Energy Management of Grid Connected PV System Based on Artificial Intelligence

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***Abstract*—** This paper presents an effective technique for power management in Grid-connected photovoltaic system with an energy storage system under load constraints. The proposed management system is designed to manage the power flow between the Photovoltaic system, utility grid and energy storage elements in order to satisfy the load requirements based on artificial neural network (ANN). In order to make correct and quick decisions the system is able to sense the continuous changes in photovoltaic power generation, Load Demands, Grid and Battery State of Charge. A five mode operational has been used for training the ANN to schedule power coming from multi source power system (Photovoltaic, Grid, Battery). The effectiveness of proposed system is validated by simulation using Matlab/ Simulink.

Keywords- *energy management, artificial neural network (ANN), grid, PV system, multi source power system.*

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I. INTRODUCTION

Energy crisis has motivated the power generation through clean energy sources. One of the most promising renewable resources for bulk power generation owing to their ability to reduce energy use is solar energy. Due to various advantages of solar its gaining importance now a days and also being a clean energy source its eco-friendly. A trend of solar energy application is Photovoltaic (PV) grid-connected generation system. The multi source power system – consisting of PV array, battery and utility grid are coupled to the load with energy management System as shown in figure 1.This system trace the maximum power from PV array and manages the power transfer in order to feed directly to the load with respect to available storage level and grid connection. In case there is insufficient of PV generated power, then the system security will be maintained by grid and storage system. Also excess of PV generated power can be Send back to the Grid and at night time continuity of power will be maintained by utility grid.

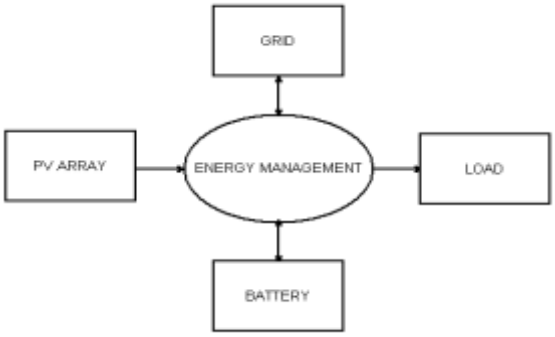

Figure. 1 Block diagram of multi energy system with energy management

This whole power flow requires an effectual Control approach that should be able to sense the continuous changes in PV power generation, Load Demands, battery state of charge and load shedding aspects in order to make robust decisions. To utilize the generated solar power effectively energy management is needed. By intelligent energy management (ANN) technique not only renewable energy can by utilized effectively but also by proper supervision wastage of energy can be minimized.

II. LITERATURE REVIEW

A unique technique of energy management is proposed in [3] for PV based Grid-connected systems. In the methodology modeling of multi-source power system components is based on discrete state modeling by interpreted Petri net PN with four layer supervisor system.

When compared with traditional methods for building power consumption prediction, artificial neural networks are more reliable, provide faster learning time with increased simplicity in analysis and adaptability to variations in power fluctuation in multi source power system and load's energy usage.

III. MOTIVATION AND PROBLEM STATEMENT

The motivation behind this work is to help schedule power using ANN. The artificial neural networks are promising for many applications and the approach is based on a non-parametric technique that can approximate complex functions. The objectives include

- Power scheduling
- Power supply Stability
- Better utilization of Green Energy Source (PV)

- Efficient Energy Balance

Once an artificial neural network (ANN) model is fully trained, model can be used to predict and evaluate the Power flow between multi source power systems.

IV. PROBLEM FORMULATION

The constraints and the conditions applied on system are given in table below.

Table 1. Constraints and the conditions applied on system

MODES	CONDITIONS	DESCRIPTION
MODE I AND MODE II	$P_{PV} \geq P_L$	PV –› BATTERY
		PV –› LOAD
MODE III	$P_{PV} \leq P_L$	BATTERY–›LOAD
MODE IV	$P_{PV} = 0$	GRID–›LOAD
MODE V	$P_L \leq 0$	PV –› GRID

V. ENERGY MANAGEMENT BY ARTIFICIAL NEURAL NETWORK (ANN)

In structure and functionality the Neural Network (NN) model is inspired by human brain.An ANN is a mathematical or computational model that is inspired by biological nervous system. ANN can establish a relationship between the input and output data by adjusting its weights through learning process [5]. An ANN consists of an interconnected group of artificial neurons and may be single layered or multi-layered. Each neuron is interconnected to each other. The knowledge gained during the training process is stored in the interconnecting neurons. The network type that has been used here is a feed forward back propagation Neural Network (NN) which consists of input, output and the hidden layers. A neural network based system is inherently adaptive because of its automatic learning property .

Each neuron of next layer proceeds summation of signals *xi* altered by connection weight *wi* for each neuron *i* of *n* neurons from previous layer showed in equation (1):

$$z = \sum_{i}^{n} w_i x_i \quad (1)$$

Output from this neuron is computed by its sigmoid activation function presented in equation (2):

$$y = \frac{1}{1 + e^{-\lambda z}} \quad (2)$$

Where λ is the slope of the sigmoid function.

These signals are propagated to output layer through all hidden layers and outputs from NN are excitations of output neurons. Feed Forward Neural Network learning is processed by updating connection weights between neurons. One of the methods that allow NN adaptation on given training set is called Back propagation[6].

In Back propagation (BP) adaptation of weights is processed by propagation of outputs error back through the network from upper layers to lower layers by comparing output to the desired output. The goal is to minimize error function, as in equation (3):

$$E = \frac{1}{2} \sum_{p=1}^{P} \sum_{j=1}^{M} (y_j - d_j)_p^2 \quad (3)$$

where error between real output from network *yj* and desired output *dj* is summed for *P* patterns of training set and for all *m* output neurons in output layer. Error minimization is done by adapting weights between neurons.

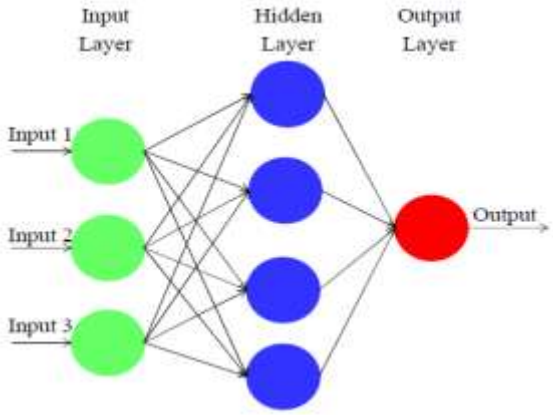

Figure 2. Neural Network design with one Hidden layer

To optimize the power distribution in a building the prediction from artificial neural network model can be used. For energy management of multi sources [9], ANN input can be PV array, electric grid and Battery parameters-voltages and currents. The output is usually power flow depending on load constrains. The proposed ANN is using the measurement voltage and current of multi source power system is the input of ANN, the output is the reference voltage that the PV obtains the maximum power at and also grid and battery parameter. The training data are determined by using Matlab/Simulink .

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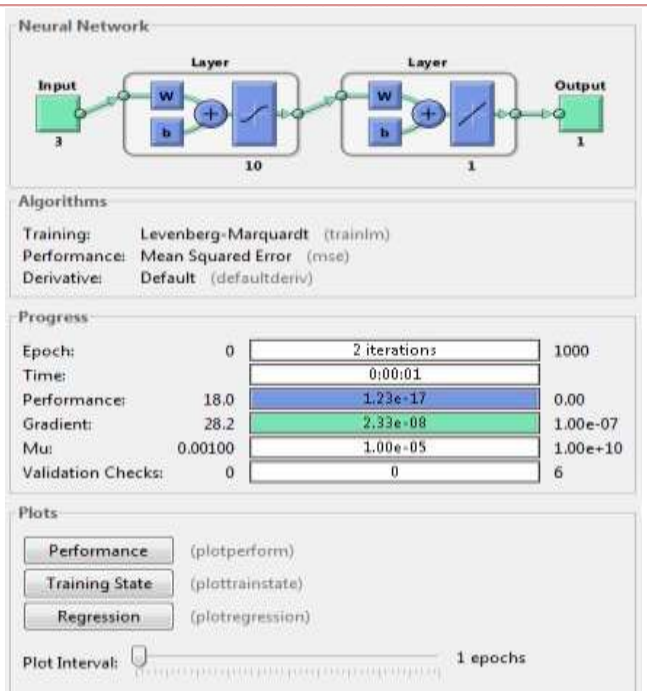

Figure.3 Results of training ANN in Matlab/ Simulink

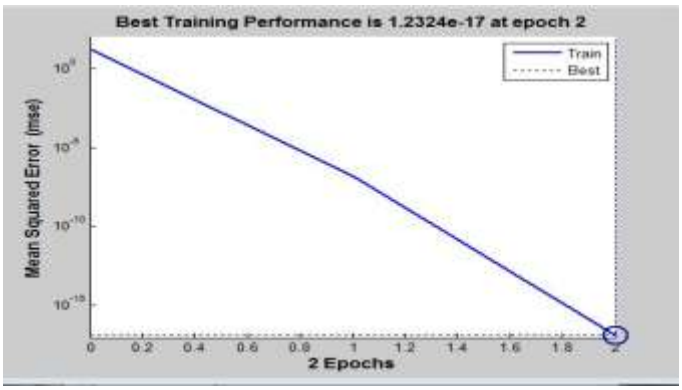

Figure 4. ANN training performance

VI. PROPOSED MODEL

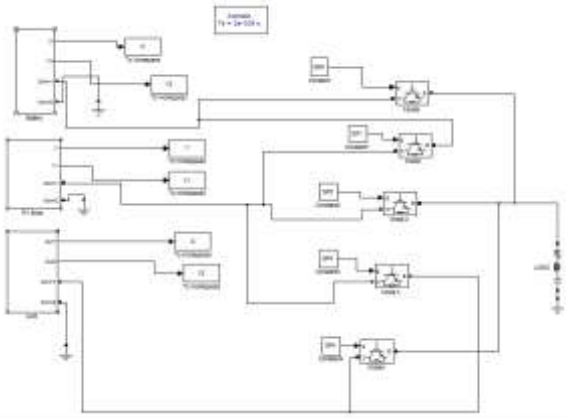

Figure 5 . Model of energy management based on artificial intelligence

VII. RESULTS ANALYSIS

A mathematical model of grid connected PV system is developed using MATLAB/Simulink platform. The performance of proposed intelligent power management scheme is being verified. Artificial neural network monitors the power among multi sources power system and takes the decision quickly and maintain continuous supply to the load. Or in else case it can be used for battery charging or send off to the grid. The grid tied PV system trace the maximum power and then converts it to sinusoidal ac power will less harmonic distortion.

Table 2. Experimental Data

Name	Value	Min	Max
Data	[0.0317;374.2446;0.0013]	0.0013	374.2446
GP1	0	0	0
GP2	0	0	0
GP3	0	0	0
GP4	1	1	1
GP5	0	0	0
I1	<150001x1 double>	-0.0481	0.0032
I2	<150001x1 double>	-0.0012	0.0872
I3	<150001x1 double>	-0.0046	0.0057
P1	0.0317	0.0317	0.0317
P2	374.2446	374.2446	374.2446
P3	0.0013	0.0013	0.0013
PL	1000	1000	1000
Ts	2.0000e-06	2.0000e-06	2.0000e-06
Ts_Control	1.0000e-04	1.0000e-04	1.0000e-04
V1	<150001x1 double>	6.9065e-09	14.7876
V2	<150001x1 double>	-43.9976	4.3953e+03
V3	<150001x1 double>	-0.2741	-1.8224e-04
Vdc_ref_Inv	680	680	680

From the given data ANN has switched to MODE IV depending on available power.
Power of PV is 3.174171e-02
Power of Grid is 3.742446e+02
Power of Battery is 1.269789e-03
Required Load Power is 1000
Power Flows from Grid to Load

VIII.CONCLUSION

This paper presented a proposed ANN-based energy management technique. ANN is trained in such a way that it is able to sense the continuous changes in PV power generation, Load Demands and Battery storage level in order to make correct and quick decisions. With respect to available storage level and taking into account the utility grid connection, the PV generated power is transferred in order to feed directly the load (building). In case the PV generated power is insufficient, the system security is ensured either by the grid-connection or by means of storage. Depending on the above constrain power flow take place thus utilizing it efficiently and minimizing the wastage.

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