POWER LOSS REDUCTION AND POWER QUALITY IMPROVEMENT IN DISTRIBUTION SYSTEMS USING A FUZZY CONTROL SYSTEM

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Abstract: **Renewable energy sources are a reliable alternative to the conventional energy sources. In this paper performance of a distributed generation converter is enhanced with the aim of reducing the power loss and improving the power quality. The proposed system not only, can control the active power flow but also mitigate the load unbalance and harmonics, and manage reactive power. In order to realize a specific structure of power electronic based converter developed by two voltage source inverter is proposed. These two inverters are parallel connected together and supposed to provide grid-connection of a one-phase distribution generation resource. Since the first inverter is operated with a low frequency switching strategy and the second has low magnitude current with high switching frequency, the total power loss will significantly less than that of individual high frequency inverters. Moreover, this converter acts as an active power filter (APF) that provides a pure sinusoidal current at unity power factor into the network by compensating the harmonic contents and also reactive power required from the load. Consequently, the desired condition is satisfied by the proposed converter and then the power quality and power losses are improved. The performances of the proposed scheme are verified through the simulation analysis in MATALB framework**.

Keywords-component; distributed generation (DG), load compensation, distribution network, loss reduction, cooperative converters.

I.INTRODUCTION

There are various methods which have been proposed to reduce the power loss in distribution networks. Reconfiguration of distribution network is the most conventional approach proposed recently for the aim of loss reduction. In this paper, the loss reduction is investigated from the power electronic converter based distributed (DG) generation interface point of view. The concept of DG resources are introduced as a proper solution for the various Issues caused by the environmental concerns as well as the investment and operation costs of large power plants. Nowadays, these resources have an important role in the utility network. Through defining of a DG resource in different references, it is supposed to be integrated into the LV and/or the MW distribution network.

In the network with significant DG resources, some of the aspects related to the power quality such as harmonic polluted load current injection into the network, poor power factor and increasing the reactive power required from the load demand causes grid line current to be increased. Therefore, the power loss will be increased, accordingly. An increase in harmonic contents not only increase the power loss, but it is followed by the other undesired phenomena such as increasing the power loss in transformers and rotational machines, creating the torque ripple and mechanical stress in electrical machines, over heating problem and ageing the power factor correction capacitor bank .The most of previous works such as have used a voltage source converter (VSI) with high frequency switching pattern in order to facilitate the integration of DG

into the grid while compensating the load current distortion. The switching loss, in this case, will be significant due to the high frequency switching and also high rate current flowing through the semiconductor based switches. Some references have suggested different structures including the combination of several VSI. Each of this topologies have the respective advantages and disadvantages. With the aim of integration of a high power solar arrays and the load current compensation, a specific scheme constructed by two parallel similar inverters has been proposed; however, the complexity of the model concluded in dqO framework is relatively high. In and, a new series-parallel structure is used for the purpose of integrating the DG into the network. The presence of non-linear loads at point of common coupling (PCC) and the respective compensation have been not considered in the mentioned approaches. In, a multi-level CHB-type converter is used for the compensation of harmonic and reactive contents of the load current. In this work, the switching frequency related to each of HB inverters is equal to the grid frequency that leads the switching loss to be significantly reduced. However, this method can eliminate only some pre- specified harmonics. In, for solving this problem and obtaining the more reduced power loss, the series converters are categories into two groups one containing the cells with low frequency switching and the other one have high frequency switching. Similar to [12], in this paper, two cooperative VSI are used such that the first one is operated with high current and low frequency switching. The second VSI is operated in contrast with the first VSI where the current and switching frequency is low and high, respectively. In this case, switching loss will be significantly reduced. The main contribution of this paper is the introduction of local linear and non-linear which are not considered in [12]. Also, modified equations are used to design the control strategy in such a way that reactive load current be efficiently compensated like load current harmonics. The reminder of the paper is as follows: Section 2 presents the structure of the proposed converter with modified equations representing the control strategy. In section 3, results of the simulations

performed in MATLAB are analyzed. Finally, section 4 concludes the paper and expresses the future scopes.

II. PROPOSED CONVERTERSTRUCTURE AND THE FUZZY CONTROL STRATEGY

The schematic of studied network is given in Fig. l. As shown in this figure, a DG resource with DC output voltage related to the PV arrays, in this paper, is considered to be connected to the PCC through the power electronic based interface. The interface is constructed by two single phase VSIs. The load connected to the PCC may be linear load, non-linear load and/or a combination of them. The aim is that using such a converter with low power losses the power generated from the PV array is injected into the grid; Also, the reactive load current and harmonic contents of grid current are compensated such that a relatively pure sinusoidal current with T H D less than 5% (according to the standards regulated in [13]) and in-phase with the grid voltage is injected/absorbed to/from the network utility.

Thus, the following conditions are satisfied and then power quality as well as power loss in the distribution network will be enhanced, 1) providing the harmonic components of load current and avoiding them to be injected to the grid; 2) providing the reactive load power and preventing the grid to supply it; and 3) reducing the total power loss of converter.
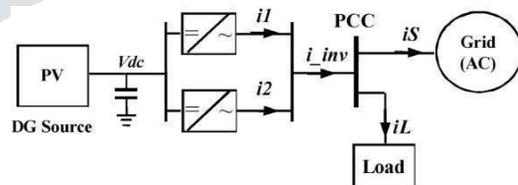

Fig 1. Structure of the studied network

a) Fuzzy Control System

A fuzzy control machine is a control gadget based on fuzzy good judgment—a mathematical machine that analyzes analog input values in terms of logical variables that take on non-stop values between zero and 1, in assessment to classical or virtual logic, which operates on discrete values of either 1 or 0 (proper or fake, respectively). Fuzzy good judgment is broadly used in device control. The term "fuzzy" refers back to the truth that the logic worried can deal with standards that can't be expressed because the "true" or "false" but instead as "in part proper".

b) Fuzzy sets

The enter variables in a fuzzy manipulate device are in fashionable mapped by units of membership capabilities just like this, known as "fuzzy sets". The system of converting a crisp enter price to a fuzzy cost is called "fuzzification". This rule through itself may be very perplexing because it looks as if it is able to be used with out bothering with fuzzy common sense, however understand that the choice is based totally on a set of regulations:

i.   All of the rules that apply are invoked, using the membership capabilities and fact values obtained from the inputs, to determine the end result of the rule of thumb.

ii.   This bring about flip will be mapped into a membership characteristic and reality price controlling the output variable.

iii.   These effects are blended to present a specific ("crisp") answer, the real brake stress, a system known as "defuzzification".

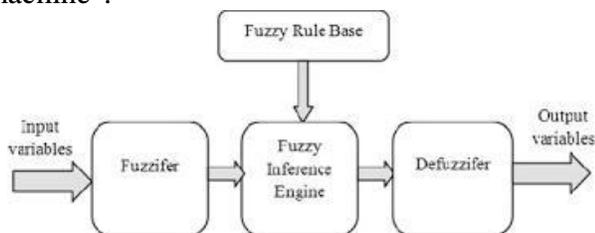This mixture of fuzzy operations and rule-based "inference" describes a "fuzzy professional machine".

Fig.2. Fuzzy System

c) Fuzzy Control in Detail

Fuzzy controllers are very simple conceptually. They consist of an enter level, a processing stage, and an output stage. The input level maps sensor or other inputs, which includes switches, thumbwheels, and so forth, to the right club functions and truth values. The processing degree invokes every suitable rule and generates a end result for each, then combines the consequences of the policies. In the end, the output level converts the mixed end result back into a particular manage output value.

The most not unusual form of membership capabilities is triangular, even though trapezoidal and bell curves also are used, but the shape is generally less important than the quantity of curves and their placement. From 3 to seven curves are typically suitable to cover the desired variety of an input price, or the "universe of discourse" in fuzzy jargon. As discussed in advance, the processing level is based on a collection of logic policies inside the shape of if-then statements, where the if part is known as the "antecedent" and the then part is known as the "consequent". Common fuzzy manipulate systems have dozens of guidelines.
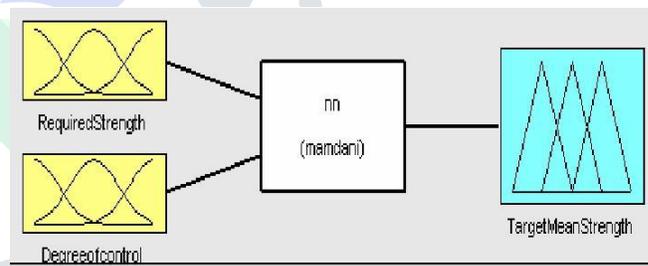

Fig.3 Fuzzy Control of a System

A. Operation of converters and the reasons for loss reduction

According to Fig. 2, each of the converters shown is a transistor H-bridge on which their output is equipped with an inductive filter because of voltage-to-current transformation.

The first converter namely low-switching frequency inverter (LSFI) has a quasi-square voltage with a low frequency that is equal to grid frequency, as shown in Fig. 3. This converter is supposed to capture the power generated form

PV arrays and inject it into the grid. Also, LSFI is used to provide the reactive power compensation corresponding the fundamental component of load current.

On the other hand, the second converter namely high- switching frequency inverter (HSFI) has a high operation frequency and it is used here to realize the harmonic compensation of the load current. In addition, HSFI has to provide the harmonic distortion of the current generated from LSFI. The cooperation ofLSFI and HSFI described here brings a pure sinusoidal current without dominant harmonic at unity power factor which will be injected / absorbed to/from the gird.

Although the current which flows through the first converter is relatively high, but the switching loss will not be significant because it's switching frequency is low. In this converter, one may use the high rated element as well as low frequency switches such as thyristors. On the other hand, HSFI is only used for compensating the harmonic contents. Therefore, the switching loss will be low as the harmonic currents are significantly less than the fundamental one. Consequently, it can be concluded that the efficiency of proposed interface versus the single inverter with high-switching frequency is enhanced.

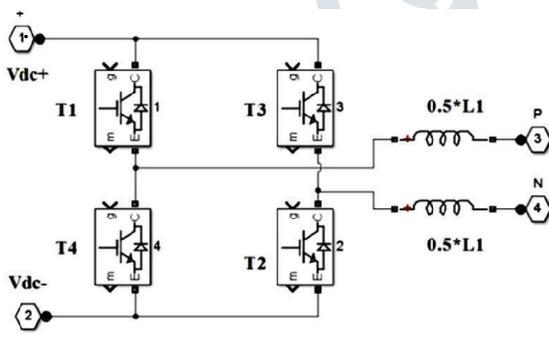B. Control strategy for the first inverter (LSFJ)

Fig..4. Structure of LSFI and HSFI HSFI, a significant dc current is created

circulating between the converters. A simple solution is to increase the resistance. However, the power loss will be increased in this manner and hence it is contrary to what the paper is aimed for. A novel approach is utilized as shown

in Fig. 4. A PI controller is used for controlling m and creating the asymmetrical quasi square
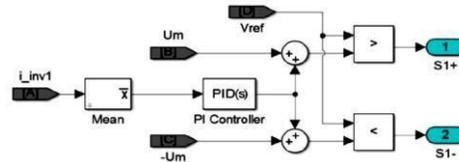

Fig.5. Controlling the DC component of LSFl output voltage for eliminating the DC component of inverter current

C. Control strategy for the seccond inverter (HSFI)

The main purpose of this inverter is to compensate the harmonic contents of load current plus the LSFI harmonics. The calculation of these values is given in this section.The generated actual current from the first converter is measured. Then, it is compared with the fundamental component of LSFI $l_{inv,1}$ which is equal to the total supplied current by Inverters ($I_{1,1}$) calculated using (3) and (4). The difference of these waveforms must be compensated by HSFI. The other part which should be generated by HSFI is the load current harmonics. The measured load current minus its fundamental component results the load current harmonies. It should be noted that the fundamental load current is calculated using FFT and expressed in (3), before. Finally, the reference signal that should be fed into HSFI is determined by summation of two mentioned harmonic contents. In this paper, hysteresis control strategy with an upper switching frequency is used to inject the desired current through HSFI to thePCC.

Simulation Results

In order to evaluate the proposed scheme, a solar array is assumed to be connected to a single phase 230V/50Hz grid through the proposed converter based interface. PV arrays used in this paper are constructed by paralleling the PVs introduced in [12]. It is also assumed that MPPT is occurred at 5220 W with 544V. As shown in MATLAB Simulation model, a typical non-linear load consisting of diode bridge rectifier (as a non-

linear) and a resistive- inductive (as linear load) is considered

The full data about the load, inverters characteristics are tabulated in Table 1-2. It is observed that the converter is preferred to firstly provide the active and reactive load power and also compensate its harmonic components. It means that no reactive absorbed from the grid and, on the other hand, THD of the current exchanged with the grid is less than 2.1 % «5% [13]). While THD of absorbed current due to the presence of non-linear load will be equal to 23.6% if the converter is not used and consequently the grid will be highly polluted. Adding the PI controller to the control system of first converter causes the DC component to be eliminated fast.

Power loss is related to two different parts namely the converter loss and the grid line loss. Both of them are investigated in this section. It can be stated that the total switching loss of two converters combination is mainly due to the second inverter (HSFI), since the power loss of first converter may be neglected because of low switching frequency. The current of inverters plotted in Fig. 9. It is shown the current of first inverter has low magnitude compared with that of the second inverter. It causes that the power losses of LSFI is less than the case in which a converter (H-bridge) is used with high switching frequency, instead of proposed cooperative converters. For the load and considered grid the power loss through the simulation study is calculated. It can be seen that the power loss of proposed converter is significantly reduced in comparison with a single inverter based converter with high switching frequency when fuzzy logic control is used with APF. The switching losses and total power loss are reduced by 76% and 24%, respectively. It is due to the contribution of the switching losses to the total power loss in a conventional converter. Hence the distortion in current waveforms are remarkably reduced which can be observed in the below shown results
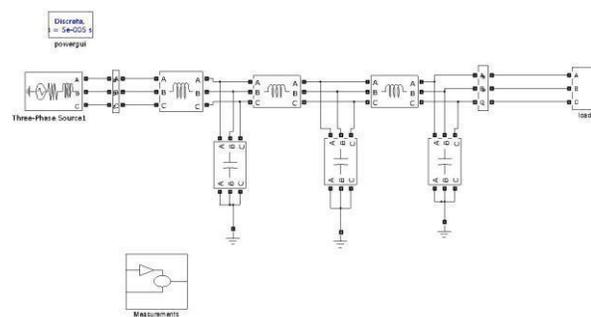
Proposed Simulation Circuit without APF

Fig 6 Proposed Simulation Circuit without Apf

TABLE 1. Main parameters of load and converters

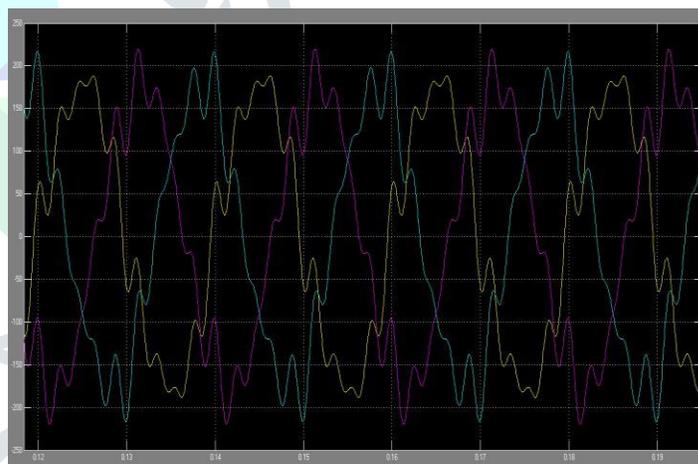| R , L	RB , CB	LB	L_{inv1}	L_{inv2}
30Ω , 90mH	40Ω , 470 μF	20mH	40mH	24mH

Simulation Results (without APF)

Fig 7. Distorted 3 phase voltages Without APF

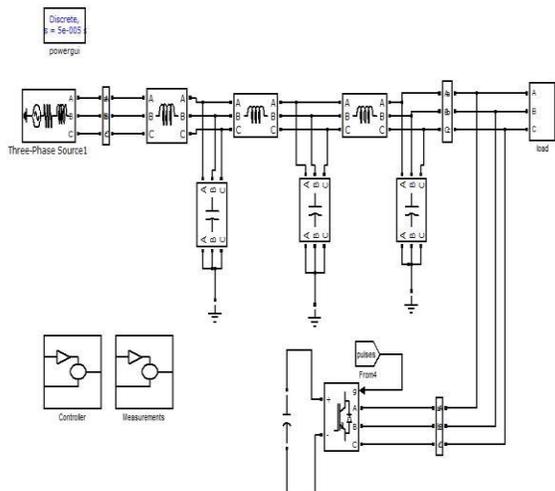## Proposed Simulation Circuit with APF and Fuzzy Logic Controller

Fig 8: Proposed system with APF & Fuzzy Controller
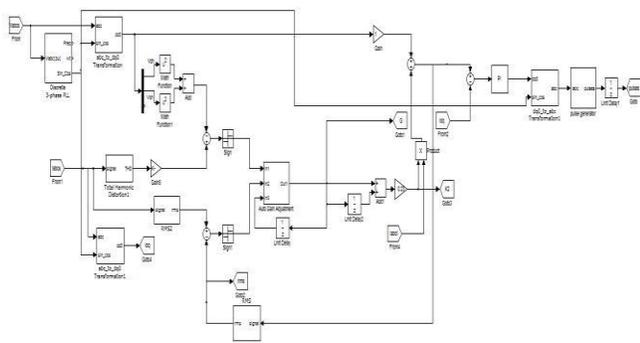
Proposed Simulation Circuit of Apf/Controller

Fig.9. Control circuit simulation with APF & Fuzzy controller
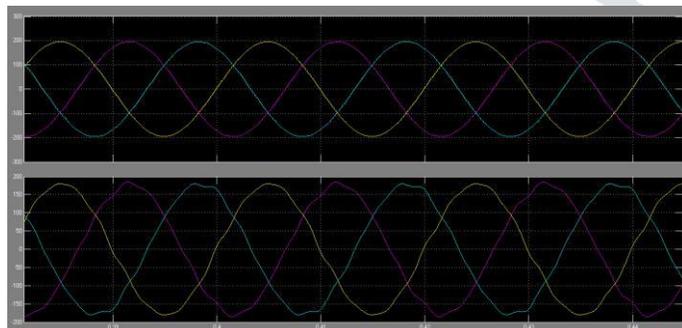
Simulation Results (with Apf)
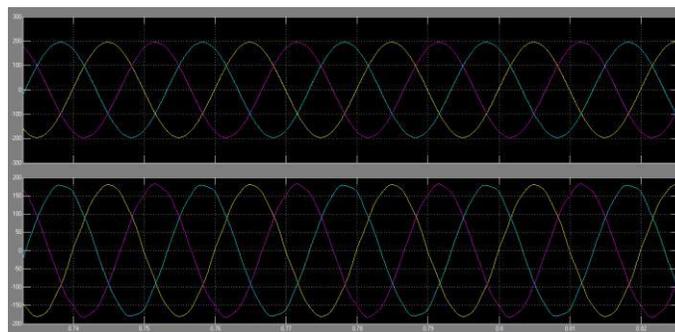

Fig.10. Source & load voltages With APF

Fig .11. source & load voltages for APF with Fuzzy control system

III. CONCLUSION

In this project, a distributed generation source is connected to grid using a converter that contains two parallel inverters with different operation for each of them. Required equations for controlling the converter are extracted. The converter is controlled in such a way that it injects the active power of the DG sources to grid and compensates the reactive power and harmonic components of the load current. So by this control method the power quality of the grid is improved and the power loss of it is reduced. On the other hand, it caused decreasing the converter and so grid losses, using low switching frequency for currents with high magnitude and high switching frequency for currents with low magnitude. For extending this research, circulating currents among parallel inverters can be investigated deeply. Also, the other suggestion is increasing the number of DG sources and evaluating the power quality and power losses of the grid in relation to their location in the grid, their number and their types.

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