ANFIS Controller for Voltage Compensation in Renewable Energy Applications

N.Soundiraraj, M.Thiruveni, K.Karthigaivel, A.Sajitha Banu.

Abstract: this article presents the adaptive neuro fuzzy inference system (ANFIS) based controller for voltage compensation in micro grid. The micro grid has more number of voltage source converters for distribute the electric energy to the small consumers. If any kind of load change in a system has a very small impact in the output voltage of the system, which is extremely sensible. This is due to unbalanced load present in connection point, further increases this problem. In order to minimize the unbalanced load effect an ANFIS based controller has been connected with the traditional voltage source converter control circuit.here, the ANFIS controller fix the reference current gain equal to the unbalanced voltage. This reference current received from ANFIS controller is added with the voltage control loop output to fix the changed current reference for a current control loop. The proposed control logic is verified both simulation and experimentally.

Keywords: unbalanced voltage, voltage source converter, micro grid, Adaptive neuro-fuzzy inference system (ANFIS) control.

I. INTRODUCTION

The micro grids are more popular in the world wide due to their capacity of independent operation, and also micro grid allows the best use of available nonconventional energy sources to feed remote locations where the power grid is not easily accessible. Then the micro grid is most likely to work in isolated mode and grid tied mode.

The micro grid working in grid tied mode, the bus voltage act as the reference voltage in voltage source converter interfaced with distributed generation system, and reduce the risk of conflict between the various voltage source converters.

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The micro grid operating in islanded mode, all the voltage source converters must be share the load current proportional to their individual power rating. Hence the entire voltage source converter tied with grid must be controlled any one control method, the first one is centralized manner with dedicated communication channel between them, and the second one is droop control method [1]. This may or may not be needed a communication channel. But the droop control technique is a most preferable and easily implementable with high reliability and high security [2].

The conventional droop control technique has some disadvantages related with load sharing of individual distribution generation systems and tied voltage source converters [3]. These are all due to load fluctuations as well as unbalanced load demand.

To reduce the above said negative points of a traditional control algorithm, various control techniques have been proposed by scientists all over the globe [4].

The negative sequence impedance technique and virtual impedance techniques are the two main control techniques have been proposed to share the load in different distributed generation systems [5].

These methods needed a measurement unit to transfer the negative sequence component of unbalanced load for all interconnected voltage source converter and distributed generation systems.

However, any inequality in actual impedance of feeder because of transformer connection, capacitor and inductor and wire connection may result in unbalanced power sharing between the distributed generation systems [6].

So the virtual impedance modifies the inverter equivalent impedance within the control loop to have correct load power sharing in all distributed generation systems [7].

The zero, negative, positive sequence components of the voltage source converter voltage and current at tied point has been separately controlled, this is in various literatures.

But, above mentioned control techniques are required a separate communication channel, and removes the advantages of plug and play performance of the grid [8].

This article demonstrates the controller based on adaptive neuro fuzzy inference systems (ANFIS), to reimburse the sick outcome of unbalanced load.

The ability of ANFIS is handling certain sudden changes, like neural system and fuzzy system. Hence, the ANFIS controller is easily handle the dynamic condition of the distributed generation system with voltage source converters.

In this proposed method, the unbalanced voltage factor is extracted from the negative sequence voltage element. This element is input of an ANFIS controller. So the ANFIS controller yields an unbalanced current element. This unbalanced current element is supplementary with the voltage control loop for customized current reference in the inner side current control loop.

II. DESCRIPTION OF THE SYSTEM

The use of micro grid gives electrical power supply to the local load in isolated locations in the absence of main power supply system or where ever not able to install the main grid.

Hence, the micro grid should have it is own distribution system, transmission system and generation system in the smaller geographical area compared with main power supply system.

The distributed generation system with voltage source converters combined together to form modern micro grid. The figure 1 shows the simple form of micro grid.

The micro grid is a combination of non conventional energy based generating systems like wind generating system, energy storage system and photo voltaic system.

The load connected in the system may be 3 phase load or 1 phase balanced load or unbalanced load.

The micro grid is a less inertia system; the voltage profile of the micro grid does not altered by dynamic load changes. But any kind of load unbalance may lead to disturbance in the voltage. So all the voltage source converters, distributed generation systems are connected in parallel to share the load. This configuration and controllers are sharing the load current without the circulating current.

III. CONTROL DESIGN

The proposed micro grid considered as a three phase system, and it is a small system with unbalanced electrical load. So very difficult to maintain accurate balanced three phase voltage at connecting terminals. Hence the output supply voltage is bounded the zero sequence, negative sequence and positive sequence elements (10).

The negative sequence components are received for reimburse the unbalanced voltage. This is the input of ANFIS controller. The negative sequence element is minimized by using of ANFIS controller.

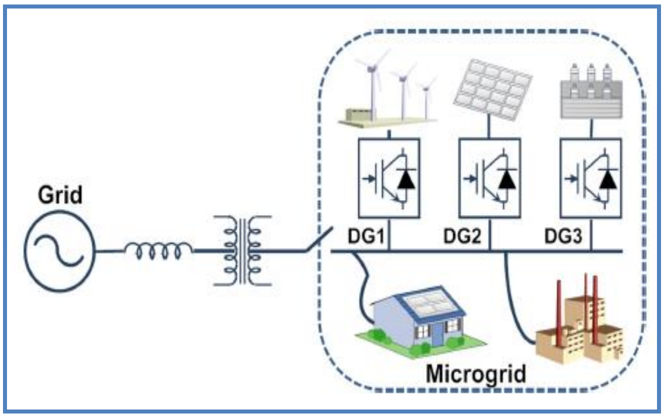

Fig. 1. Micro grid

A. Extraction of Voltage in Negative Sequence

The explanation of unbalanced condition in electrical power system circuits is one of the most highly complicated tasks. The distorted voltage in the system or asymmetry in the power system is determined by symmetrical components technique, this is the most common technique to find system voltage distortion.

The control system implementation and regulation of a system voltage are done by using parks and Clarkes transformations. The second order harmonics introduced in the system voltage due negative sequence voltage at unbalanced load condition.

Hence, the voltage regulation purpose, the parks and Clark's equations are tuned to obtain negative sequence element.

The three phase system voltage equations in terms of positive element and negative element without neutral wire are shown below.

$$Va = Vp\cos(\omega t) + Vn\,.\cos(-\omega t) \quad \text{------------ ---------} \ (1)$$

$$Vb = Vp\cos(\omega t - 2\Pi/3) + Vn\cos(-\omega t + 2\Pi/3) \ \text{------}(2)$$

$$Vc = Vp.\cos(\omega t - 2\Pi/3) + Vn\cos(-\omega t + 2\Pi/3) \ \text{--------} \ (3)$$

$$V\alpha = Vp\cos(\omega t) + Vn\cos(\omega t) = Va + V\alpha- \quad \text{-------} \ (4)$$

$$V\beta = Vp\sin(\omega t) - Vn\sin(\omega t) = V\beta+ \ + \ V\beta- \quad \text{------} \ (5)$$

The equations (4) and (5) modified as (6) and (7) shown below

$$V\alpha+(t) = \tfrac{1}{2}\,(V\alpha\,(t) - V\beta\,(t - T/4) \ \text{-------------------} \quad (6)$$

$$V\beta+(t) = \tfrac{1}{2}\,(V\alpha\,(t - T/4) + V\beta(t) \ \text{----------------} \quad (7)$$

$$V\alpha-(t) = \tfrac{1}{2}\,(V\alpha(t) + V\beta\,(t - T/4)\ \text{---------------} \quad (8)$$

$$V\beta-(t) = \tfrac{1}{2}\,(V\alpha\,(t - T/4) - V\,\beta\,(t) \ \text{--------------} \quad (9)$$

The equations (8) and (9) yield the negative sequence component, this is fed to input of the ANFIS controller, and the figure 2 shows the fuzzy membership functions.

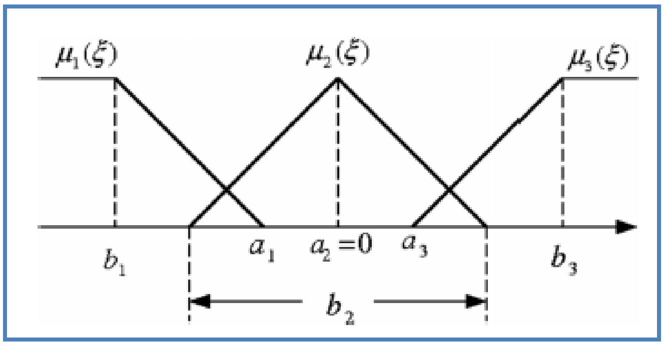

Fig 2.Fuzzy membership functions

B. ANFIS controller design

The aim of this proposed controller is to reduce the negative voltage sequence to zero in connection terminals of distributed generation system when three phase unbalanced load.

During unbalanced load condition, the conventional P,PI controllers not able to regulate the output voltage. Hence the ANFIS controller design is necessary; the figure 3 shows the ANFIS architecture. The figure 2 indicates the fuzzy membership functions in trapezoidal waveforms, which membership functions expressed in mathematical form is shown in expression (10).

$$\mu_{A_1}(\xi) = \begin{cases} 1, & \xi \leq b_1 \\ \frac{\xi - a_1}{b_1 - a_1}, & b_1 \langle \xi \langle \; a_1 \\ 0, & \xi \geq a_1 \end{cases} \tag{10}$$

$$\mu_{A_2}(\xi) = \begin{cases} 1 - \frac{\xi - a_2}{0.5 b_2}, & |\xi - a_2| \leq 0.5 b_2 \\ 0, & |\xi - a_2| \geq 0.5 b_2 \end{cases} \tag{11}$$

$$\mu_{A_3}(\xi) = \begin{cases} 0, & \xi \leq a_3 \\ \frac{\xi - a_3}{b_3 - a_3}, & a_3 \langle \xi \langle \; b_3 \\ 1, & \xi \geq b_3 \end{cases} \tag{12}$$

The precondition data's are referred in the first layer, the multiplication layer is at the second segment, output of second layer is input to the third layer, and here the signals are normalized. The fourth segment is named as consequent layer.

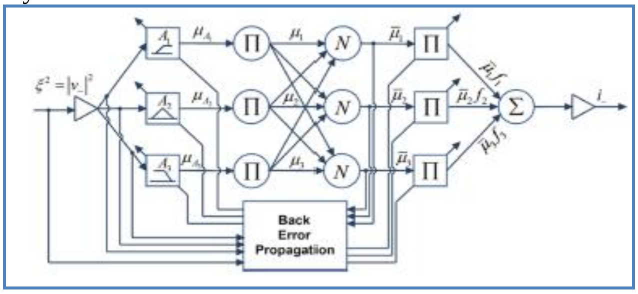

Fig 3.ANFIS architecture

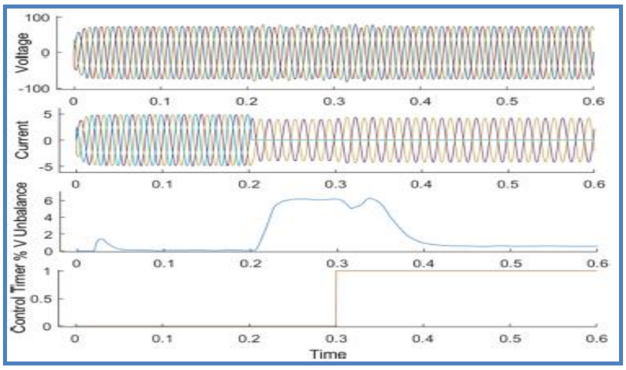

Fig 4 Simulation results

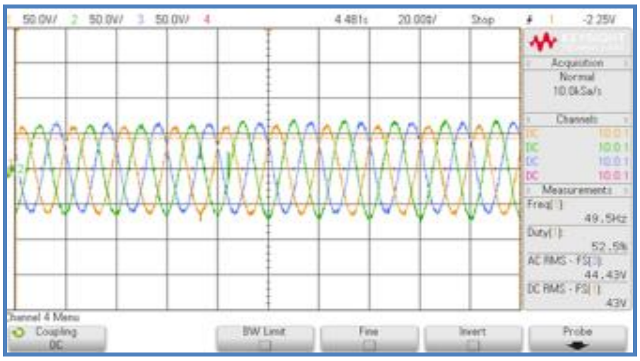

Fig 5 zoomed in voltage waveforms

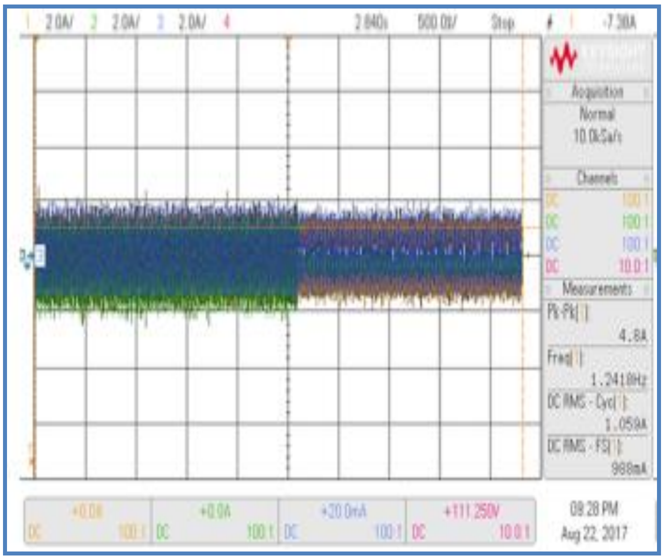

Fig 6.Actual current waveform

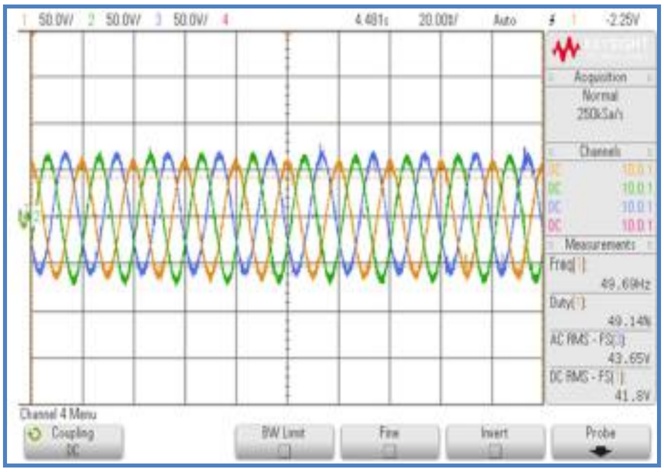

Fig 7.Zoomed in current wave form

The figure 4 shows the simulation results of current wave and voltage wave forms. The relationship between unbalanced voltage and time period is indicated in this waveform

The figure 5 shows the zoomed in voltage of the distribution generation system, and the figure 6 indicates the actual current waveform of interconnected distributed generation system,The figure 7 represents the current waveform of the distribution generation system in zoomed condition.

IV. RESULT ANALYSIS AND DISCUSSION

This article presents the proposed ANFIS control system modeled and simulation results are taken from MATLAB platform. The simulation result waveforms are depicted in the figure 4.In these results proves that the correctly balanced voltage at initial conditions. This balanced voltage because of three phase balanced load, and voltage unbalance is all most zero. The figure 8 shows the voltage waveform without controller, and the figure 9 shows the voltage waveform with ANFIS controller. Hence the ANFIS controller gives better performance compared with other P,PI controllers.

TABLE I SPECIFICATION DETAILS

parameters	INV-I
Droop coefficient voltage (mf)	2.2V/kVar
Droop coefficient frequency(mf)	1 Hz/kW
Line inductance	L=3.3 mH
Line resistance	R=0.15 ohm
Nominal AC voltage	55V
Nominal AC voltage simulated	232V
Nominal frequency	50Hz
Filter capacitance	26μF,1.1Ω
Filter inductance	22Mh
DC voltage	163V
PWM frequency	4kHz

V. CONCLUSION

This article presents the ANFIS controller modeling, simulation results and verified the results with experimental setup. This result indicates that each voltage source converters can be controlled in a micro grid connected with renewable energy sources.Here, the voltage stability is increased for sudden load changes. The various test conditions are carried out to check the output voltage stability. However, the up normal load variations does not affect the stability of the output voltage. The results obtained both simulation and experimental are the same; this validates the feasibility of the proposed control algorithm. Hence this controller is suitable for voltage source converters application in renewable energy sources.

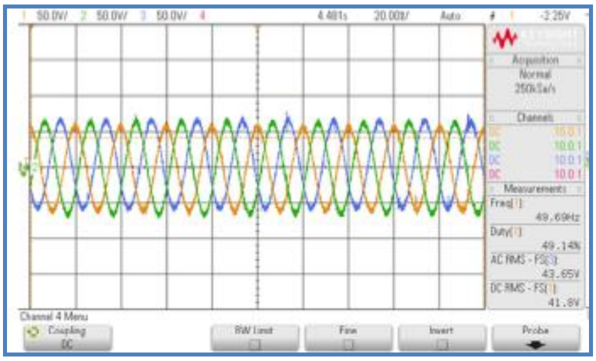

Fig 8 Voltage waveform without controller

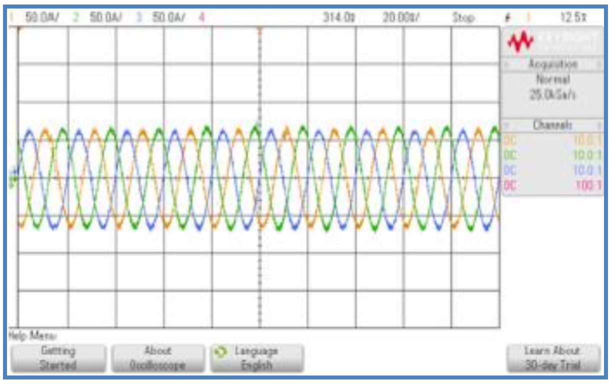

Fig 9 voltage wave form with ANFIS controller

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