Journal of Engineering and Applied Sciences 13 (Special Issue 7): 5517-5522, 2018
ISSN: 1816-949X

Harmonic Mitigation and Neutral Line Currents Reduction of Distribution Systems Using Adaptive Neuro-Fuzzy Inference System Based D-STATCOM

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Abstract: This study describes about a novel controller based hybrid power compensator is introduced for improving power quality of the network. The proposed system consist of tuned filter and D-STATCOM, it will reduces the %THD, reactive power and -ve sequence component of currents induced by utilization of non-linear loads and unbalanced loads. By introducing soft computing technique in controlling of STATCOM will results enhanced quality of power. The proposed system contains Adaptive Neuro-fuzzy Inference System (ANFIS) will respond fast with parameter deviation between reference, measure and reduction of distortions in fundamental component of currents to a greater extent.

Key words: D-STATCOM, harmonics, ANFIS, -ve sequence currents, unbalanced loads, fundamental component

INTRODUCTION

Nowaday's utilization of electrical energy is increased due to increase in industrialization of world. The most industries have non linear loads, variable and unbalanced loads. These loads are effects quality of power to a considerable extent. Most of the non linear loads are industrial drives and automated systems. The major components of drives and automated systems are power electronic converters because converters can give variable output as per requirement of the system. The utilization of non linear loads will introduces harmonic currents at source side leads to droop power quality (Wu *et al*., 2014; Wagner *et al*., 1993). Some of the loads are unbalanced in nature, this are causes for flow of ve sequence of current in neutral line. This loads are consumes more reactive power from the source.

There four due to harmonics, reactive power, -ve sequence component of current are degrades quality of power. These are results, dropping system performance, losses and increased power consumption (Dugan *et al*., 1996). The quality of power can improved by controlling the harmonic currents, reactive power and -ve sequence component of current. This can be achieved by introducing filers in industrial networks.

Basically two types of filters are used for improving power quality of supply. Those are active and passive filters, the passive filters are used for constant and linear loads. The active filters are used for time varying and non linear loads. The futures of this two can be achieved by using hybrid filers. Because hybrid filters consist of active and passive filers. In this study, the hybrid filer having tuned type of passive filer and D-STATCOM used as an active filter. This hybrid filters controlled by Srinivasan *et al*. (2006) and Akagi (1994) ANFIS controller will enhances the performance of the system (Daneshdoost *et al*., 1998).

Implentation of hybrid D-STATCOM: The system under study consists of sources consists of non liner loads and hybrid D-STATCOM in shunt with loads. Gannett *et al*. (2002) the hybrid filters having tuned filer, zig zag transformer and D-STATCOM. The tuned type of filers are used for selective harmonic elimination and placed in series with D-STATCOM. It will shows reduced stresses on D-STATCOM power electronic devices. Most likely tuned filters are used for fifth order harmonics. Asiminoaei *et al*. (2005) The zig zag transformer is in parallel with tuned and active filers used for controlling -ve sequence component of current with the combination of single stage converter.

Figure 1 and 2 show the components involved in hybrid filter (Czarnecki, 2006). The tuned filter can suppress fifth order harmonic completely. Due to his the stress on D-STATCOM power electronic devices reduces to a greater extent. The D-STATCOM is used for reduction of other than fifth harmonic component on to reduce reactive power consumed by non linear load from source.

By Chen and Jouanne (2001) the D-STATCOM controller will calculate percentage of harmonics introduced by load into source and reactive power

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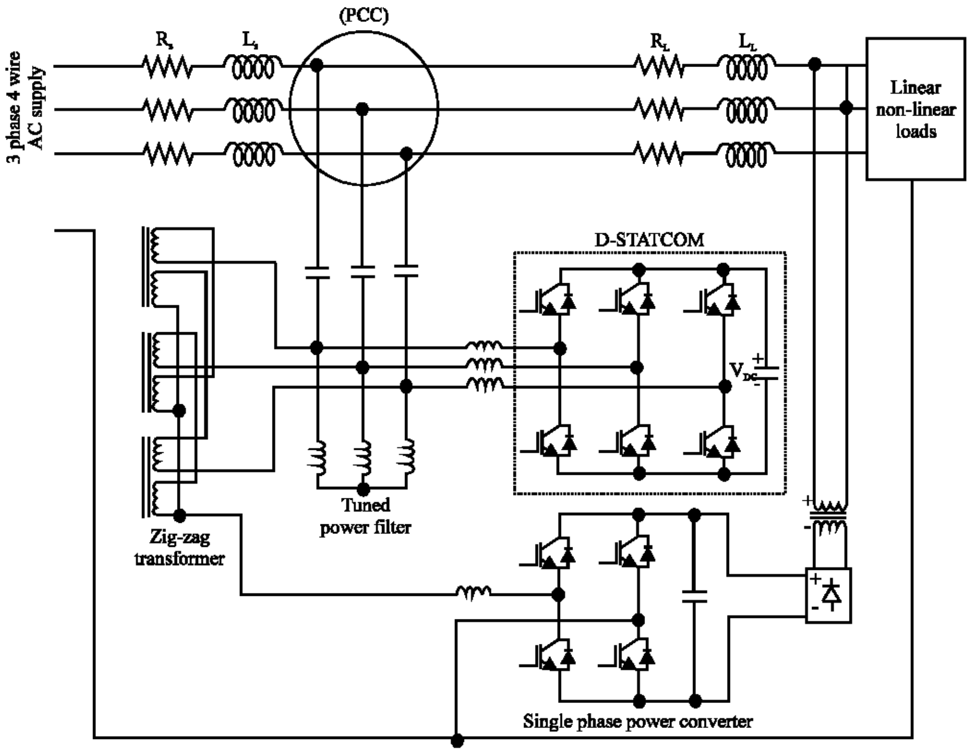

Fig. 1: System configuration of proposed D-STATCOM

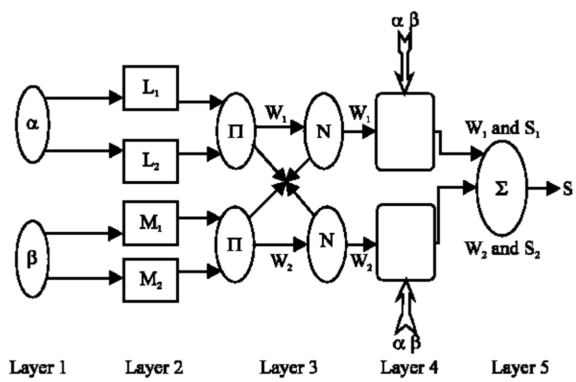

Fig. 2: Structure of ANFIS

consumed by load. The D-STATCOM will injects harmonic currents are injected in phase opposition with harmonic current injected by load and reactive power consumed by load.

The -ve sequence component of currents are introduced by unbalanced loads. Nauck (1995) this -ve sequence components are flowing in neutral line will shows effect on system balance, i.e., system goes to unbalance conduction. Ozpineci *et al*. (2005) the system balancation was restrain by injecting the -ve sequence component in neutral line in phase opposition with neutral line unbalanced component caused by the load.

MATERIALS AND METHODS

Control structure design: ANFIS (Adaptive Neuro-Fuzzy Inference System) is the combination of fuzzy logic controller and neural networks. ANFIS is a trained logical controller. In this sugeno type of fuzzy controller is used for logical structure design (Ubeyli *et al*., 2010) because ANFIS can give better response with sugeno type of rule base. A neural network is used for trine ANFIS. Conventional fuzzy logic controller membership function design is depends on input error parameters. Wu *et al*. (2012) but in ANFIS fuzzy logic controller membership function are altered continuously with neural networks. They are altered by adjusting the weights of neural networks for getting better performance by training process. Here:

Number of inputs = 2 α, β

Number of outputs = 1 $\rightarrow$ S

If α is L_k and $M_k \rightarrow S_i = a_k^{\alpha} + b_k^{\alpha} + c_k$, K = 1, 2, 3, ...,

Here, the input is S_k and a_k, b_k and c_k are proportionality constants of roots, L_k and M_k are (Choubey *et al*., 2011; Gill and Singh, 2009) fuzzy set labels. A neuron output is represented by D_k^l. Here, K is number of neurons in next layer and L id the layer number and L_k, M_k are member ship functions.

Fuzzy set are represented as:

$$D_k^l = \gamma_{LK}(\alpha)$$
$$D_l^k = \gamma_{MK}(\beta)$$

Here, $\gamma_{LK}(\alpha)$ and $\gamma_{MK}(\beta)$ are calculated member ship functions for enhanced operation.

Topology operation description: Considering each phase in a three-phase system where mains voltage is V_s is a purely sinusoidal:

$$V_s = V_p \sin \omega t \quad (1)$$

Where:
V_p = Peak voltage
ω = The angular frequency

The periodic non-sinusoidal currents of nonlinear loads can be represented by fourier progression as follows:

$$i_l(t) = I_1 \sin(\omega t+\varphi_1)+\sum_{n=3}^{\infty}\left[I_n \sin\left(n\omega t+\varphi_n\right)\right] \quad (2)$$

Where:
t = The time in seconds
I_1 = The fundamental component
φ_n = The respective angle
I_n = The harmonic component

The non-linear current i_l can be written as:

$$i_l = i_a+i_d \quad (3)$$

Where:
i_a = The active component
i_d = The reactive component and harmonics

The converter control method will be such that it validates the following expression:

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

where i_f is the current form the filter making the assumption that it is easy to verify that the mains current will result in its active component then:

$$i_s = i_l+i_f = i_a+i_d+(-i_d) = i_a \quad (5)$$

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

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 (Shubhangi Giripunje, 2007). In a three phase five switches system the active harmonics is as follows:

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

Where:
n = The active harmonic component
k = 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 an nonlinear load connected to the power supply system.

RESULTS AND DISCUSSION

Hybrid shunt active power filter have been used for mitigation of harmonics and negative sequence current flowing in neutral point (Fig. 3).

Hybrid filter has been activated at 0.4 sec. The period 0-0.4 having more harmonics in source currents, after 0.4 sec it will be reduced due to the switching of hybrid filter in distribution system (Fig. 3-7). From Fig. 8 and 9 THD is almost equal to ZERO. Because no non-linear loads are acting on the system (Table 1).

Table 1: Comparison of total harmonic distraction

Controller	THD (%)
Without controller	20.12
PI controller	14.63
Fuzzy controller	9.25
ANFIS controller	5.74

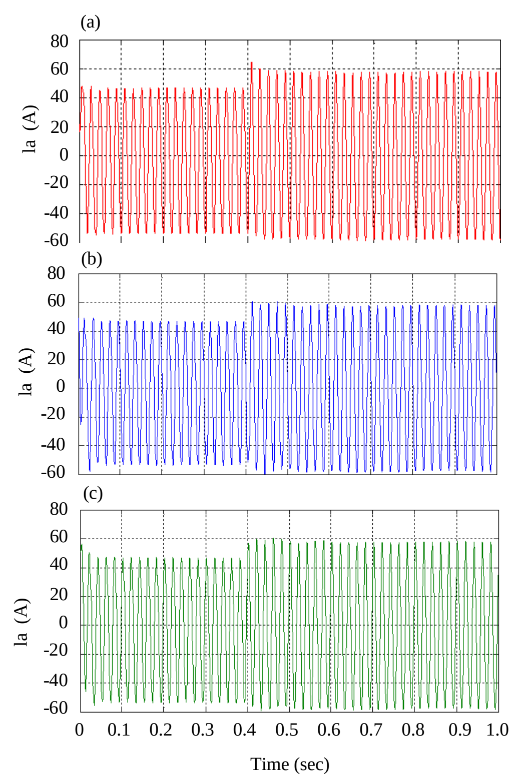

Fig. 3: Continue

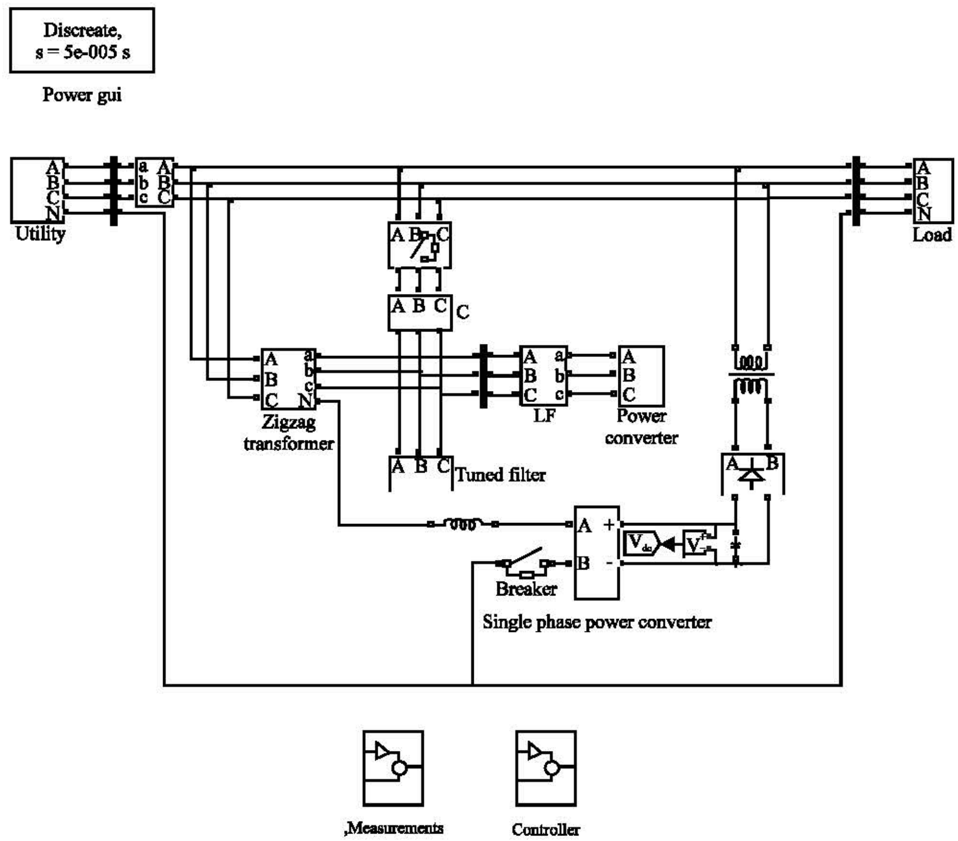

Fig. 3: a) I_a in current; b) I_b current; c) I_c current and d) Simulation diagram of ANFIS based D-STATCOM configuration

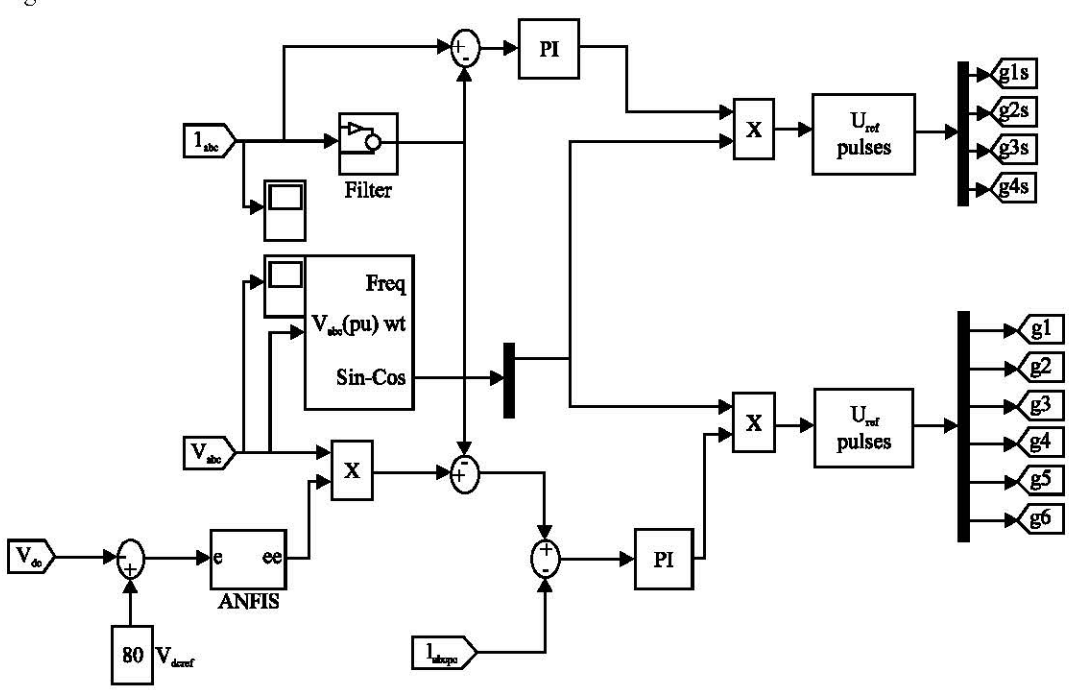

Fig. 4: Simulation diagram of ANFIS controller diagram

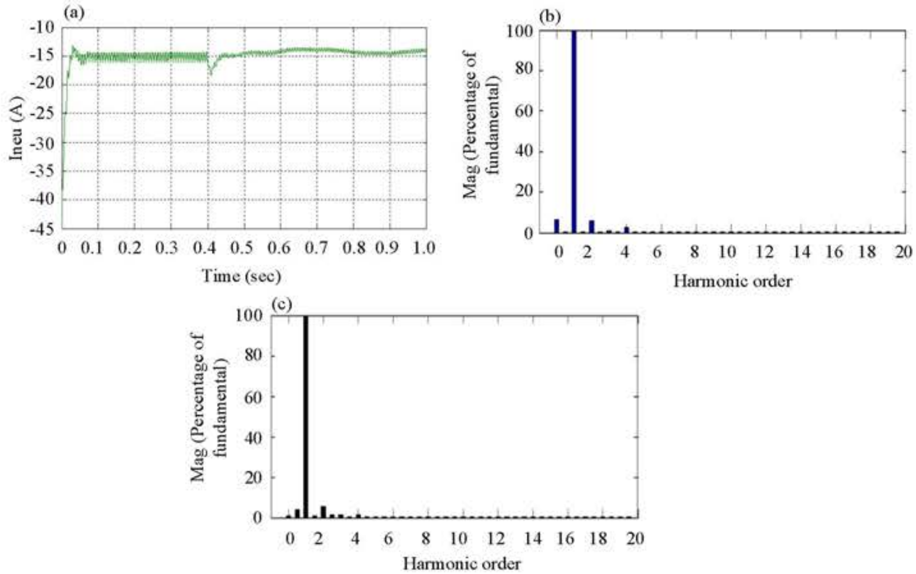

Fig. 5: In current (neutral currents); Total harmonic distraction 6.11%; Linear load results; a) I_a in current; b) I_b in current and c) I_c in current

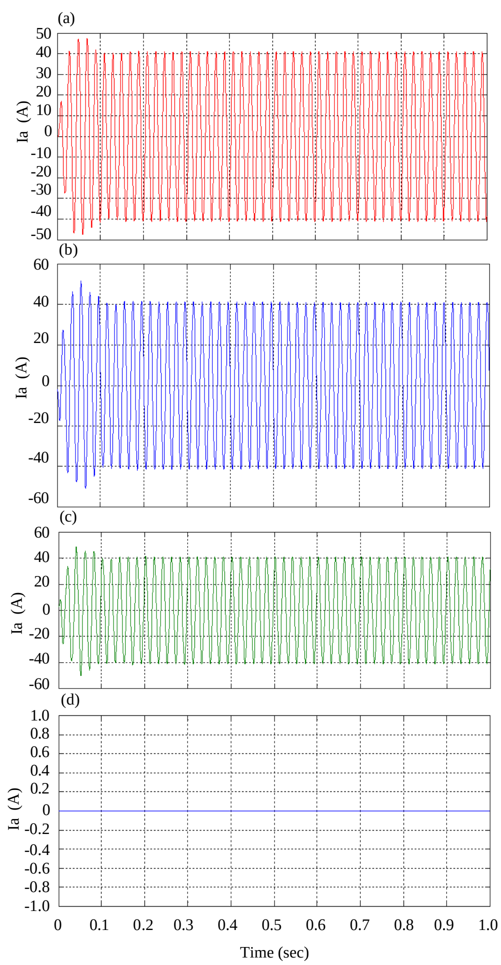

Fig. 6: Non-linear loads

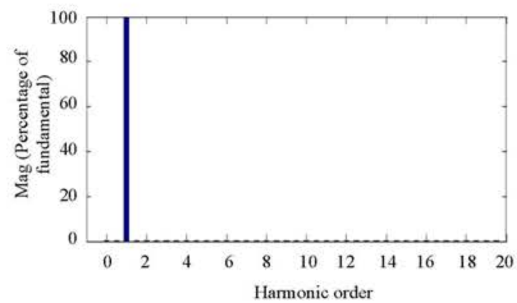

Fig. 7: Total harmonic distraction 5.74%

CONCLUSION

In this study, proposed hybrid multilevel compensator reduces total harmonic distraction (%THD), reduces DC link voltages and improves power factor of the system. ANFIS controller was used in proposed hybrid system, the proposed controller wills reduces source current distraction that is %THD of source current 9.25-5.74%. From this the proposed controller reduces the %THD effectively than conventional fuzzy controller.

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