the different harmonic, respectively. Points, the DFT treats the data as if it were periodic (i.e., $f(N)$ to $f(2N - 1)$ is the same as $f(0)f(N - 1)$).

**RESULTS ANALYSIS**

Performance of shunt active power filter is checked with the use of MATLAB software. In the proposed scheme two types of loads have been considered as nonlinear loads: (i) Resistive rectifier load and (ii) Inductive rectifier load. Fig. 6

![Fig.5 Source current](image)

![Fig.6 Compensating current](image)

![Fig.7 Load current](image)
shows the performance of shunt active power filter under resistive rectifier load. In this case the before the insertion of the shunt active power filter, Total Harmonic Distortion (THD) of source current was 27.17 % and after the insertion it comes down up to 1.02%. Similarly, for inductive rectifier load, THD of source current before insertion of was 25.82 % and after the insertion of shunt active filter it reaches to 2.46 %. Output result of source current for this case is shown in fig. 11. The shunt active filter was inserted at 0.06 second in both the cases. Moreover, comparison of effective elimination of low order harmonics is shown in Fig. 6 and Fig. 7.

CONCLUSION

The DFT-based controller is given the selective harmonic elimination in the system, according to the frequency characteristics of the system at different harmonic, respectively. The proposed controller is reducing the current-based and voltage-based power quality problems. Hence it is also supporting reactive power and achieve a very precise tracking the current in the periodic disturbance. To prove the concept of the proposed controller have been verified using Atmega 328 microcontroller by the experimental results. The results show better compensation for selective harmonic elimination in the grid system.

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