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Energy Management of distributed Generation Inverters in A microgrid Through ANFIS Strategy

KEYWORDS: Distributed generation (DG), power management, microgrid, adaptive neural interface system (ANFIS)

k.sreekanth	T.vara prasad
PG Student [EPS], Dept. of EEE, SVPCET, puttur A.P.,India	Assistant professor, Dept. of EEE, SVPCET,Puttur A.P.,Andhra Pradesh, India

ABSTRACT *This project introduces a micro grid, which consists of different distributedgeneration units which are connected to the distribution grid. The operations of the DG units are coordinated by the power management algorithm in grid and islanded operations. The primary generation unit of the micro grid is the wind turbine and the proton exchange membrane fuel cell is used to supplement the variability in the power. In micro grid a battery is incorporated to overcome the difficulty of shortage of power demand during Islanded operation and to improve crest demands throughout grid connected operation.ANFIS controller is used as the control design which reduces the design complexity as the logical operations are performed to find out critical values, the power quality such as harmonic compensation for nonlinear loads of the distribution system, will be improved when compared to model predictive algorithm control designand also It has fast response*

I. INTRODUCTION

In the near future, the demand for electric energy is expected to increase rapidly due to the global population growth and industrialization. This increase in the energy demand requires electric utilities to increase their generation. Recent studies predict that the world's net electricity generation is expected to rise from 17.3 trillion kilowatt-hours in 2005 to 24.4 trillion kilowatt-hours (an increase of 41%) in 2015 and 33.3 trillion kilowatt-hours (an increase of 92.5%) in 2030. Currently, a large share of electricity is generated from fossil fuels, especially coal due to its low prices. However, the increasing use of fossil fuels accounts for a significant portion of environmental pollution and greenhouse gas emissions, which are considered the main reason behind the global warming. For example, the emissions of carbon dioxide and mercury are expected to increase by 35% and 8%, respectively, by the year 2020 due to the expected increase in electricity generation. Moreover, possible depletion of fossil fuel reserves and unstable price of oil are two main concerns for industrialized countries. To overcome the problems associated with generation of electricity from fossil fuels, renewable energy sources can be participated in the energy mix. One of the renewable energy sources that can be used for this purpose is wind energy that is atmospheric air in motion. This wind energy can be converted to clean electricity through the turbine process. The use of wind turbine systems for electricity generation started in the seventies of the 20th century and is currently growing rapidly worldwide.

To reduce the variability in the renewable sources, energy storage devices are used such as batteries and ultra capacitors. The inclusion of energy storage devices is also difficult for organizing demands and deviation in the load requirement. In present project, a micro grid composed of a Photovoltaic array (PV Array), PEMFC i.e., a proton-exchange membrane fuel cell, and storage battery (SB) is planned. PEMFC (a proton-exchange membrane fuel cell) is employed as a backup generator unit to give back the power produced by the discontinuous nature of -Photovoltaic array. The Storage Battery is incorporated to overcome the difficulty of shortage of power demand during Islanded operation and to improve crest demands throughout grid connected operation. In micro grid to organize the distribution of power between different DG units an energy-management algorithm is designed. The controller design proposed for the inverters of DG units is MPC Controller design.

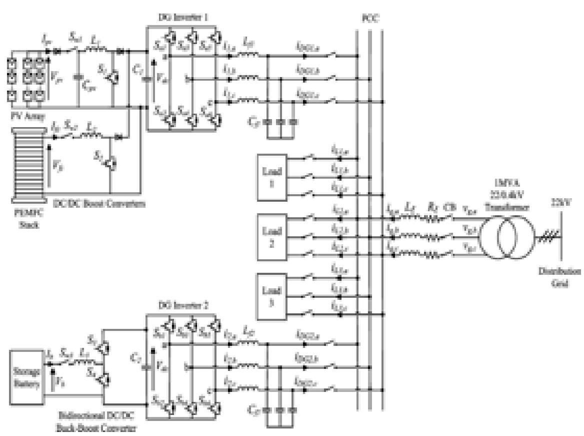

Fig 1.1: Overall configuration of the Existing micro grid architecture.

II. .DG INVERTER MODELLING

The switched voltage across the output of the *n*th DG inverter is represented by $u_n V_{dcn}$, where u_n is the control input and n=1, 2. The output side of the DG inverter is connected with an LC filter denoted by C_{fi} and L_{fi} to abolish the high switching frequency harmonics produced by the DG inverter.

Fig 2.1 and 2.2 show the equivalent single-phase illustration of the DG inverters for islanded-connected and grid-connected operation.

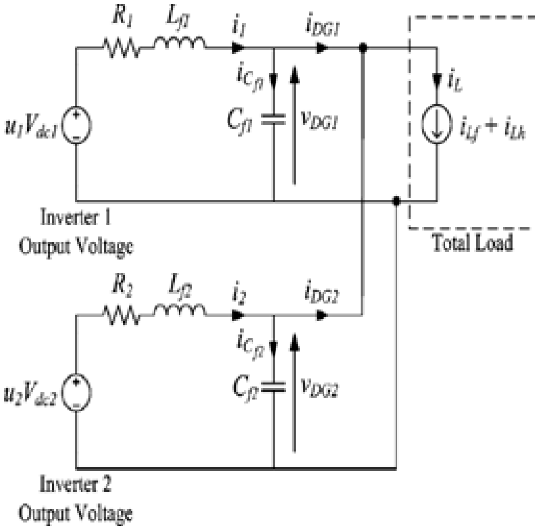

Fig. 2.1. Equivalent Diagram for single-phase of the DG inverters islanded operation.

The resistance R_j reflects the loss of the DG inverter. Total load current i_L is the summing of the currents given to the load k (k=1, 2, 3), is represented by

$$i_L = \sum_{k=1,2,3} i_{Lk} = i_{L1} + i_{L2} + i_{L3}$$

and also it can be divided as two components composed of harmonic i_{Lh} and fundamental frequency i_{Lf} with amplitudes I_{Lf} and I_{Lh} and is represented by

$$\begin{aligned} i_L &= i_{Lf} + i_{Lh} = I_{Lf}\sin(\omega t - \varphi_{Lf}) \\ &\quad + \sum_{h=3,5,\ldots}^{N} I_{Lh}\sin(h\omega t - \varphi_{Lh}) \\ &= I_{Lf}\sin\omega t\cos\varphi_{Lf} - I_{Lf}\cos\omega t\sin\varphi_{Lf} \\ &\quad + \sum_{h=3,5,\ldots}^{N} I_{Lh}\sin(h\omega t - \varphi_{Lh}) \\ &= i_{Lf,p} + i_{Lf,q} + i_{Lh} \end{aligned}$$

where Φ_{Lh} and Φ_{Lf} are the phase angles of the harmonic components and fundamental components of i_L and $i_{Lf,p}$ and $i_{Lf,q}$ are the instant fundamental phase and quadrature components of i_L. To attain unity power factor on the grid side, Balance for the harmonics in the load currents and simultaneously attain load sharing, DG unit of the inverter supplies a current i_{DGj} .

$i_{DGj} = (i_{Lf,p} - i_g) + i_{Lf,q} + i_{Lh}$

where i_g is the grid current. As shown in Fig.3.1, the utility substation supplies the voltage to a distribution grid represented by a voltage source V_g during grid-connected operation, and is interfaced to the microgrid and to the loads through a distribution line with inductance L_l and resistance R_L.

During the grid-connected operation, the grid voltage is identified and the microgrid shares the load requirement with the grid. Hence, to manage the power delivered to the loads, by using the CCM (current control mode) the DG inverter output current is controlled.

For the duration of islanded operation, the total load requirement will be supplied by microgrid as shown in Fig. 3.2, and by using VCM (Voltage control mode) it is necessary that the output voltage can be regulated to a pure sine wave with a fixed magnitude.

To obtain a state-space model for the DG inverter through both grid-connected operation and islanded operations, Kirchhoff's current and voltage laws are applied to the current loop as shown in Fig. 3.3,

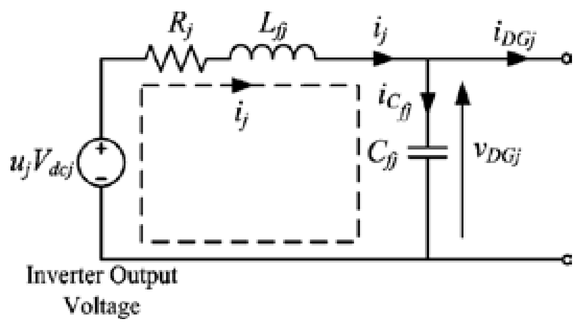

Fig 2.2. Single-phase illustration of the nth DG inverter inIslanded and grid-connected operations.

$$\frac{dij}{dt} = -\frac{Rj}{Lfj}ij - \frac{1}{Lfj}vDGj + \frac{Vdcj}{Lfj}uj$$

$$\frac{dvDGj}{dt} = \frac{1}{Cfj}ij - \frac{1}{Cfj}iDGj$$

where i_j is the current passing through L_{fi} . therefore, the grid interfaced DG inverter model can be define as

$$\begin{aligned} \dot{x}_{gj} &= A_{gj}x_{gj} + B_{gj1}v_j' + B_{gj2}u_j \\ y_{gj} &= C_{gj}x_{gj} + D_{gj1}v_j' + D_{gj2}u_j \end{aligned}$$

where the subscripts g and j represent the model of DG inverter j during grid-connected operation (j=1, 2,3) and

$$A_{gj} = Agj = -\frac{Rj}{Lfi}; Bgj1 = \left[-\frac{1}{Lfj} \;\; 0\right];$$

$$Bgj2 = \left[\frac{Vdcj}{Lfi}\right]; C_{gj}=1 ; \; Dgj1= [\,0\text{-}Cfj]; \quad Dgj2=0$$

Xgj=$i_j$is the state;V_j' =[$_{vDGj}$ d vDGj /dt]^T is the exogenous input. u_j is the control input, with-1<=u_j<=1; and $y_{gj=}i_{DGj}$ is the output.

While islanded operation, due to the microgrid power disparity the frequency will differ. PMS will detect the changes in frequency in microgrid, such that PMS is used to manage and monitor power dispatch by each DG unit. the change in frequency will be detected by PMS then the PMS will have need of the main DG unit and the Storage Battery to produce the essential power to meet up the overall load demand in the microgrid as shown in the flowchart of Fig. 2.2, such that (1) is satisfied. In islanded operation, it follows from (7) and (8) that DG inverter can be modelled as

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$$\dot{x}_{ij} = A_{ij}x_{ij} + B_{ij1}i'_j + B_{ij2}u_j$$
$$y_{ij} = C_{ij}x_{ij} + D_{ij1}i'_j + D_{ij2}u_j$$

where the subscript i denotes the model of the DG inverter j during islanded operation (j=1 , 2) and

$$A_{ij} = \begin{bmatrix} -\frac{R_f}{L_{fi}} & -\frac{1}{L_{fi}} \\ \frac{1}{C'_f} & 0 \end{bmatrix}; B_{ij1} = \begin{bmatrix} 0 \\ -\frac{1}{C'_f} \end{bmatrix}; B_{ij2} = \begin{bmatrix} \frac{V_{dcj}}{L_{fj}} \\ 0 \end{bmatrix}$$
$$C_{ij} = \begin{bmatrix} 0 & 1 \\ 1-\frac{C_{fi}}{C'_f} & 0 \end{bmatrix}; D_{ij1} = \begin{bmatrix} 0 \\ \frac{C_{fi}}{C'_f} \end{bmatrix}; D_{ij2} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

with $C_f' = \Sigma^2_{j=1} C_{fj}$; $x_{ij}=[i_j \ V_{DGj}]^T$ is the state vector; $i'j=i_{L-} \Sigma n \neq j \, i_n$ is the exogenous input of the DG inverter

j; u_j is the control input, with $-1 <= u_j <= 1$ and

$y_{ij}=[V_{DGj} \ i_{DGj}]^T$ is the output, which will be regulated to find the needed reference waveform. Note that even though the importance is on the voltage V_{DGj}. To ensure that the power is delivered by using VCM V_{DGj} and i_{DGj} will be regulated. Moreover it is believed that the exogenous input i_j' in the model is not straightly measurable by the DG inverter because it involves quantities outside that inverter. specifically, i_j' is the addition of all load currents minus the addition of all i_n from the other DG inverters n ≠ j in the microgrid.

III. **. ANFIS :** The idea of fuzzy logic and artificial neural network for organize problems has been grown in recent years. The motive is that the traditional control theory frequently requires a mathematical model for designing the controller. The inexactness of mathematical modeling generally degrades the performance of the controller, particularly for complex and nonlinear control problems. The introduction of the neural controllers and fuzzy logic controllers (FLC) based on multi layered neural networks has motivated new resources for the possible understanding of improved and high efficient control. In latest years, the combination between fuzzy logic and neural network that is fuzzy neural network (FNN) has been projected and developed. Generally the multiplexing of fuzzy logic and neural network is known as ANFIS (Adaptive Neuro Fuzzy Inference System). Neural system has numerous inputs and also has many outputs but the fuzzy logic has numerous inputs and only one output, so the integration of this two is know as ANFIS which is used for nonlinear applications.

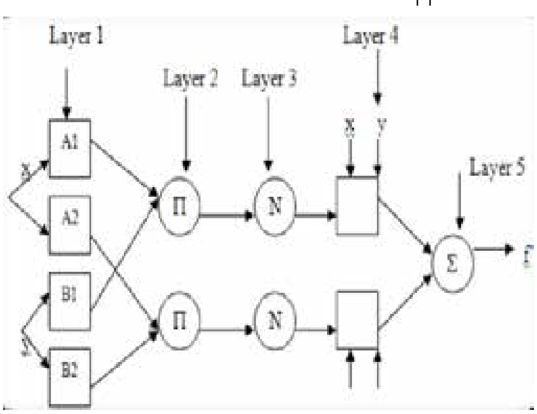

Fig 3.1: ANFIS structure for 2 –input variables for TSK Model

Layer 1: In this layer each node i is a square node with a node function where x is the input to node 0, and A is the label related with this node function. In other words, μ is the membership function of A, and it determines the degree to which the given x satisfies the quantifier Ai. Gaussian Membership function is chosen with utmost equal to 1 and least equal to 0. In this layer the Parameters are referred to as premise parameters. Membership functions are used for each of the input in this layer.

$$O_{1,i} = \mu_{A_i}(x) = exp\left[-\left(\frac{x-m_i}{\sigma_i}\right)^2\right] for$$

$$O_{1,i} = \mu_{B_{i-2}}(x) = exp\left[-\left(\frac{x-m_i}{\sigma_i}\right)^2\right] fo$$

Layer 2: In this layer each node is a circle node labeled H, which multiplies the incoming signals and sends the product out. For instance, each node output represents the firing strength of a rule.
$O_{2,i}=W_i=\mu_{Ai*} \ \mu_{Bi}$ for i=1,2

Layer 3 : In this layer each node is a circle node labeled N. The i-th node defines the ratio of the i-th rule's firing strength to the sum of all rules' firing strengths

$$O_{3,i} = \overline{w}_i = \frac{w_i}{w_1 + w_2} \ for \ i = 1,2$$

For convenience, outputs of this layer will be called normalized firing strengths.

Layer 4 : In this layer each node i is a square node with a

$$O_{4,i} = \overline{w}_i f_i = \overline{w}_i(p_i x + q_i y + r_i)$$

Where $\overline{w}_i$, is the output of layer 3 and {pi, qi, ri} is the set of parameters. In this layer the Parameters are referred to as consequent parameters.

Layer 5: In this layer the single node is a circle node labeled E that calculates the total output as the addition of all incoming signals, i.e.

$$O_5 = f = \sum_i \overline{w}_i f_i$$

IV. SIMULATION RESULTS

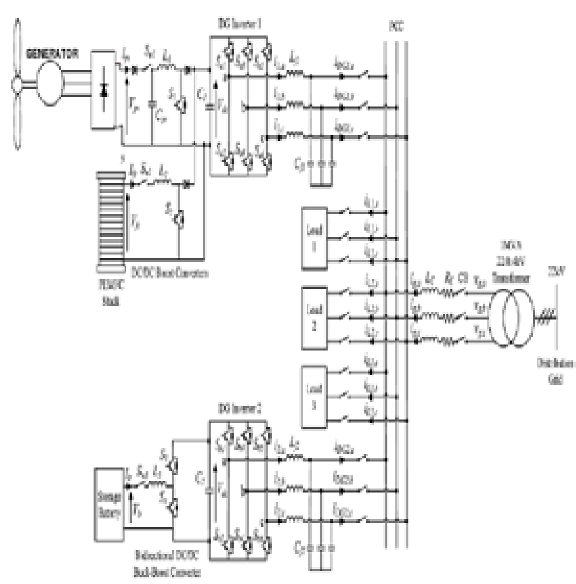

Fig 4.1: configuration of the proposed micro grid architecture.

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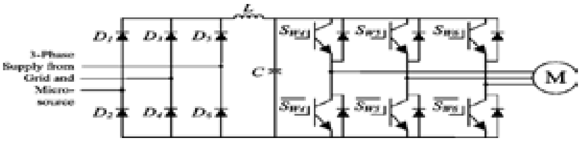

Fig. 4.2. Configuration of a 15-kVA three-phase ASD.

The micro grid is experienced under various conditions to estimate its capabilities during grid connected and islanded operations from the distribution grid.

Three types of loads containing of linear and nonlinear loads are measured in these conditions. For load 1, a 15-kVA three-phase PWM adjustable speed drive (ASD) with its configuration as shown in Fig.5.2 is used and load 2 is made up of a three-phase RL load rated at PL2=28 kW and QL2=18.5 kVAr. Load 3 is a noncritical three-phase dimmer load rated atPL3= 18 kW and QL3=12.3 kVAr, which is nonlinear in nature and will be shed under emergency conditions when the generation of the microgrid is unable to meet the load demand.

Parameter	Value
Distribution grid voltage	V_g=230V
DC link voltage	V_{dc}=400V
Distribution Line Impedance	R_l=0.0075Ω, L_l=25.7μH
LC Filter	L_f=1.2mH, C_f=20 μH
DG Inverter loss resistance	R_f=0.01Ω

Table 4.1 Parameters Of The Proposed System

Test Case 1: Improvement Of Quality of a power During Grid-Connected Operation

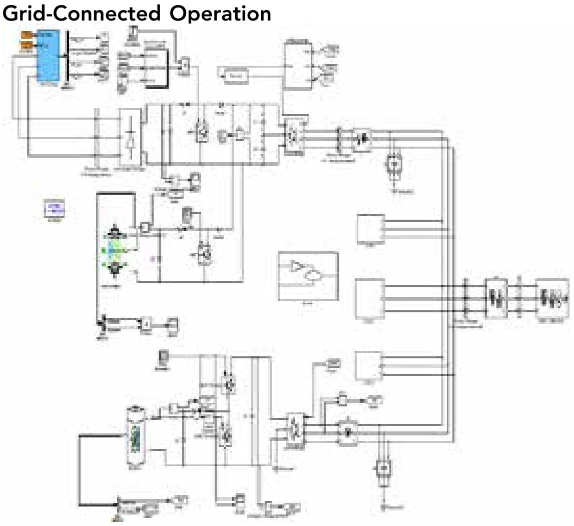

Fig 4.3: simulation Model during grid connected Operation

The first case shows the ability of the micro grid to enhance the power quality of the distribution network by compensating for the harmonics in the total load current i_L. As the nonlinear loads are interfaced to the distribution network, such that the harmonics will not spread to the rest of the distribution network in grid-connected operation. The Storage Battery is working in the charging mode to accumulate energy in off-peak period where the cost of generation from the grid is short to meet up future unexpected demands for power. The Storage Battery current i_b and the SOC during charging for 0≤ t < 0.6s are shown in Fig.5.6. The waveforms of the total load current i_L, the current given by the main DG unit i_{DG} and grid current i_g in this case are shown in Fig. 5.4. The per-phase currents iL_1, iL_2 and iL_3 drawn by loads 1, 2, and 3 for 0≤ t ≤ 0.6 s are shown in Fig. 5.5.

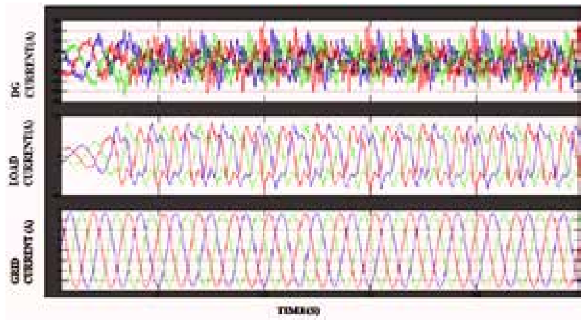

Fig. 4.4. three-phase three-phase DG current i_{DG} (top), load current i_L(middle), and three-phase grid current i_g (bottom) During Grid Connected Operation.

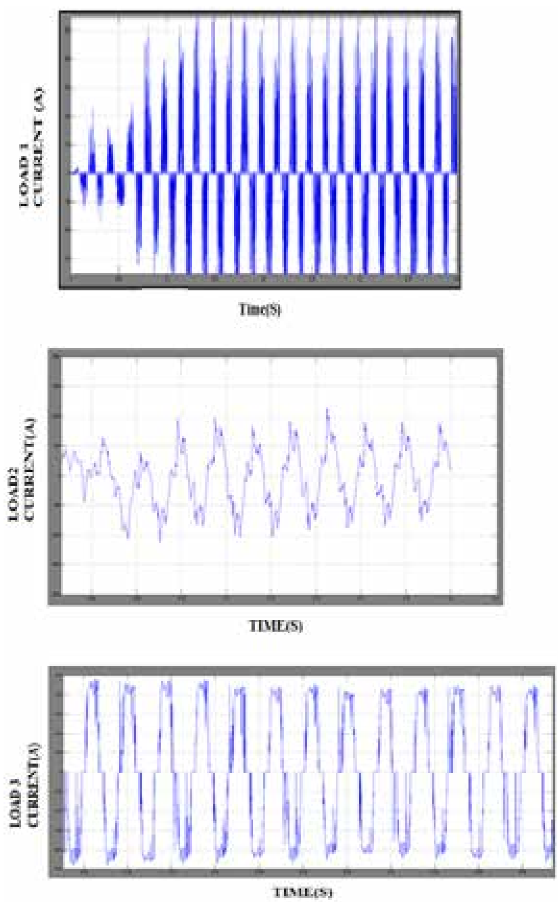

Fig.4.5. Per-phase currents drawn by loads 1, 2, and 3 During Grid Connected Operation.

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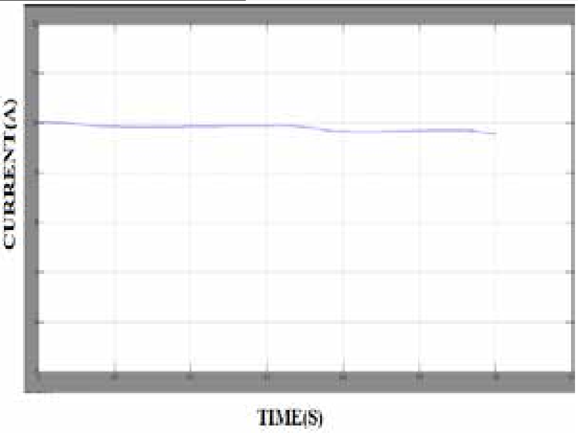

Fig.4.6: Waveform of the SB current during charging During Grid Connected Operation.

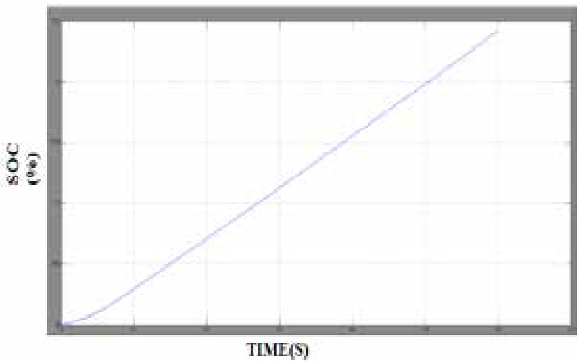

Fig.4.7: SOC of the SB during charging in Grid Connected Operation.

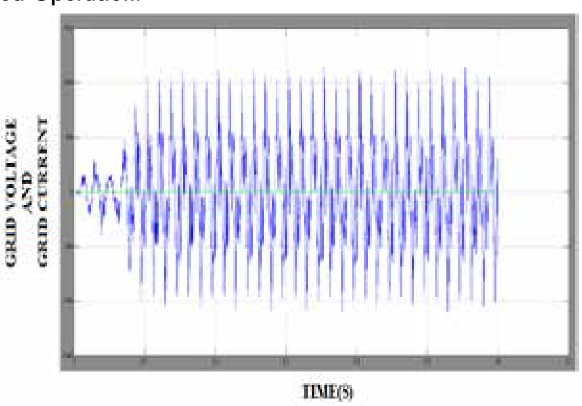

Fig 4.8 : Wave forms of Grid Voltage and Current During Grid Connected Operation.

The total harmonic distortion (THD) value of load current i_L is 29.02% as shown in Fig. 5.9. With the ANFIS controller THD value of is improved to about 14% when compared to previous methods (MPC Controller) as shown in fig.5.10

Test Case 2: Load Shedding During Islanded Operation

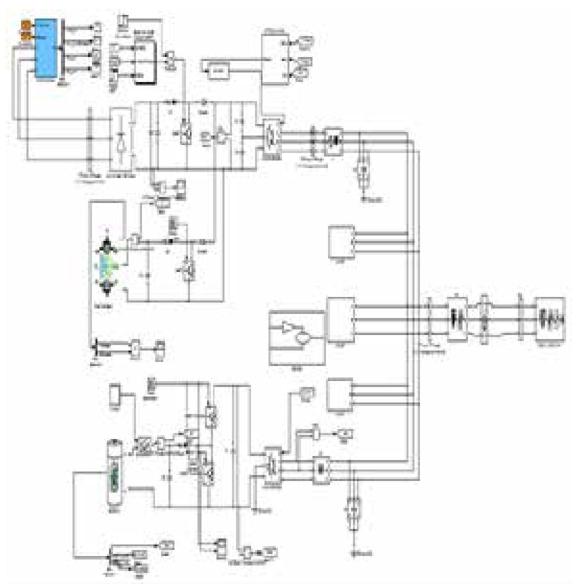

Fig 4.9: simulation Model during Islanded Operation

In islanded operation, the total generation power of the micro grid may not be able to maintain its generation to meet up the power requirement of the loads. During such conditions, consumers will permit the non-critical load to be discarded so as to keep the constant function of the micro grid. The second test case shows the function of the microgrid which is islanded from the grid. In this case, the microgrid is primarily functioning in the grid-connected mode for 0 ≤ t < 0.2 s. The Storage Battery is primarily functioning in the idle mode and its State of charge is 80%. As an error occurs on the network of the distribution grid, the Circuit Breaker function is to disconnect the microgrid from the distribution grid at t= 0.2 s.

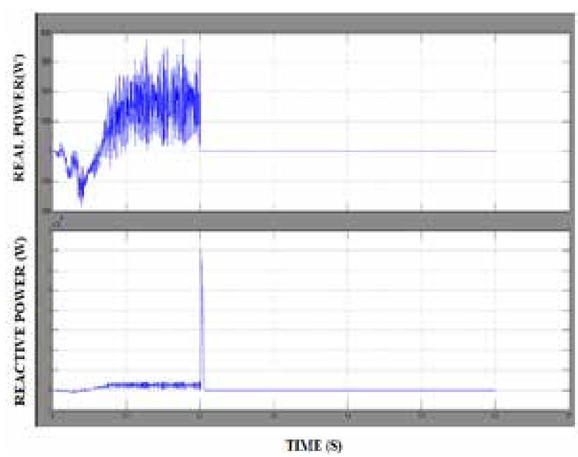

Fig. 4.10 the waveforms of the real and reactive power supplied by the grid.

The Circuit Breaker manages to separate the microgrid from the distribution grid, ensuing in zero real and reactive power delivered by the grid for 0.2≤ t < 0.6s. The real power given by DG inverter 2 of the Storage Battery is shown in Fig. 5.12.

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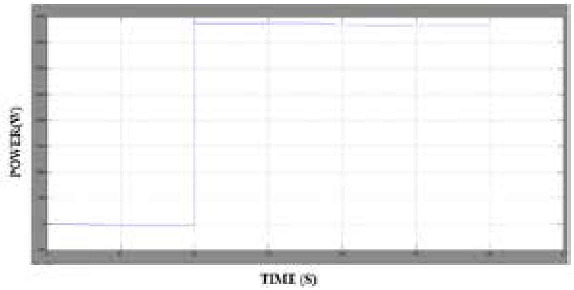

Fig 4.11: Power delivered by Storage Battery during Islanded Operation.

0 ≤ t < 0.2s, the Storage Battery is in the idle mode. After the beginning of the islanding operation at t= 0.2 s, the DG inverter 2 is tasked by the PMS to enhance its generation to offer real power of about 4 kW to the loads.

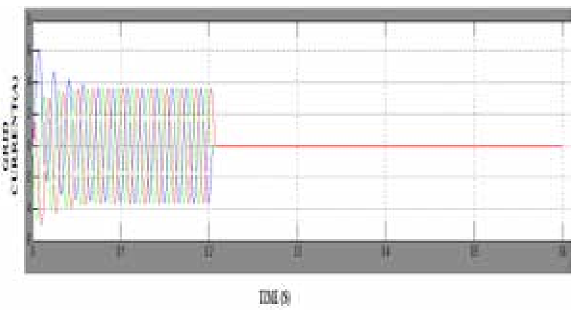

Fig 4.12 : Waveforms of Grid Current During Islanded Operation

V. CONCLUSION

In this Thesis, an Adaptive Neuro fuzzy Interface control system coordinates the operation of multiple DG inverters in a micro grid for grid-connected and islanded operations has been presented. The proposed controller for the DG inverters is predicated on an incipiently developed ANFIS in order to reduce the overall computation time. The control design is to extract the harmonic spectra of the load currents and to engender the compulsory references for the controller. The DG inverters can compensate for load harmonic currents in a homogeneous way as conventional compensators, such as active and passive filters, and, hence to realize the perspicacious grid concept, an assortment of Power-management functions, such as peak shaving and load shedding, have additionally been demonstrated in the simulation studies. The results have validated that the micro grid is able to handle different operating conditions efficaciously during grid-connected and islanded operations, thus incrementing the overall reliability and stability of the micro grid. The entire proposed system will be tested using MATLAB/SIMULINK and the simulation results demonstrate the attractive performance characteristics of the proposed system.

FUTURE SCOPE

The proposed controller i.e. ANFIS for the DG inverters is utilized rudimentary Pulse width Modulation technique, it can reduces the higher order harmonics only, that can be elongated to Current Control loop so that, we can reduce the lower order harmonics also.

REFERENCE

[1] S. Braithwait,"Behavior management," IEEE Power and Energy Mag.,vol. 8, no. 3, pp. 36–45, May/Jun. 2010. | [2] N. Jenkins, J. Ekanayake, and G. Strbac , Distributed Generation.London, U.K.: IET, 2009. | [3] M. Y. Zhai, "Transmission characteristics of low-voltage distributionnetworks in China under the smart grids environment," IEEE Trans.Power Del., vol. 26, no. 1, pp. 173–180, Jan. 2011. | [4] G. C. Heffner, C. A. Goldman, and M. M. Moezzi, "Innovative ap-proaches to verifying demand response of water heater load control,"IEEE Trans. Power Del. , vol. 21, no. 1, pp. 1538–1551, Jan. 2006. | [5] R. Lasseter, J. Eto, B. Schenkman, J. Stevens, H. Vollkommer, D.Klapp, E. Linton, H. Hurtado, and J. Roy, "Certs microgridlaboratorytest bed, and smart loads," IEEE Trans. Power Del. , vol. 26, no. 1, pp.325–332, Jan. 2011. | [6] A. Molderink, V. Bakker, M. G. C. Bosman, J. L. Hurink, and G. J. M.Smit, "Management and control of domestic smart grid technology,"IEEE Trans. Smart Grid , vol. 1, no. 2, pp. 109–119, Sep. 2010.