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# A Hybrid Active Filter For Harmonic Reduction Of Single Phase System By Voltage Injection At Line Side

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**Abstract**— This proposal describes a hybrid active filter intended for eliminating the line-side harmonic currents of a single-phase 8-pulse diode rectifier used as the front end of a medium-voltage high-power motor drive without regenerative braking. In Existing methods the 18-pulse and 24-pulse diode rectifier along with Multiwinding phase-shift transformer and PWM inverter is used and it may results in voltage imbalances that produce bad effect on cancelling harmonic currents at line side and cost will be more. In this method the hybrid active filter is characterized by series connection of a single tuned LC filter and an active filter. This circuit configuration brings low cost, small size, and light weight to the hybrid filter. The LC filter is tuned to the 11th-harmonic frequency, and the active filter is based on a three-level neutral point-clamped pulse width modulation converter (NPCPWM) with a dc capacitor voltage as low as 28 V. The controller continuously checks the line distortions with help of potential transformer connected to the line and injects the harmonics to the line from the active filter and the $1^{st}$, 5th, $7^{th}$, $11^{th}$ or $13^{th}$ harmonics are reduced. The efficiency of the front end motor drive will increase and the results in lower cost and smaller size than the former system

**Index Terms—**Active filters, Harmonic distortion, Motor drives, NPCPWM- Neutral Point-clamped Pulse Width Modulation, Rectifiers.

## 1 Introduction

A medium voltage motor drive for energy savings requires neither fast-speed control nor regenerative braking when it is applied to fans, blowers, pumps, and compressors. This allows a manufacture to use a single-phase eight-pulse diode rectifier as the front end of the medium-voltage motor drive. However, the diode rectifier produces a large amount of harmonic current at the line side, and therefore, it does not comply with harmonic guidelines or regulations. The so-called pulse width modulation (PWM) rectifier or active front end is capable of drawing three-phase sinusoidal currents from the ac mains, so that it may be preferable to the diode rectifier in specific low-voltage applications. The diode rectifier, however, is much more efficient and reliable as well as much less expensive than the PWM rectifier in medium-voltage motor drives without regenerative braking .This hybrid filter consists of series connection of a simple LC filter tuned to the 11th-harmonic frequency with a small-rated active filter using a three-level neutral-point clamped NPC PWM converter. The hybrid active filter has the following advantages over a pure active filter and a traditional passive filter consisting of multiple-tuned LC filters and a high pass filter: the active filter taking part in the hybrid filter is much smaller in converter capacity than the pure active filter. The simple single-tuned LC filter used in the hybrid filter is much smaller in size, lower in cost and weight, than the traditional passive filter.

In a normal alternating current power system, the voltage varies sinusoidally at a specific frequency, usually 50 or 60 hertz. When a linear electrical load is connected to the system, it draws a sinusoidal current at the same frequency as the voltage (though usually not in phase with the voltage).

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When a non-linear load, such as a rectifier, is connected to the system, it draws a current that is not necessarily sinusoidal. The current waveform can become quite complex, depending on the type of load and its interaction with other components of the system. Regardless of how complex the current waveform becomes, as described through Fourier series analysis, it is possible to decompose it into a series of simple sinusoids, which start at the power system fundamental frequency and occur at integer multiples of the fundamental frequency. Further examples of non-linear loads include common office equipment such as computers and printers, and also adjustable speed drives.

One of the major effects of power system harmonics is to increase the current in the system. This is particularly the case for the third harmonic, which causes a sharp increase in the zero sequence current, and therefore increases the current in the neutral conductor. This effect can require special consideration in the design of an electric system to serve non-linear loads.

In addition to the increased line current, different pieces of electrical equipment can suffer effects from harmonics on the power system.

Electric motors experience hysteresis loss caused by eddy currents set up in the iron core of the motor. These are proportional to the frequency of the current. Since the harmonics are at higher frequencies, they produce more core loss in a motor than the power frequency would. This results in increased heating of the motor core, which (if excessive) can shorten the life of the motor. The 5th harmonic causes a CEMF (counter electromotive force) in large motors which acts in the opposite direction of rotation. The CEMF is not large enough to counteract the rotation, however it does play a small role in the resulting rotating speed of the motor.

The untrained human ear typically does not perceive harmonics as separate notes. Rather, a musical note composed

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of many harmonically related frequencies is perceived as one sound, the quality, or timbre of that sound being a result of the relative strengths of the individual harmonic frequencies. Bells have more clearly perceptible in harmonics than most instruments. Antique singing bowls are well known for their unique quality of producing multiple harmonic partials or multiphonics.

## 2. PROPOSED SYSTEM

In this method the hybrid active filter is characterized by series connection of a single tuned LC filter and an active filter. This circuit configuration brings low cost, small size, and light weight to the hybrid filter. The LC filter is tuned to the 11th-harmonic frequency, and the active filter is based on a three-level Neutral Point-Clamped Pulse Width Modulation (NPCPWM) converter with a dc capacitor voltage as low as 28 V. The controller continuously checks the line distortions with help of potential transformer connected to the line and injects the harmonics to the line from the active filter and the 5$^{th}$, 7$^{th}$, 11$^{th}$ or 13$^{th}$ harmonics are reduced.

## 3. CONTROL SYSTEM OF THE ACTIVE FILTER

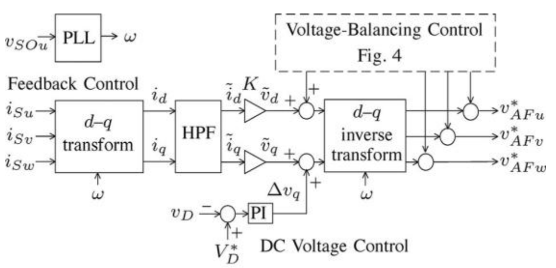


Fig.1. Control block diagram of the active filter.

Fig.1 shows the control block diagram of the active filter using a three-level NPC PWM converter. The PWM method is based on the so-called level-shift PWM, which has two triangle-carrier signals with the same frequency but different dc bias levels. The triangle-carrier frequency is assigned 10 kHz, so that the actual switching frequency of each MOSFET is 5 kHz, i.e., a half of the triangle-carrier frequency. The fully digital controller used in this experiment consists mainly of a DSP and field-programmable gate arrays (FPGAs).

The control system based on the *p*–*q* theory consists of feedback control, dc-voltage control, and voltage balancing control. Note that the feed forward control is excluded from the control system because it is impossible to detect feed forward signals (fifth-harmonic and seventh-harmonic currents) when the hybrid filter is connected to the fourth winding. The feedback control and the dc-voltage control are similar, but the voltage-balancing control is different in voltage injection.

## 4. THEORETICAL ANALYSIS OF THE HARMONICVOLTAGES INJECTION

*A. Background*

The theoretical analysis of a common harmonic zero-sequence voltage injection for voltage balancing of the two split dc capacitors in the active filter, when the hybrid filter is used for harmonic mitigation of a three-phase six-pulse diode rectifier. This paper applies the analysis to a single-phase 8-pulse diode rectifier, and adopts a common 12th-harmonic zero-sequence voltage injection with an optimal initial phase of $\phi_{12} = 0$. This paper conducts theoretical analysis of the harmonic voltages injection under no-load and light-load conditions, and experiments confirm the voltage-balancing performance.

*B. Theoretical Analysis*

The line-to-neutral voltage in the primary of the four-winding transformer $v_{SO}$ and the current flowing into the hybrid filter $i_F$ can be given by

$$V_{so} = \sqrt{2} V_{SO} \sin(\omega t - 2\pi n/3) \quad (1)$$
$$i_F = \sqrt{2} I_{F1} \cos(\omega t - 2\pi n/3) \quad (2)$$

Where $n$ = 0, 1, and 2 correspond to the $u$-phase, $v$-phase, and $w$-phase. Moreover, the 11th and 13th-harmonic currents are eliminated from $i_F$ because they are smaller than the fundamental-frequency current. The active filter voltage $v_{AF}$ is a sum of the fundamental-frequency voltage $v_{AF1}$ that is in phase with $v_{SO}$, and the second-harmonic negative-sequence voltages $v_{AF2}$. Therefore, it is given by

$$v_{AF} = \sqrt{2} V_{AF1} \sin(\omega t - 2\pi n/3) + \sqrt{2} V_{AF2} \sin(2\omega t + 2\pi n/3 - \phi_2) \quad (3)$$

Where $\phi_2$ is the initial phase of the second-harmonic voltages with respect to $v_{SO}$ (3) to be changed into the following equations(4) &(5):

$$vAF = \sqrt{2(V^2_{AF1} + V^2_{AF2})} \times \sqrt{1 + \frac{2V_{AF1}V_{AF2}}{V^2_{AF1}+V^2_{AF2}} \cos(\omega t - 2\pi n/3 - \varphi 2} \times \sin(\omega t - 2\pi n/3 + \varphi(t)) \quad (4)$$

$$\varphi(t) = -\tan{-1}\left\{\frac{V_{AF1}\sin(\omega t - 2\pi n/3 + \varphi_2)}{V_{AF2}\cos(\omega t - 2\pi n/3 + \varphi_2) + V_{AF1}}\right\} \quad (5)$$

## 5. BLOCK DIAGRAM

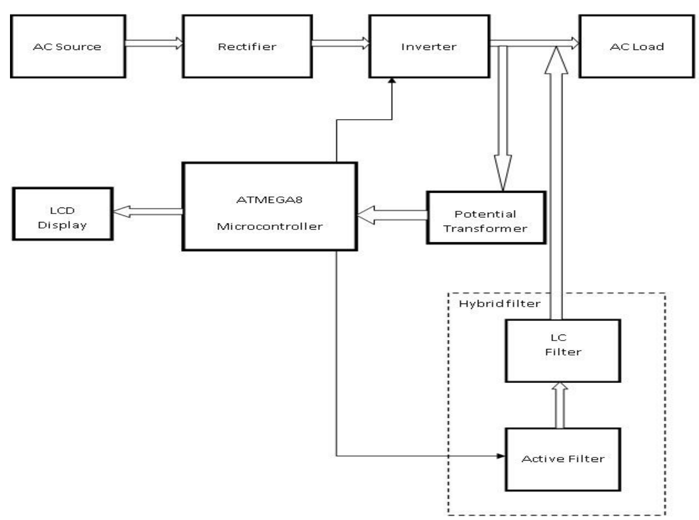


Fig.2. The block diagram

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The Figure.2 shows the block diagram of the Hybrid active filter for the Front end motor driveThe AC source is fed to the rectifier unit which converts the AC source to DC source, the rectifier unit consists of Diode this source is given to the Inverter circuit in which based on the pulse signal the output AC source is generated and that AC source have the harmonics. That line harmonics is eliminated by connecting the Hybrid filter unit in the line side of the AC load. The Hybrid filter consists of two filters one is series connected LC filter and another is Active filter. The potential Transformer connected to the microcontroller gives the analog input for calculating the harmonics in the line side.

The microcontroller which continuously checks the line harmonics and produces the pulse signal to the active filter according to the pulse signal the active filter produces the harmonics and that harmonic is fed into the line side of the load. By injecting the line side harmonics to the load side the AC load will get the harmonics free AC source. The microcontroller produces the pulse for the both Inverter and Active filter. The LCD shows the amount of harmonics in the line side and the amount of harmonics injecting to the line.

For AC to DC conversion Diode Rectifier is used and in the Inverting section MOSFET is used which requires the pulse to conduct the electricity, depends on the pulse signal given to MOSFET it produces the output. The active filter unit consists of MOSFET which produces the harmonics for injecting purpose. The pulse given to the Active filter and Inverter is 8-pulses.

## 6. HARDWARE IMPLEMENTATION

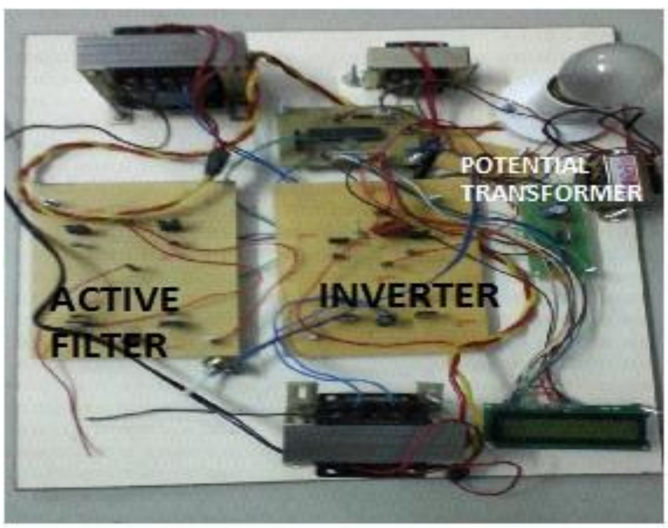


Figure.3. Hardware Implementation

To reduce the harmonic in the line by injecting the equal amount of harmonics i.e. the voltage to the line side of the load. The AC source is first converted in to DC by the Bridge rectifier and given as input to the inverter circuit and converted to AC which consists of the harmonics and by using the LC circuit the harmonics is reduced at basic level. Due to harmonics the Motor will get damage and which causes more effects to the motor.

The Harmonics is eliminated by injection of voltage, the harmonics is detected by the potential transformer which sends the voltage and that AC voltage is converted into DC by the Bridge rectifier and that DC voltage is send to the Microcontroller which continuously checks the harmonics voltage and also sends the pulse signal to the MOSFET in the Inverter. When there is a harmonics in the line side of the motor the microcontroller senses and sends the equal amount of harmonics to the line side. The Active filter feeds the harmonics as the voltage injection to the line.

## 7. RESULTS

For eliminating the line-side harmonic currents of a single-phase system which is used as the front end supply of the motor drive, In which the order of the harmonics level are $1^{st}$,$5^{th}$,$7^{th}$,$11^{th}$ and $13^{th}$ are eliminated and the Total Harmonics Distortion (THD) value is calculated by the microcontroller and shown in the LCD display.

The Total Harmonic Distortion (THD) value is the percentage of harmonics in the line side and which can be eliminated by the voltage injection from the active filter. From Table, 7.1 the harmonics level and amount of Total Harmonics Distortion is shown.

**Table7.1. Harmonic Levels and THD%**

| HARMONIC LEVEL | PERCENTAGE OF HARMONICS ELIMINATED (THD) in % |
|---|---|
| $1^{st}$ | 4.62 |
| $5^{th}$ | 5.05 |
| $7^{th}$ | 5.28 |
| $11^{th}$ | 5.66 |
| $13^{th}$ | 5.88 |

The Total Harmonics distortion percentage is calculated frequently by the microcontroller and the equal amount of harmonics is injected to the line side. The Active Filter and the LC filter which reduces the Line side harmonics. While using LC filter alone the amount of harmonic elimination is less and While using combination of Active filter and LC filter as Hybrid filter. For operating the Active filter the pulse signal is send from the microcontroller, the total amount of pulse required for the Inverter and Active filter is 8-pulses.

## 8. CONCLUSION

This proposal has described a hybrid active filter for harmonic current mitigation of a three-phase 12-pulse diode rectifier used as the front end of a high-power motor drive without regenerative braking. The hybrid filter is characterized by series connection of a simple LC filter tuned to the 11th-harmonic frequency and a small-rated active filter using a three-level NPC PWM converter. Two types of system configurations related to the point of installation of the hybrid filter have been demonstrated with the focus on harmonic-filtering performance. Technical Contributions of this paper can be summarized as follows.

1) Theoretical analysis of the voltage balancing achieved by three-phase second-harmonic negative-sequence voltages injection has been conducted with reasonable approximations, leading to an optimal initial phase of $\phi 2 = 0$. The validity of the optimal initial phase, along with stable balancing performance, has been confirmed experimentally by a 400-V 15-kW downscaled system.

2) This circuit configuration brings the Hybrid filter low cost, small size, and light weight.

3) The efficiency of the front end motor drive will increase and the results in lower cost and smaller size than the former system.

## 9. FUTURE WORK

- Instead of ATMEGA8 controller we can use PID controller.
- The number of pulses given to the inverter and active filter will reduce.
- This proposal can implement this method for all domestic applications to protect them from damage due to fluctuations.

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