

Suppressing harmonics and Neutral-Line Current Using Adaptive Neuro-Fuzzy Inference Process (ANFIS)

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ABSTRACT: In this paper, a brand new hybrid power conditioner is proposed for suppressing harmonic currents and impartial-line present in three-phase four-wire distribution power systems. Also this paper grants a three-section hybrid energy filter situated on artificial intelligence manipulate procedure. It contains C-type passive filter in parallel with a shunt lively filter that's controlled by an adaptive Neuro-Fuzzy inference process (ANFIS) controller. The energetic filter is established on a three-phase voltage inverter with six manipulate switches. The AC facet of the filter is hooked up in parallel with the nonlinear load by means of an interface reactor, while the DC side connected to a DC-link capacitor. The process will estimate harmonic content in the supply present, produced by way of nonlinear load and generate reference waveform for control voltage supply inverter.

KEYWORDS: Harmonic, neutral-line current, power converter

I. INTRODUCTION

Electrical energy is the most efficient and popular form of energy and the modern society is heavily dependent on the electric supply. The life cannot be imagined without the supply of electricity. At the same time the quality of the electric power supplied is also very important for the efficient functioning of the end user equipment. The term power quality became most prominent in the power sector and both the electric power supply Company and the end users are concerned about it. The quality of power delivered to the consumers depends on the voltage and frequency ranges of the power. If there is any deviation in the voltage and frequency of the electric power delivered from that of the standard values then the quality of power delivered is affected. Now-a-days with the advancement in technology there is a drastic improvement in the semi-conductor devices. With this development and advantages, the semi-conductor devices got a permanent place in the power sector helping to ease the control of overall system. Moreover, most of the loads are also semi-conductor based equipment. But these semi-conductor devices are non-linear in nature and draws non-linear current from the source. And also the semi-conductor devices are involved in power conversion, which is either AC to DC or from DC to AC. This power conversion contains lot of switching operations which may introduce discontinuity in the current. Due to this discontinuity and non-linearity, harmonics are present which affect the power quality delivered to the end user. In order to maintain the power quality delivered, the harmonics should be filtered out. Thus, a device named Filter is used which serves this purpose. There are many filter topologies in the literature like- active, passive and hybrid. In this project the use of hybrid power filters for the improvement of electric power quality is studied and analyzed.

As the neutral point of an electrical supply system is often connected to earth ground, ground and neutral are closely related. Neutral is a circuit conductor that carries current in normal operation, which is connected to ground (or earth). Current carried on a grounding conductor can result in objectionable or dangerous voltages appearing on equipment enclosures, so the installation of grounding conductors and neutral conductors is carefully defined in

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electrical regulations. Where a neutral conductor is used also to connect equipment enclosures to earth, care must be taken that the neutral conductor never rises to a high voltage with respect to local ground.

The task of a power converter is to process and control the flow of electric energy by supplying voltages and currents in a form that is optimally suited for the user loads. Energy was initially converted in electromechanical converters. Today, with the development and the mass production of power semi-conductors; static power converters find applications in numerous domains and especially in particle accelerators. They are smaller and lighter and their static and dynamic performances are better.

II. THREE-PHASE FOUR-WIRE HYBRID POWER FILTER

Fig.1 suggests the configuration of a traditional shunt-type hybrid power filter utilized to the three-phase 4-wire distribution power system. Within the traditional shunt-type hybrid power filter, the power converter is attached to the passive power filter in series and then connected to the weight in parallel. The power converter can also be configured by way of a four-arm bridge structure or a three-arm bridge constitution with a cut up-capacitor arm. The passive energy filter is configured through three-phase tuned energy filters with an inductor and a capacitor connected in series in every section, and their tuned frequency is the dominant harmonic frequency of the burden. The tuned frequency of the tuned power filters is designed at the third harmonic frequency in the application of three-phase 4-wire distribution power methods. As noticeable in Fig.1, the major part of the utility voltage will drop on the passive power filter. In this manner, the dc bus voltage and voltage score of the power converter may also be drastically diminished. However, the present of the power converter, together with the harmonic currents of the load and the predominant reactive present of the passive power filter, isn't diminished.

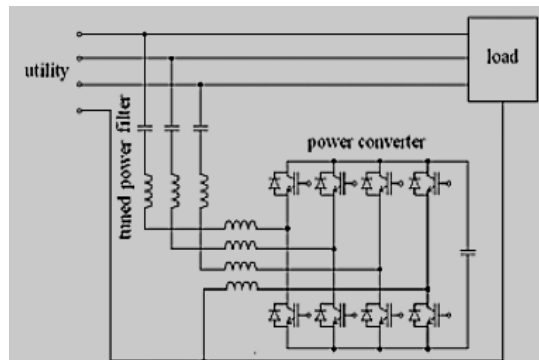


Fig.1. Configuration of the conventional shunt-type hybrid power filter.

A complicated hybrid power filter, shown in Fig.2, is proposed to extra limit the energy ranking of the power converter. As obvious in Fig. 2, the power converter is attached to the inductors of the three-phase tuned power filter in parallel.

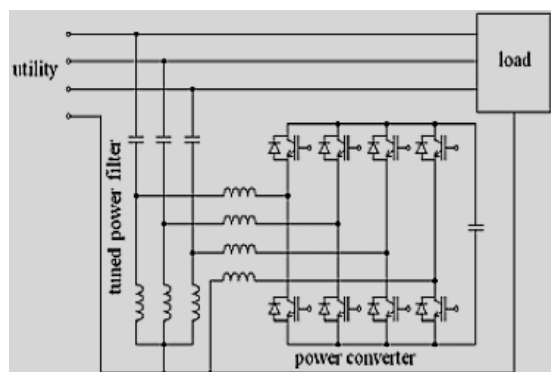


Fig.2. Configuration of the advanced hybrid power filter.

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Considering the energy converter is parallel to the inductors of the tuned energy filters, the major essential reactive present of the three-phase tuned power filter and the dominant harmonic present of the burden will go with the flow through the inductors of the three-phase tuned power filter via proper manage of the power converter, hence lowering the present flowing via the power converter. The major role of the conventional shunt-type hybrid power filter applied to the three-phase four-wire distribution power system is to filter harmonic currents of the load. If the three phase loads are unbalanced, the neutral-line current of the load contains a fundamental component. The conventional shunt type hybrid power filter cannot respond to this fundamental component of the neutral-line current. Therefore, it cannot effectively suppress the neutral-line current under the unbalanced load.

III. SYSTEM CONFIGURATION OF THE NEW HYBRID POWER CONDITIONER

Fig.3 suggests the procedure configuration of the proposed hybrid power conditioner. In assessment with the traditional hybrid power filter, a neutral-line present attenuator is integrated into the hybrid power filter in the proposed hybrid power conditioner. The built-in impartial-line current attenuator can strengthen the filter efficiency of the hybrid energy filter below the unbalanced load. As a result, the proposed hybrid power conditioner can simultaneously and easily remedy the problems of harmonic currents and neutral-line present in three-segment 4-wire distribution power techniques. To extra cut back the power rating of the power converter, the advanced hybrid power filter is used with the three-phase power converter related to the inductors of the three-section tuned power filter in parallel. By way of incorporating the neutral-line present attenuator, the hybrid power filter is utilized to suppress most effective the nonzero-sequence harmonic currents in three-phase four wire distribution power systems. For this reason, the three-section energy converter is configured with the aid of a three-arm bridge structure and the tuned frequency of three-segment tuned power filter is about at the fifth harmonic frequency. With an broaden in tuned frequency of the tuned energy filters, the inductance of inductors can also be lowered. For that reason, the volume and weight of the three section tuned energy filter are reduced.

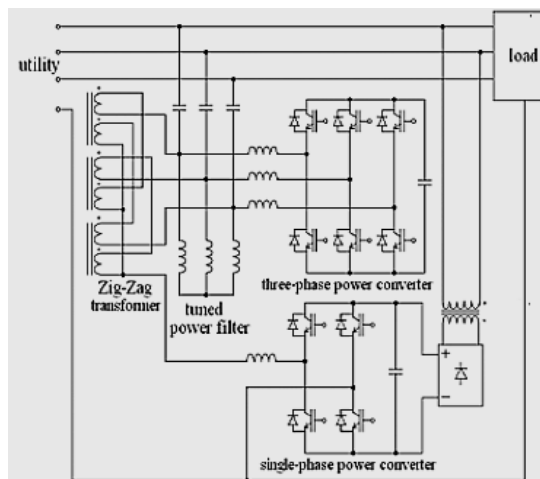


Fig.3. System configuration of the proposed hybrid power conditioner.

The neutral-line current attenuator of the hybrid power conditioner is employed to suppress the impartial-line current. Conventionally, the neutral-line present attenuator is connected between three-segment traces and the neutral line of the three-segment 4-wire utility [6]. As a consequence, the voltage ranking of the zig-zag transformer utilized in the traditional neutral-line current attenuator is the segment voltage of the three-segment 4-wire utility, consequently enlarging the quantity and weight of the zig-zag transformer. As can also be shown in Fig.3, the impartial-line present attenuator is attached to the capacitors of tuned power filters in sequence, and the important aspect of segment voltage will drop on these capacitors. The voltage ranking of the zig-zag transformer is almost equal to the voltage of inductors

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within the tuned power filters, and its voltage could be very small compared with the zigzag transformer used in the conventional impartial-line current attenuator.

Consequently, the quantity and weight of the zig-zag transformer used in the proposed neutral-line present attenuator are lowered. The only-section power converter is hooked up to the zig-zag transformer in sequence to develop the performance of the zig-zag transformer. As noticeable in Fig.3, the neutral line of the weight is straight linked to that of the utility, and the fluctuation in ground voltage of the burden can hence be kept away from. As a result of power loss brought about by means of the operation of the single phase power converter, the dc bus voltage of the energy converter is reduced. Nonetheless, the energy loss is low in view that the dc bus voltage of the single-phase power converter is low. A simple single-section diode rectifier is employed to supply power to the dc bus of the single-phase power converter to maintain the dc bus voltage at an acceptable variety. A transformer is employed to step down the line-to-line voltage. The input present of the single-segment diode rectifier is small.

A. Adaptive Neuro-fuzzy inference system

ANFIS is a hybrid soft computing model composed of a neuro-fuzzy system in which a fuzzy inference (high-level reasoning capability) system can be trained by a neural network-learning (low-level computational power) algorithm. ANFIS has the neural network's ability to classify data in groups and find patterns and further develop a transparent fuzzy expert system. Moreover, ANFIS has the ability to divide and adapt these groups to arrange a best membership function that can cluster and deduce the desired output within a minimum number of epochs [12]-[13]. The fuzzy inference system can be tuned by the learning mechanism. A given input/output data set, ANFIS constructs a fuzzy inference system (FIS) whose membership function parameters can be tuned (adjusted) using either a back-propagation algorithm alone or in combination with a least squares type of method.

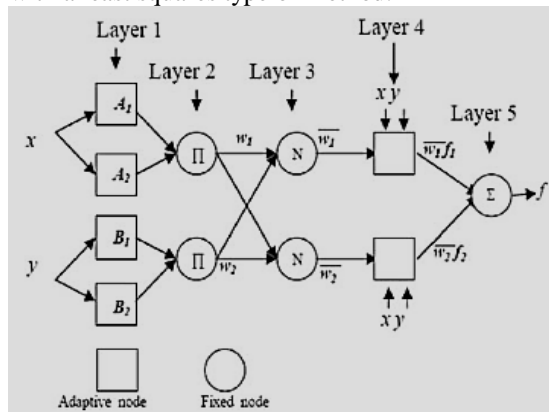


Fig. 4. ANFIS architecture.

Figure 4 shows the ANFIS architecture used in this work. This system has two inputs x and y and one output, whose rule is:

if x is A_i and y is B_i , then $f_i = p_i x + q_i y + r_i$, $i=1,2$

where f_i is the output and p_i , q_i and r_i are the consequent parameters of i th rule. A_i and B_i are the linguistic labels represented by fuzzy sets. The output of each node in every layer can be denoted by O_i^l where i specifies the neuron number of the next layer and l is the layer number. In the first layer, called fuzzifying layer, the linguistic labels are A_1 and B_1 . The output of the layer is the membership function of these linguistic labels and is expressed as

$$O_i^1 = \mu_{A_i}(x)$$

$$O_i^1 = \mu_{B_i}(y)$$

where $\mu_{A_i}(x)$ and $\mu_{B_i}(y)$ are membership functions that determine the degree to which the given x and y satisfy the quantifiers A_i and B_i . In the second layer, the firing strength for each rule quantifying the extent to which any input data belongs to that rule is calculated.

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IV. NEW TOPOLOGY OF HYBRID POWER FILTER

The new hybrid power filter system consist of the following major parts; mains supply, nonlinear load, data acquisition and controller, APF with interface reactor and C-type high-pass passive filter network as illustrated in fig.5.

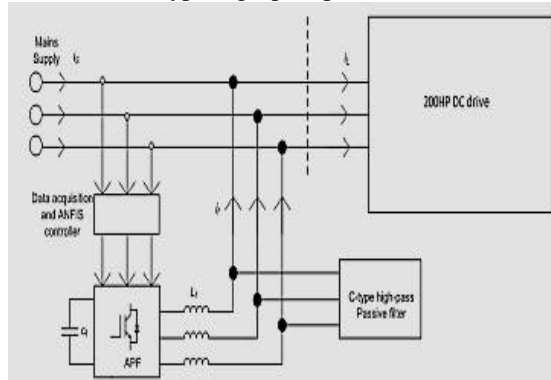


Fig.5: principle topology of analysed hybrid power filter

Harmonic current generated by a nonlinear load is detected and used to generate gating pulse with the use of ANFIS controller. The output of the gating signals controller controls the voltage-source inverter that provides part of reactive power required by nonlinear load. The passive filter is placed in parallel with the APF which makes the inverter to be smaller than when it was used alone, because it also provides reactive power and attenuates high frequencies that might be generated by the filter itself.

A. Topology Operation Description

Considering each phase in a three-phase system, where mains voltage is v_s is a purely sinusoidal:

$$v_s = V_p \sin \omega t \quad \dots \dots \dots (1)$$

With V_p representing peak voltage and ω is the angular frequency. The periodic non-sinusoidal currents of nonlinear loads can be represented by Fourier progression as follows:

$$i_1(t) = I_1 \sin(\omega t + \phi_1) + \sum_{n=3}^{\infty} I_n \sin(n\omega t + \phi_n) \quad \dots \dots \dots (2)$$

Where t is the time in seconds, I_1 is the fundamental component; ϕ_n is the respective angle and I_n is the harmonic component.

The non-linear current i_1 can be written as:

$$i_1 = i_a + i_d \dots \dots \dots (3)$$

Where i_a is the active component and i_d is the reactive component and harmonics. The converter control method will be such that it validates the following expression:

$$i_f = -i_d \dots \dots \dots (4)$$

Where i_f is the current from the filter. Making the assumption that it is easy to verify that the mains current will result in its active component then,

$$i_s = i_1 + i_f = i_a + i_d + (-i_d) = i_a \dots \dots \dots (5)$$

$$i_s = i_p \sin(\omega t) \dots \dots \dots (6)$$

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Where i_p is the amplitude of the source current. This means that the non-linear load current plus the hybrid filter actuates as a pure resistive linear load current.

In a three phase five switches system the active harmonics is as follows:

$$n = 5k \mp 1 \text{ for } k=1,2,3 \dots \dots \dots (7)$$

Where n is the active harmonic component and k is the sequence. The target of the HPF is to identify these harmonic currents and generate inverse equivalent that will cancel out maintaining characteristics of linear load for a nonlinear load connected to the power supply system.

B. Design procedures for c-type high pass filter

The C-type HPF topology is employed in the proposed hybrid power filter as mentioned earlier. It consists of a capacitor C , a capacitor C_a , an inductor L and an inductor bypass resistor R as shown in fig.6. This section describes the design procedure for C-type high pass filter using the passive elements. These elements are determined based on the filter type and the following parameters;

- (i) Reactive power at nominal voltage
- (ii) Cut-off frequency
- (iii) Quality factor

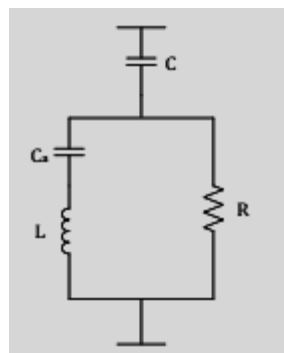


Fig.6: C-type high-pass filter

Using the following formulae, the damped C-type passive filter is set to attenuate 13th order harmonic and above.

V. CONCLUSION

In this paper the effectiveness of the new hybrid filter topology and controlled strategy based on ANFIS control technique has been verified. A three-phase balanced load of a DC drive is simulated with active filter and later with hybrid power filter. From the results, it clearly indicates that, the current compensation is much better using hybrid power filter compared to Active power filter.

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