

Hybrid Filter for Dynamic Harmonics Filtering and Reduction of Commutation Notches

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ABSTRACT : Active filters are today widely-used to improve voltage quality in industrial power grids. They are sometimes considered a generic solution and detailed analysis of the voltage quality in the affected grid is neglected. However, interactions between an active filter and the connected network are always present and may affect filter performance. This paper discusses the interaction of voltage perturbations and active filter systems and presents a case study of a hybrid filter installed in a metal processing plant. The hybrid filter consists of an active filter and a passive voltage notch filter realized through a series connection of resistors and capacitors. It achieves dynamic harmonics filtering and reduction of voltage notches in a low voltage distribution network where severe commutation notches would otherwise prohibit the operation of active filters without additional measures. Discussion of the filter effect is based on power quality measurements.

KEYWORDS : Active filters, Dynamic harmonics, Passive filters, Notch filters.

I.INTRODUCTION

In power systems, harmonic compensation has become increasingly important due to the widespread use of a adjustable speed drives, arc furnace, switched-mode power supply, uninterruptible power supply. Harmonics produce unwanted disturbance to the communication network and also increase the losses. There were a number of mitigation solutions that were being proposed. In order to reduce these harmonics, the active filters are used.

Active filters (AFs) are today a well researched and established technology for improving voltage quality in industrial power grids. The term was first used in 1976 and much of the scientific research on AFs that defines today's main literature on the matter was conducted in the 1990s, which was also when many commercial products were introduced . Recent years have seen growth in the AF market with numerous commercial companies entering or expanding their portfolio. This development coincides with the deployment of variable-frequency drives and increasing attention paid to voltage quality by utilities and industrial facilities. AFs exhibit various advantages over passive LC filters tuned to a specific frequency . A key advantage of AFs is that they can be used to filter an arbitrary number of harmonics and that the selection of these harmonics can be parameterized. The "Recommended multipliers for increases in harmonic current limits" introduced in the 2014 version of IEEE 519 [1] present an additional factor benefiting the standardized deployment of active filters wherever this standard is applied. The presence of harmonics in electrical systems means that current and voltage are distorted and deviate from sinusoidal waveforms. Different harmonic mitigation techniques like phase shifting transformers, higher pulse converters and shunt filters - in particular AFs with their ability to selectively filter multiple harmonics - are put on equal footing. Line notches are just that - an irregularity in the voltage waveform that appears as a notch. They are typically present in the waveform during SCR commutation. Commutation occurs when an SCR in one phase is turned on to turn off an SCR in another phase.

II. DYNAMIC HARMONICS FILTERING

One of the most important problems that have been reported in the literature concerns the difficulty of the frequency control within the micro-grids and the increase of the total harmonic distortion. These two factors may negatively impact on the protection system, power quality analysis and other intelligent electronic devices (IEDs), in which digital algorithms assume that the fundamental frequency is constant. Based on this fact, here has been an increasing interest in signal processing techniques for detecting and estimating harmonic components of off-nominal frequencies. Their correct estimation has become an important issue in measurement equipment and compensating devices. Although many methods have been proposed in the literature, it still remains difficult to detect and estimate harmonics of off-nominal frequencies. The harmonic components (voltage or current) can change its frequencies due to continuous changes in the system configuration and load conditions, to the rapid proliferation of distributed resources, and to possibilities of new operational scenarios (e.g., islanded micro grids). Also the need for massive monitoring of networks is unquestionable within the concept of smart-grid. An important line of research in the smart grids context is to identify and estimate harmonics that may appear in the current and voltage signals, and from this information, correct and adjust the digital algorithms that are part of electronic devices. The most used technique for harmonics estimation is based on the discrete Fourier transform (DFT).

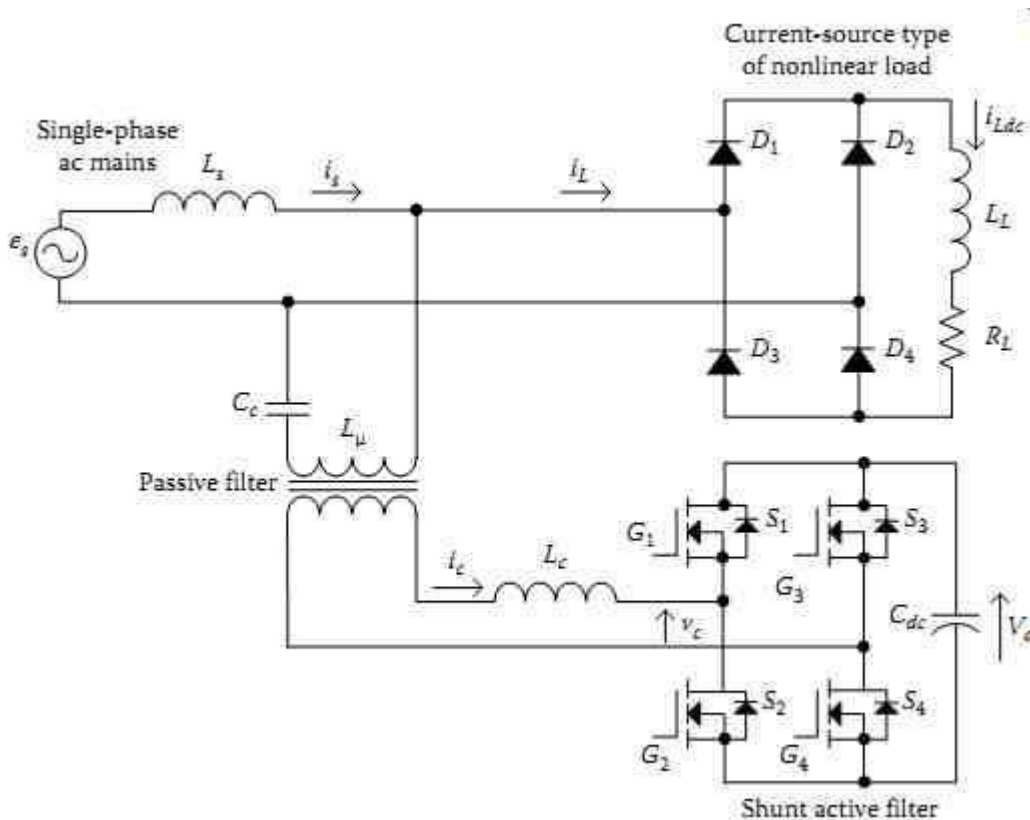
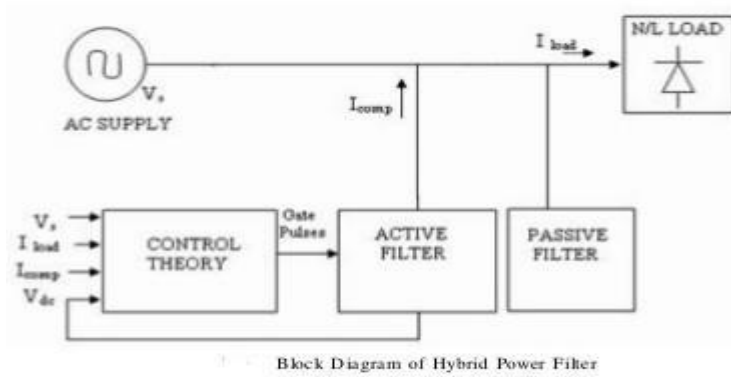


Fig:1 Block Diagram and Circuit Diagram of Hybrid Filter



Simulation Results

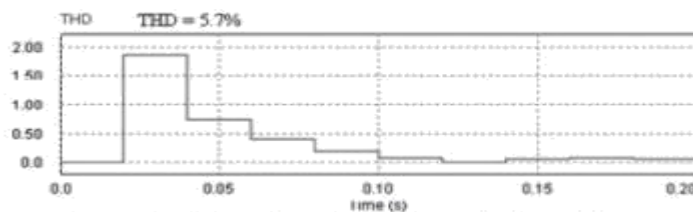
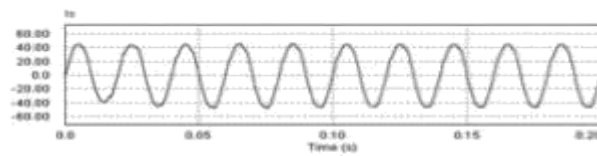


Fig. 2. Source current, THD of the system with active filter alone

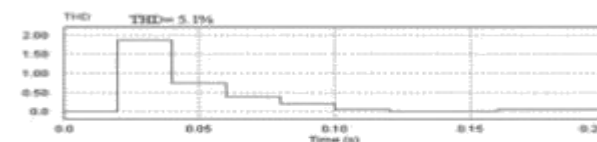
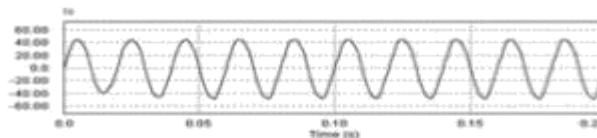


Fig. 3. Source current, THD of the system with hybrid filter

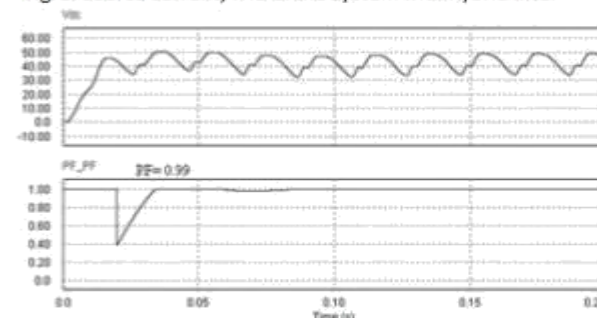
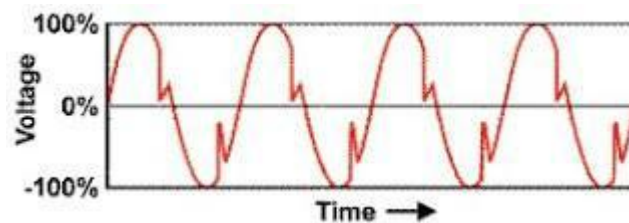


Fig. 4. DC Capacitor voltage of active filter, Power Factor of the system with Hybrid filter

III. COMMUTATION NOTCHES

Voltage Notching is described by IEEE as a recurring power quality disturbance due to the normal operation of power electronic devices (i.e. rectifier), when current is commutated from one phase to another. Conventionally, the current waveform is used as the starting point for harmonic analysis, and voltage notching is simply derived from the IZ drops of the harmonic currents. In addition, voltage notching characterizes an unusual case that falls between [harmonics](#) and [transients](#). This is because notching takes place in steady-state, thus, it can be distinguished by the harmonic spectrum of the affected voltage. On the other hand, the components of the frequency related to voltage notching are somewhat high and may not be promptly categorized with a measurement device commonly employed for harmonic analysis.



Voltage Notching

Sources

Voltage Notching is primarily caused by three-phase rectifiers or converters that generate continuous DC current. As mentioned, the voltage notches happen when the current commutates from one phase to another. Subsequently, a momentary short circuit between two phases will occur during this period. Moreover, the depth of the notch at any point in the system is influenced by the source inductance, the isolating inductance between the rectifier/converter, as well as the point being examined. Consequently, the width of the notch is the commutation angle.

$$\mu = \cos^{-1}[\cos \alpha - (X_s + X_t)I_{dc}] - \alpha \cos \mu$$

$$= 1 - (2E_x/E_{d0})$$

where:

μ = commutation angle α =

delay angle

X_s = system reactance in per unit on converter base

X_t = converter transformer reactance in per unit on converter base I_{dc} =

DC current in per unit on converter base

E_x = direct-voltage drop caused by commutating reactance E_{d0} =

theoretical direct voltage

Effects and Solution

Voltage Notches introduce harmonic and non-harmonic frequencies that are much higher than those found in higher voltage systems. Usually, these frequencies are in the radio frequency range, that cause negative operational effects, such as signal interference introduced into logic and communication circuits. Also, when of sufficient power, the voltage notching effect may overload electromagnetic interference filters, and other similar high-frequency sensitive capacitive circuits.

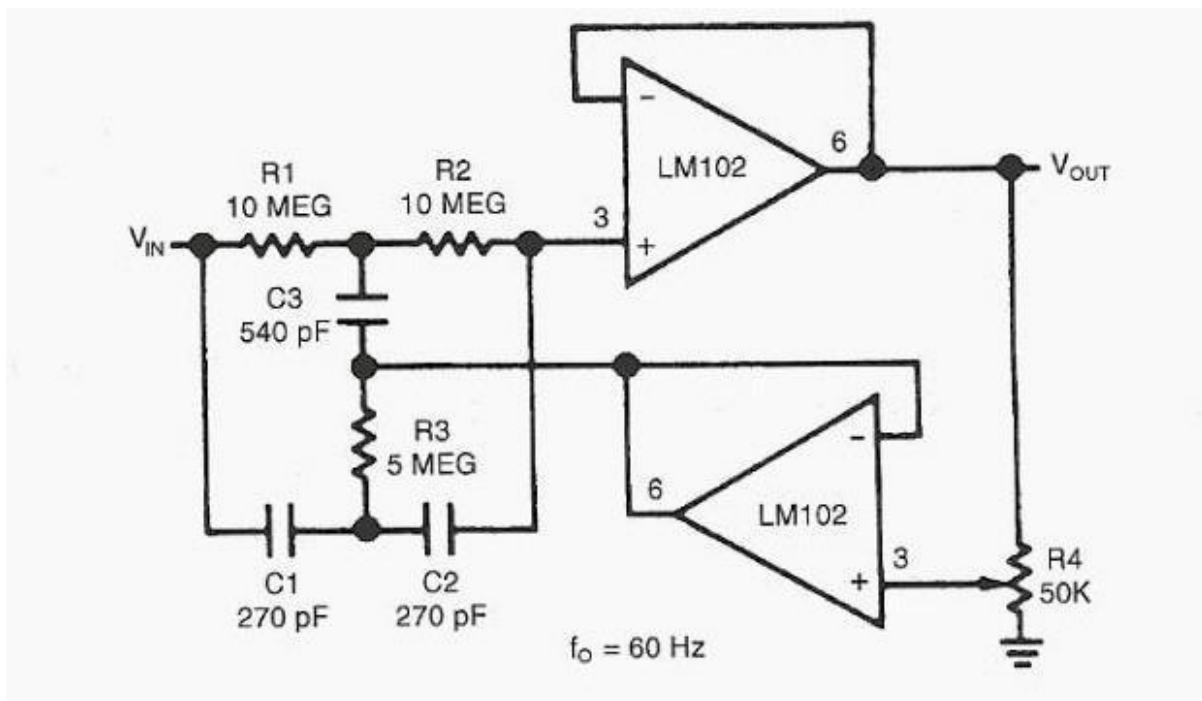


Fig. 5. Adjustable Q-notch filter circuit

The ideal response for any notch filter would be a completely flat response over the usable range with the exception of the notch frequency. Here it would fall very fast providing a high level of attenuation that is able to remove the unwanted signal.

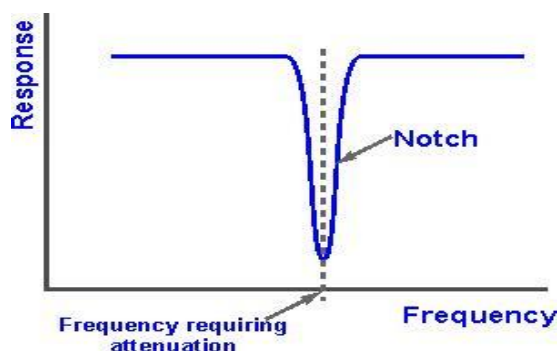


Fig. 6. Notch filter response

To calculate the notch frequency,

$$F_{\text{notch}} = 1 / (2 * \pi * R * C)$$

Where, $\pi = 3.142$

R and C are the values of the resistors and capacitors as in the circuit

The operation of offshore drilling rigs and production platforms requires the extensive use of Variable Speed Drives. Historically this involved DC drives almost exclusively, but more recently, AC drives have begun to find their way onto these facilities. Often it is a combination of DC and AC drives that are used. Silicon Controlled Rectifier (SCR) or thyristor bridge based DC drives will distort the supply voltage by creating commutating notches. These notches can become quite deep if the source is weak, the DC drive load is heavy and line reactors are not installed. Excessive voltage notching can cause operational problems and/or failures in other loads connected to the bus. When system resonance causes ringing of these notches, the problem becomes even more severe. One such susceptible load is the AC drive. Wide spectrum filters designed to reduce the harmonic currents being drawn by the AC drive can also be used to protect the drive from the harmful effects of commutation notching and other associated disturbances.

Eliminated voltage notching

Eliminating voltage notching requires that the source of the notching (commutation) be isolated or buffered from other sensitive equipment using the same distribution system. Considering the DC drive or other SCR controller as a source of "notch voltage" and the characteristics of the distribution system, it is only required that other sensitive equipment not share the same voltage source or a single voltage source. The simplest method to use to eliminate the voltage notch is to isolate each piece of equipment with an input transformer. If the impedance of the distribution system is low, generally dc drives will not create a severe voltage notch that affects other equipment. However, if the impedance of the distribution system is high (soft line) than voltage notching will occur and likely impact other equipment. An alternate method can use line reactors to reduce the voltage notch and reduce the possibility of affecting other equipment. It is important to note that notches created by dc drives will normally not affect the dc drive that is causing the notching. It is other equipment that can be affected. It is important that we understand and consider where other sensitive equipment connects to that same voltage source. In order to protect the sensitive equipment, we must reduce the notches before they get to that equipment. We will do this through the creation of a simple voltage divider network.

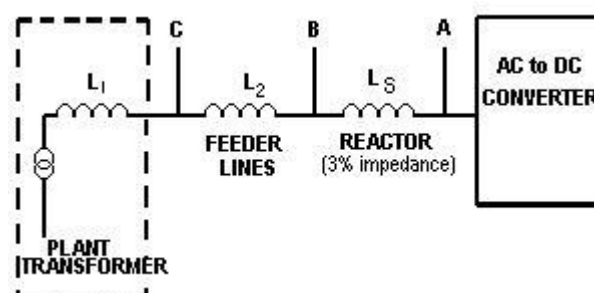


Fig. 7 Notch Eliminator

If we add impedance, in the form of inductive reactance, in series with the SCR controller, and between the controller and the point of other equipment connection, (point B) then the notch voltage will distribute itself across the new impedance (reactance) and the pre-existing line to source impedance. If the added impedance ($L_3 = L_1 = L_2$) is one-half as much as was already present, then 1/3 of the notch voltage is dropped across the new impedance and two thirds still remains at the point of common connection with the other equipment.

$$\text{NOTCH DEPTH} = \frac{L1+L2}{L1+L2+L3}$$

IV. RESULT AND DISCUSSION

The problem reduction of dynamic harmonics and commutation notch has been analyzed. Voltage notching can introduce harmonics on the distribution system. It is important that distribution system be designed with the lowest possible impedance. Prior to the use of power electronic equipment, designing an electrical system with impedance served to reduce the short circuit current or fault current in a system. With the use of power electronic equipment and its self contained current limiting feature, the need for system impedances to control fault current has been reduced.

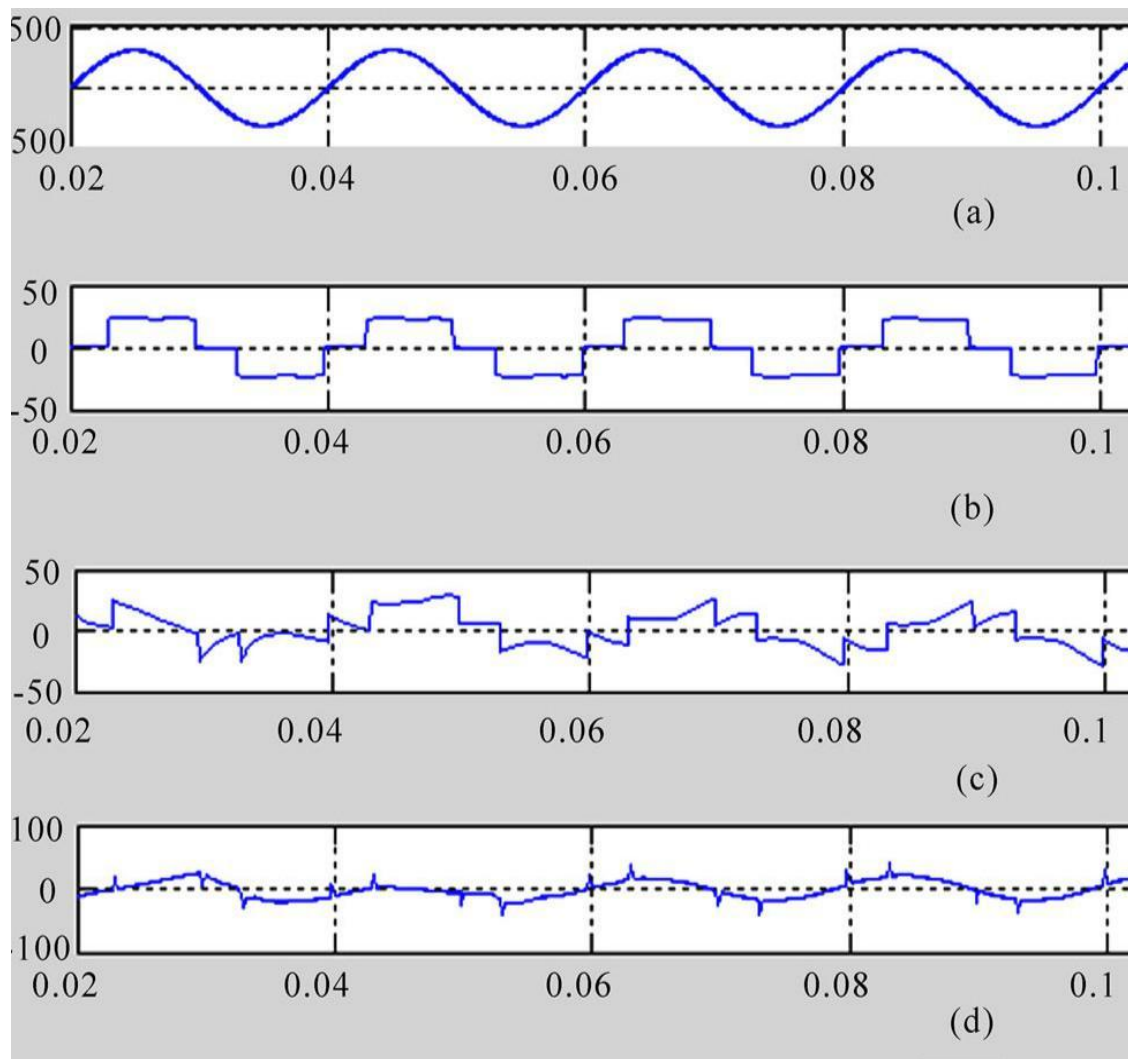


Fig. 8. Simulation result

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BIOGRAPHY



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