International Journal of Engineering Research and General Science Volume 6, Issue 4, July-August, 2018
ISSN 2091-2730

INTELLIGENT CONTROL OF DISTRIBUTION GENERATION FOR VOLTAGE SAG MITIGATION IN DISTRIBUTION SYSTEM

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Abstract—. Voltage dips are most frequent problems occurring in distribution systems. Voltage sags are expansive and are most severe power quality problem. Identification and correction of voltage dip can be done in many ways. Voltage injection by using Distributed Generation (DG) are quite useful in mitigating the voltage sags. This paper addresses correction of voltage sag with solar PV system with inverter side controls using Proportional integral(PI), Fuzzy and ANFIS under balanced and un balanced loading conditions. Usefulness of the proposed controllers is examined through simulation using MATLAB software and the results have shown the validation of the controllers used in the mitigation of voltage dips using DG schemes

Keywords— Voltage sag, Solar PV System, Fuzzy, ANFIS

INTRODUCTION

Power quality issues comprise of a wide range of disturbances such as voltage dip voltage swell , transient voltages harmonics ,flicker and interruptions. In distribution systems voltage dip are most severe than voltage swells. Voltage sag can causes malfunction failure of sensitive equipment and could cause large voltage and current unbalances which lead to tripping of circuit breakers. The voltage dip can be expansive to the consumers and hence there is a need to mitigate voltage dips on the distribution systems[1]. Numerous methods are available in the literature to mitigate voltage dips, but use of custom power device is found to be most effective.

K.J.P. Macken et al. [2] introduce a shunt current or a series voltage into the system is the solution for voltage dip in transmission networks. DG plays a key role during this process. This technique is extended for DG grid connected system, along with power electronic converter and a series compensator. this method has noticeable Disadvantages as follows

i) At the time of interruptions Series compensation do not be used
ii)power electronic components necessity is huge so series compensation is not an profitable solution.

To eliminate voltage dip, KJ.P. Macken et al. [2] also suggested transfer to micro grid operation. In this scheme, the DG system has to be designed for both grid-connected operation and micro grid operation. During grid-connected operation the converter controller of the DG system regulates the current (i.e. current-mode control), whereas m micro grid operation, the controller regulates the voltage (i.e. voltage mode control).

Disadvantage of this method is its operation during voltage dip is less reliable than the series compensator

This paper introduces distribution generation scheme(Solar PV system) and its principle to mitigate voltage sag condition arising in the distribution network with the help of inverter side controls proportional plus integral controller is done to show the effectiveness of the intelligent control techniques.

2.Test system:

Figure 1 shows the test system consisting of a 5-bus radial distribution network and is used to carry out the various simulations with conventional and adaptive controllers for both balanced &un balanced voltage sags. In balanced case all loads are balanced, Load 1 = 24 + j10.2 pu, Load 2 = 21 + j9 pu, Load 3= 30 + j12.6 pu [3][4] .This results in balanced line current and voltages. In unbalanced case, loads are unbalanced which result in unbalance of the line currents and voltages. Here the bus voltage is 25kv.and source voltage is 20kv.

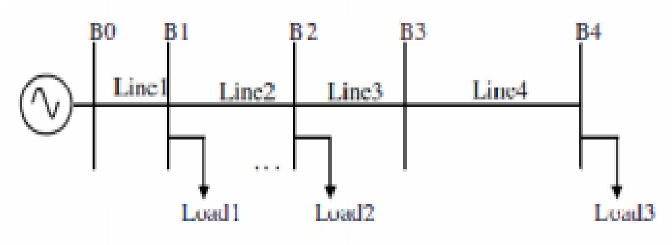

Figure.1:Test system

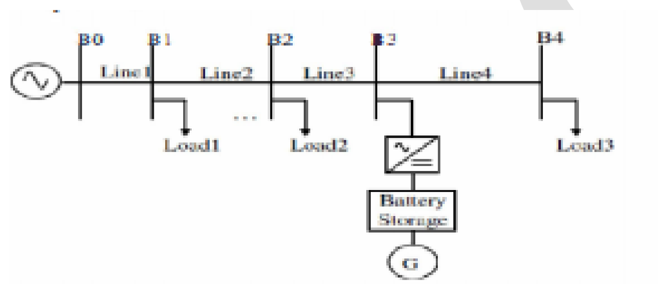

Figure.2: Optimal location of DG

3. Solar PV System

The solar PV array is connected in series with supply load. PV array is connected to grid via a converter a DC-DC boost converter and a three-phase three-level Voltage Source Converter (VSC). Maximum Power Point Tracking (MPPT) is implemented using the 'Incremental Conductance + Integral Regulator' technique. This MPPT system automatically varies the duty cycle in order to generate the required voltage to extract maximum power. The VSC control system uses two control loops: an external control loop which regulates DC link voltage and an internal control loop which regulates I_d and I_q grid currents (active and reactive current components). Id current reference is the output of the DC voltage external controller. Iq current reference is set to zero in order to maintain unity power factor. V_d and V_q voltage outputs of the current controller are converted to three modulating signals U_{abc}-reference used by the PWM Generator. The control system uses a sample time of 100 microseconds for voltage and current controllers as well as for the PLL synchronization unit. Pulse generators of Boost and VSC converters use a fast sample time of 1 microsecond in order to get an appropriate resolution of PWM waveforms.

4.Control Scheme

4.1 PI controller:

The error signal obtained from the reference voltage and the RMS value of the terminal voltage is the input to the PI controller .Such error is handle by a PI controller and the output of a PI controller is the angle which is supply to the pulse with modulation(PWM) signal generator. The pulse signals to the IGBT gates of Voltage Source Converter generated by PWM generator. it is only capable of determining the instantaneous value of the error signal without considering the change of the rise and fall of the error, which in mathematical terms is the derivative of the error signal, denoted as de/dt[5][6].that’s why PI controller is its inability to react to sudden changes in the error signal ,this is the main disadvantage of PI controller.

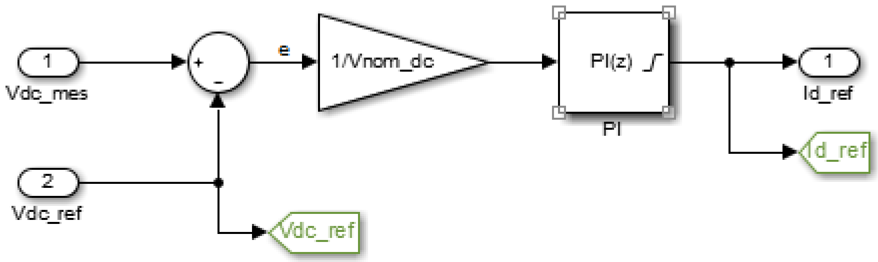

Fig.3:PI controller block in inverter side of solar PV system

4.2 Fuzzy controller:

Error signal and the derivation of the error are the two inputs of the fuzzy controller has. fuzzification, rule execution, and defuzzification are the three stages of a fuzzy logic controller. the inputs e and de/dt are the subsets and these are defined as (NB,NM, NS, Z, PS, PM, PB) Taking into account of the coverage, sensitivity, robustness of universe, the fuzzy subsets of the membership functions use triangular membership function[6][7][8]

Table.1: Fuzzy rule table

e / de/dt	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NM	NS	Z	PS	NB	NM
NS	NM	NS	N	PS	PM	NB	NM
Z	NS	Z	PS	PM	PB	NB	NS
PS	Z	PS	PM	PB	PB	NS	Z
PM	PB	PM	PB	PB	PB	Z	PS
PB	PM	PB	PB	PB	PB	NB	NB

4.3 ANFIS controller:

An adaptive neuro-fuzzy inference system or adaptive network-based fuzzy inference system (ANFIS) is a type of artificial neural network that is based on Takagi–Sugeno fuzzy inference system. The method was developed in the early on 1990s. while it integrates equally neural networks and fuzzy logic principles, it has probable to capture the benefits of both in a single framework. Its inference system corresponds to a set of fuzzy IF–THEN rules that have wisdom capability to estimated nonlinear functions. Hence, ANFIS is measured to be a universal estimator[9][10][11][12].

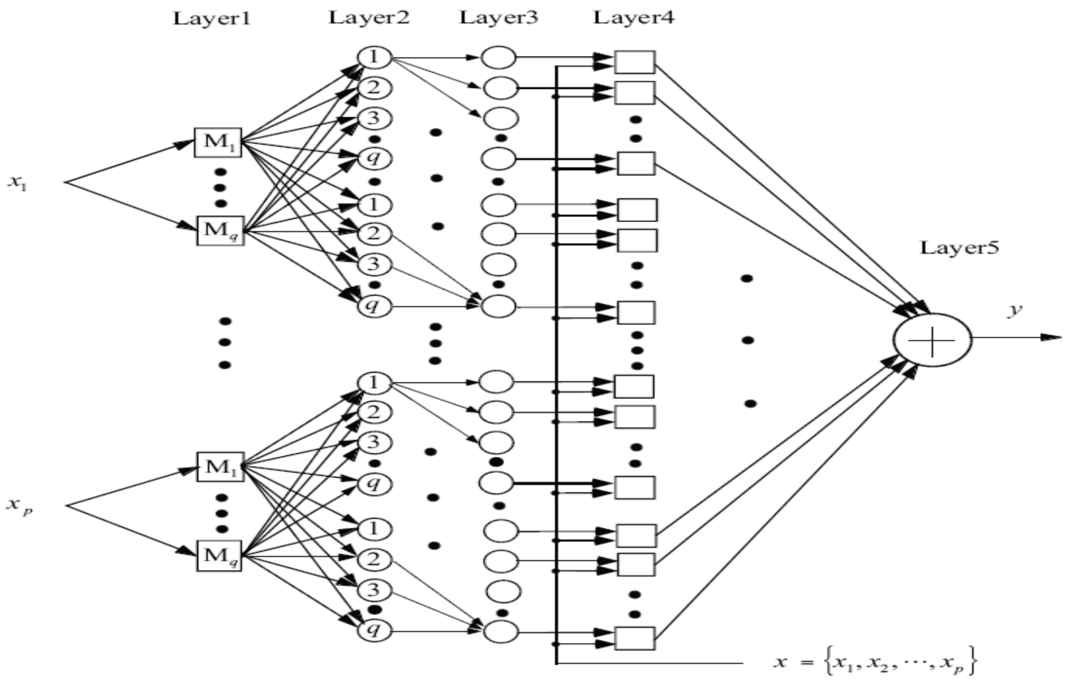

Fig.4: ANFIS Structure

5.Simulation results:

To know the performance of Solar PV System the test system which is shown in Fig.1 is simulated in MATLAB. Simulation results are performed for each case (balanced load and unbalanced) loading conditions. By using PI ,Fuzzy,ANFIS controllers.,

5.1. Balanced load under fault condition

a) With PI controller: The PI controller based DG Scheme: Solar PV System IS able to mitigate the voltage dip for balanced load condition with three phase fault initiated during 0.2ms-0.4ms.as shown in Figures: 5.1.1 and 5.1.2

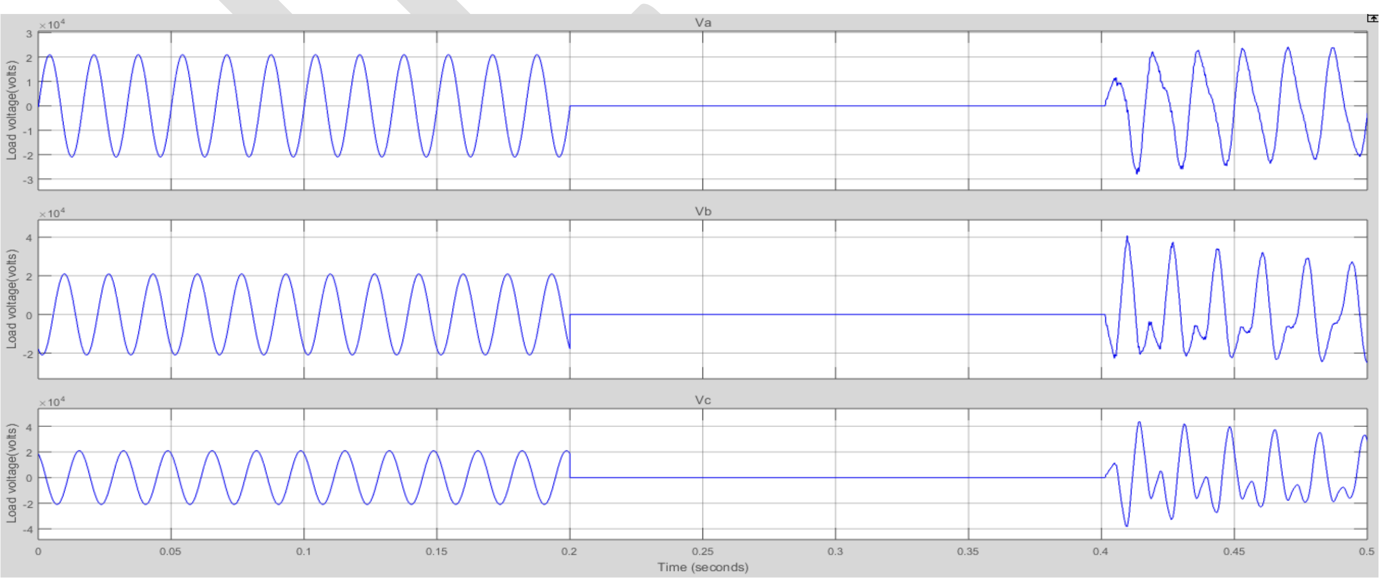

Fig.5.1.1: Fault condition

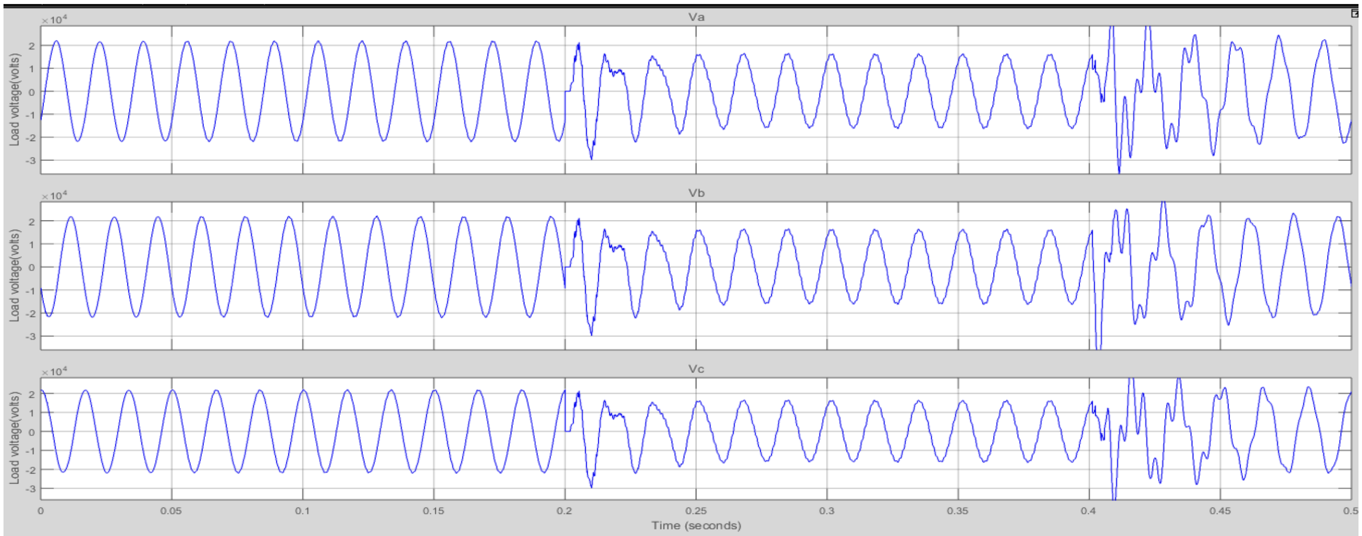

Fig.5.1.2: Solar PV system injected voltage waveforms with PI controller

b) With fuzzy controller: Fuzzy controller based DG Schemes are able to mitigate the voltage dip for balanced condition with three phase fault with fault duration between 0.2ms-0.4ms,results as shown in Figure 5.1.3

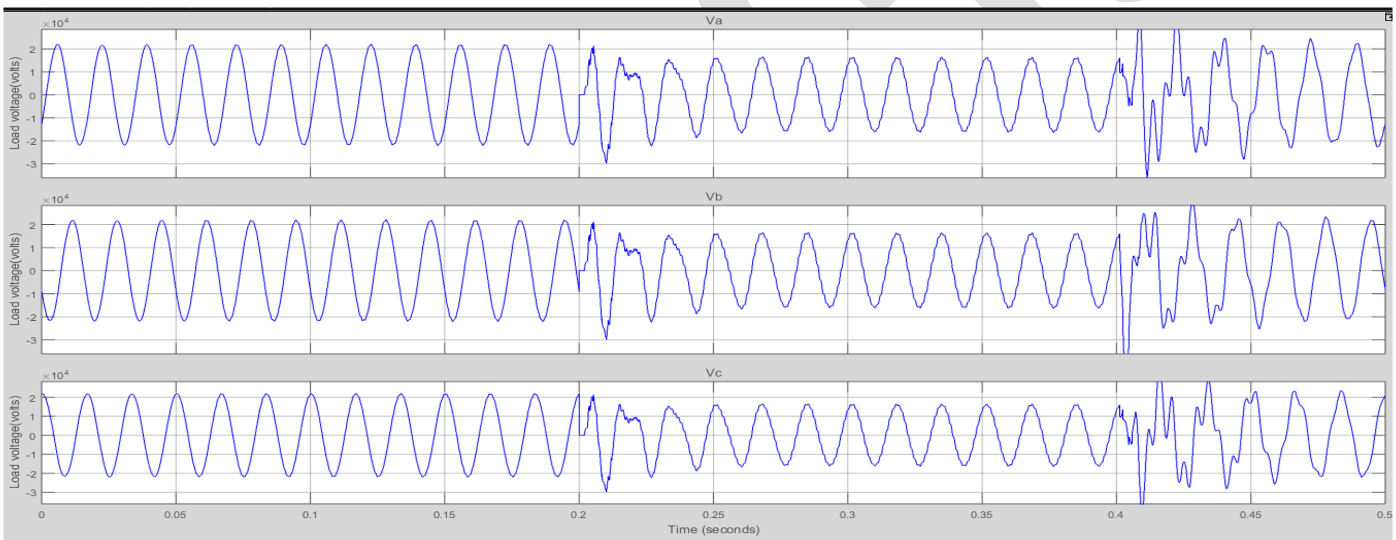

Fig.5.1.3: Solar PV System injected voltage waveforms with Fuzzy controller

C)With ANFIS controller:ANFIS controller based DG Schemes Considered are able to mitigate the voltage dip efficiently for balanced condition with three phase fault with fault duration between 0.2ms-0.4ms,as shown in Figure5.1.4.

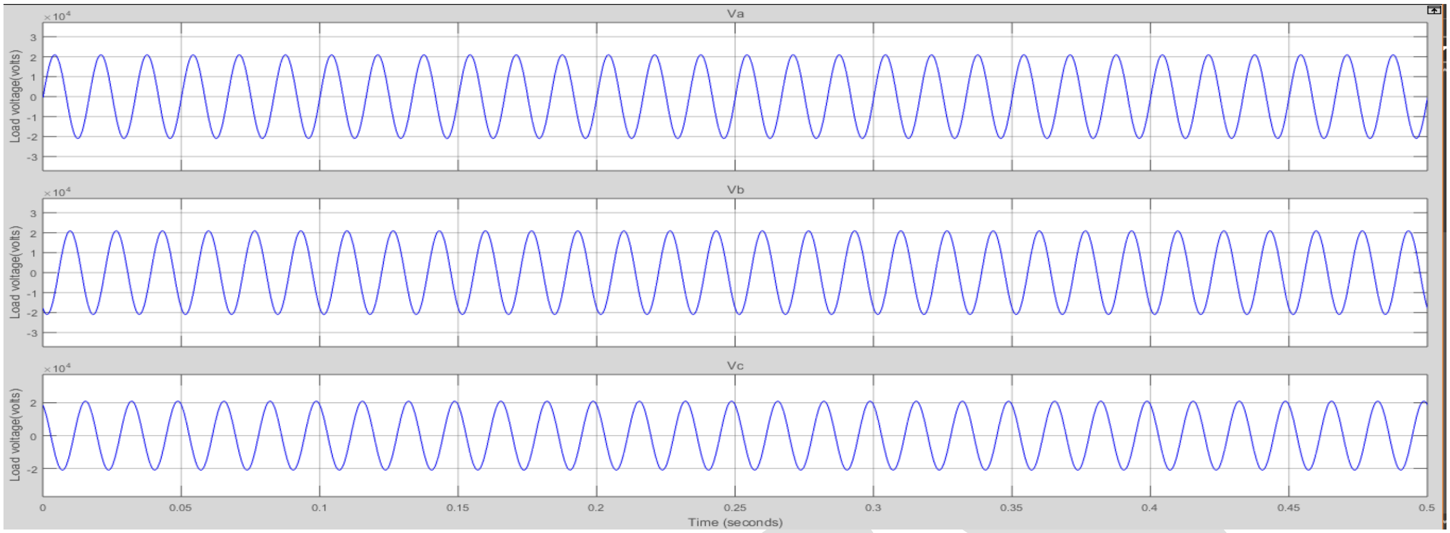

Fig.5.1.4: Solar PV System injected voltage waveforms with ANFIS controller

5.2 Unbalanced load

a) With PI controller:

The PI controlled based solar PV system technique is able to mitigate the voltage dip for unbalanced condition also as shown in figures: 5.2.1&5.2.2

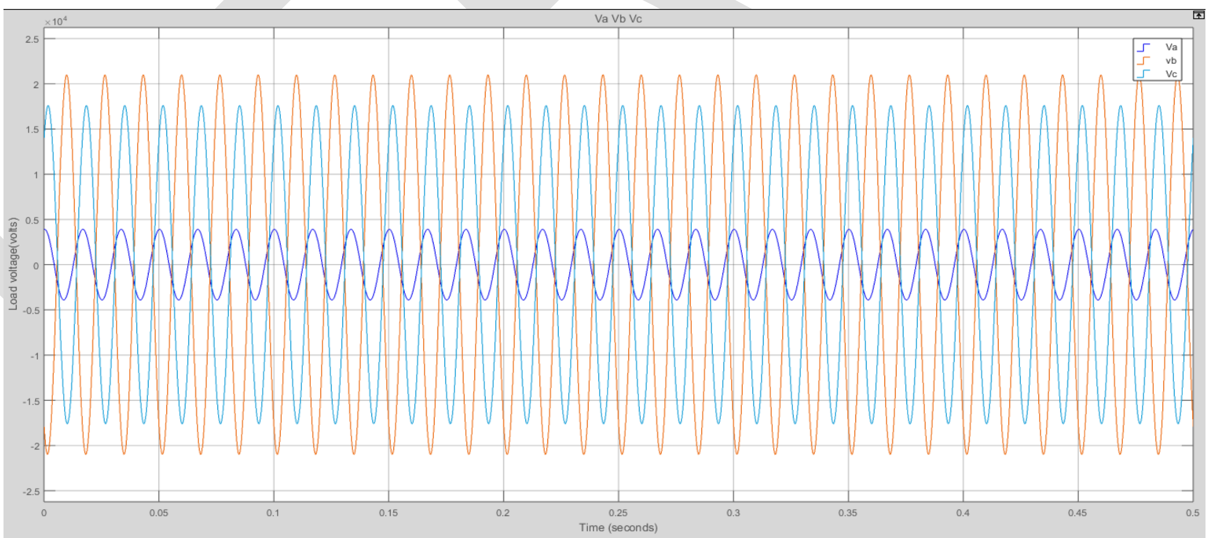

Fig.5.2.1: Unbalanced voltages

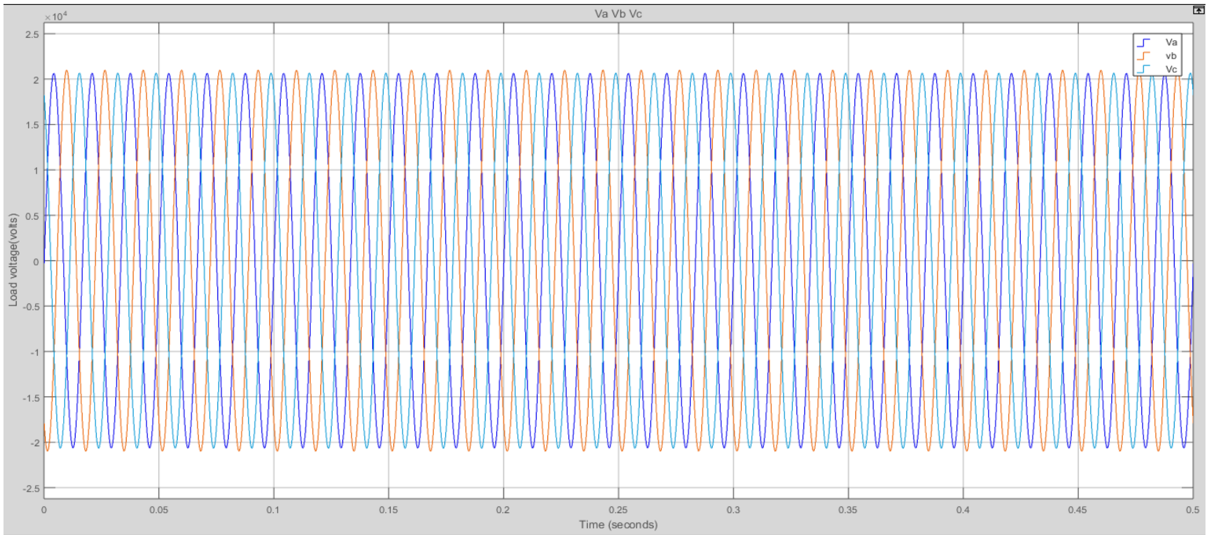

Fig.5.2.2:Solar PV system injected voltage waveforms with PI controller

b) With Fuzzy controller:

The fuzzy controller based DG Scheme is able to mitigate the voltage dip for unbalanced condition as shown in figure 5.2.3.

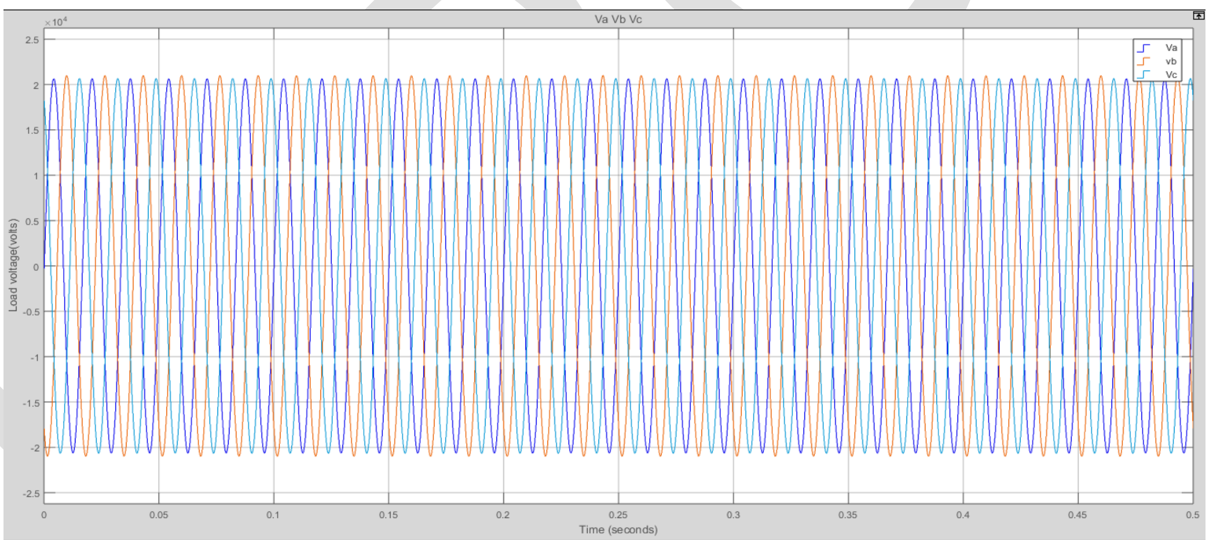

Fig.5.2.3:Sloar PV System injected voltage waveforms with Fuzzy controller

C) With ANFIS controller:

The fuzzy controller based DG Schemes isable to mitigate the voltage dip for unbalanced condition as shown in figure 5.2.4

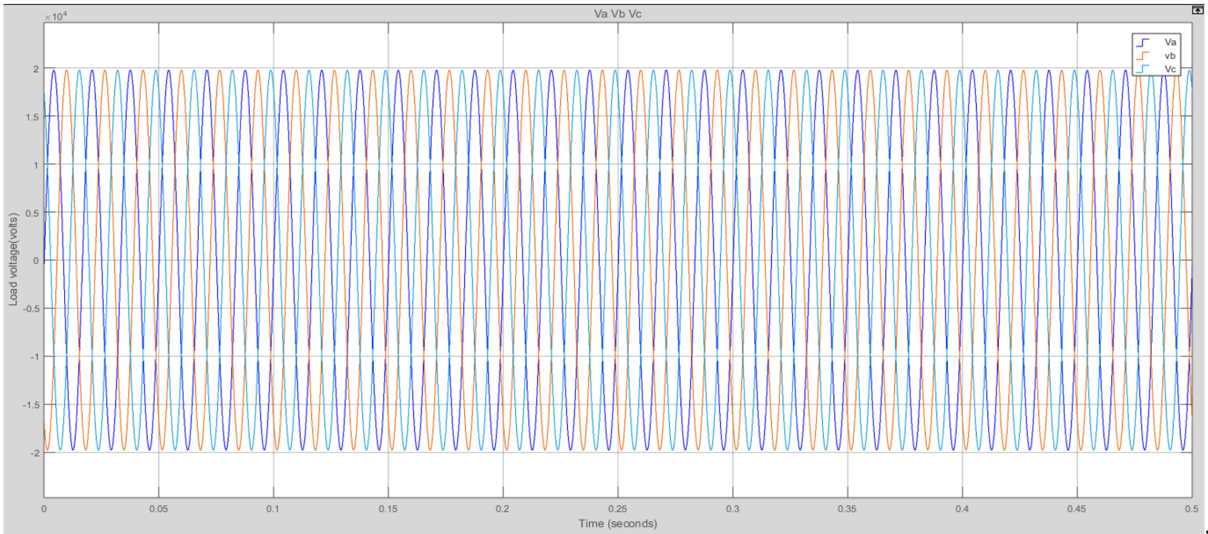

Fig.5.2.4: Solar PV System injected voltage waveforms with ANFIS controller

5.4 Discussion of results: Simulations of the five-bus radial distribution test system to compensate the voltage sag using DG are performed using MATLAB/SIMULINK with balanced and unbalanced loading conditions.

Balanced load with fault: In this case the simulation is performed by considering a three phase fault at bus -2 in the test system delivering power to load. Fault is started at 0.2sec and ends at 0.4sec. DG is connected at bus -3 in the system to inject the voltage during the fault.

Unbalanced load: Simulation is performed with unbalanced loads and the result is presented in Fig 5.2.1. to compensate the voltage sag again DG is connected to the system. Wave forms for this case are shown in figures 5.2.2 to 5.2.4.From the obtained results it is noticed that the output waveforms after compensation is balanced.

CONCLUSION

When DG is directly connected to the distribution system, it influences the background waveform distortions, modifies the harmonic impedances and contributes to modification of voltage harmonic profiles at all of the distribution system buses. Connection through the power electronic interface can inject harmonic currents, which can lead to a voltage distortion increase. The optimal placement and sizing of DG help in loss reduction, voltage profile improvement and voltage dip mitigation, which might lead to undistorted power at the PCC.

This paper presents the analysis of voltage dip mitigation using Solar PV System with balanced and unbalanced voltage sags. The load voltage waveforms clearly indicates that the ANFIS controller is better performance than the PI and Fuzzy controllers to mitigate the voltage sag.

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