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IMPLEMENTATION OF POWER CONTROL AND MANAGEMENT IN A HYBRID AC/DC MICROGRID BASED ON ARTIFICIAL NEURAL NETWORK CONTROL

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ABSTRACT- In this project, the grid-connected hybrid AC/DC Microgrid is investigated. Different Renewable Energy Sources – photovoltaic modules and wind turbine generator -have been considered together with Solid Oxide Fuel Cell and Battery Energy Storage System. The aim of this project is to design and implementation of hybrid AC/DC network and Artificial neural network controllers in an efficient manner. Adaptive Neural Networks are used to track the Maximum Power Point of renewable energy generators. It control the power exchanged between the Front-End Converter and the electrical grid. The operation of the hybrid microgrid has been tested in the Matlab/Simulink environment under different operating conditions. The obtained result is the effectiveness, the high robustness and the self-adaptation ability of the proposed control system.

I.INTRODUCTION

Nowadays, the wide diffusion of distributed RES presents a for regulation of distribution networks and availability of new technologies for storage systems .It is encourages their use in power systems. In general, a hybrid AC/DC MG integrates different Distributed Generators (e.g. solar power sources, wind power generators, cogenerate, etc.), an energy storage system and a number of AC and DC loads. A FEC can interface the MG with the electric grid and can operate grid connected system. The use of a PMS is crucial to optimize the power flow through the different components of the MG and the exchange of energy with the electric grid. Moreover, since the power produced by RESs depends on the climatic conditions. MPPT algorithms are needed in order to harvest the maximum available energy and tracking control. The intermittent nature of RESs with the time-varying loads demand make the use of advanced control structures in order to make the operation of the MG reliable, economic, and secure under different operating

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conditions. The MG must also guarantee a high quality power supply to both local loads and electrical grid. Three Phase ac power systems have existed for over 100 years due to their efficient transformation of ac power at different voltage levels.Recently more renewable power conversion systems are connected in low voltage ac distribution systems as distributed generators.

II.LITERATURE REVIEW

Xiong Liu, Peng Wang and Poh Chiang Loh (2011) have developed a hybrid ac/dc micro grid to reduce the processes of multiple dc–ac–dc or ac–dc–ac conversions in an individual ac or dc grid. The hybrid grid consists of both ac and dc networks connected together by multi-bidirectional converters. AC sources and loads are connected to the ac network dc sources and loads are tied to the dc network. Energy storage systems can be connected to dc or ac links. This hybrid grid can operate in a grid-tied or autonomous mode. The coordination control algorithms are proposed for smooth power transfer between ac and dc links and for stable system operation under various generation and load conditions. The advantages are Minimize the power transfer between AC and DC networks and Maintain stable operating condition of both ac and dc grids. The disadvantages are Less accurate control system.

Whei-Min Lin, Chih-Ming Hong, and Chiung-Hsing Chen (2011) have presented a stand-alone hybrid power system. The system consists of solar power, wind power, diesel engine, and an intelligent power controller. To achieve a fast and stable response for the real power control, the intelligent controller consists of a radial basis function network (RBFN) and an improved Elman neural network (ENN) for maximum power point tracking (MPPT). The pitch angle of wind turbine is controlled by the ENN, and the solar system uses RBFN, where the output signal is used to control the dc/dc boost converters to achieve the MPPT.The advantages are Very fast and more stability. The disadvantages are Output power fluctuation is high and Low efficiency. Christo Ananth et al.[5] presented a brief outline on Electronic Devices and Circuits which forms the basis of the Clampers and Diodes.

Ahmad Al Nabulsi and RachedDhaouadi (2012) have presented a new digital control scheme for a standalone photovoltaic (PV) system using fuzzy-logic and a dual maximum power point tracking (MPPT) controller. The first MPPT controller is an astronomical two-axis sun tracker, which is designed to track the sun over both the azimuth and elevation angles and obtain maximum solar radiation at all times. The second MPPT algorithm controls the power converter between the PV panel and the load and implements a new fuzzy-logic (FLC)-based perturb and observe (P&O) scheme to keep the system power operating point at its maximum. The FLC-MPPT is based on a voltage control approach of the power converter with a discrete PI controller to adapt the duty cycle. The input reference voltage is adaptively perturbed with variable steps until the maximum power is reached. Advantages are Improve efficiency, Reduce steady state oscillation.The disadvantages are High computational complexity.

In electrical power generation, droop speed control is a speed control mode of a prime mover driving a synchronous generator connected to an electrical grid. This mode allows synchronous generators to run in parallel, so that loads are shared among generators in proportion to their power rating.

When at least two Renewable Energy Sources (RES) are connected through energy converters to the MG, the droop control method are often applied, what provides the correct parallel operation of voltage source converters (VSI). The presented technique is similar to the equivalent circuit of synchronous generator; hence the active and reactive power of K^{th} converter connected to ac MG can be described as,

$$P_k = \frac{E_k V}{X_k} \sin\varphi_k \quad (1)$$

$$Q_k = \frac{E_k V \cos\varphi_k - V}{X_k} \quad (2)$$

Where *P*, active power; *E*, converter voltage amplitude; *V*, voltage amplitude in PCC; *X*, coupling impedance; and □, angle of converter voltage. Based on above equations it can be assumed as below.

1) Active power *P* mainly depends on changing by *ω*.

2) Reactive power *Q* depends on voltage amplitude *E*.

In order to implement these characteristics in VSI control algorithm, the outer droop control loops are created, which can be described by,

$$\omega = \omega^* - G_p(s).(P - P^*) \quad (3)$$

$$E = E^* - G_q(s).(Q - Q^*) \quad (4)$$

Where, E and ω referenced amplitude voltage and frequency for inner control loops, $E^*$and ω^* are nominal voltage amplitude and frequency, P and Q are calculated active and reactive power, P^* and $Q^*$are the active and reactive power referenced values, and $G_p(s)$ and $G_q(s)$ are corresponding transfer functions.Typically in classical droop control $G_p(s)$ and $G_q(s)$ are proportional droop coefficients. It has happened, when MG not includes any energy storage and total load cannot absorb total injected power. These proportional coefficients can be calculated by (5) and (6).

$$G_p(s) = m = \frac{\Delta\omega_{max}}{P_{max}} \quad (5)$$

$$G_q(s) = n = \frac{\Delta E_{max}}{Q_{max}} \quad (6)$$

where, m active power coefficient; n, reactive power coefficient; $\Delta\omega_{max}$, maximum allowed voltage frequency droop; ΔE_{max}, maximum allowed voltage amplitude droop; P_{max}, maximum allowed active power; and Q_{max}, maximum allowed reactive power.

III. PROPOSED METHOD

A hybrid AC/DC Micro Grid (MG) integrates different Distributed Generators (e.g. solar power sources, wind power generators, cogenerators, etc.), a energy

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storage system and a number of AC and DC loads. In this project, a grid-connected hybrid MG which consists of a PV source, a WT generator, a SOFC, a BESS and two equivalent DC and AC loads is studied. A Front End Converter can interface the DG with the electric grid and can operate either in a grid-connected or islanded mode. The use of a Power Management System is crucial to optimize the power flow through the different components of the MG and the exchange of energy with the electric grid. Moreover, since the power produced by RESs depends on the climatic conditions, MPPT algorithms are needed in order to harvest the maximum available energy Online-trained NNs based MPPT for the RESs in addition to ADALINE based linear controllers for both SOFC stack and BESS are introduced. A simplified deadbeat based predictive control scheme is applied for the WEGS. A Feed Forward Neural Network (FFNN) is proposed for the regulation of the DC-bus voltage

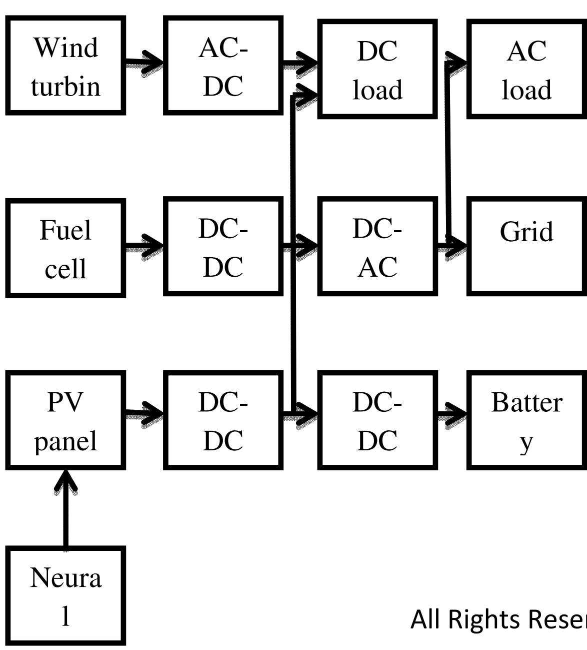

Fig.1 Hybrid Microgrid configuration

Principle of the AI Algorithm for NN Training

The adjustment of the NN weights with the adaptive interaction algorithm is equivalent but simpler than the well-known BP approach. Moreover, it does not need to back propagate the output error through the network. The most prominent features of the AI approach are the adaptation during the interaction of neurons and the low computational requirements in comparison to the BP algorithm. In this subsection, the NN weights adaptation law based on the AI algorithm is given. The output of each node in the l-th layer of a NN is calculated as:

$$x_n^{(l)} = f_n^{(l)}\left(net_n^{(l)}\right) f_n^{(l)}(\textstyle\sum_{i=1}^{N} w_i x_i^{(l-1)} \quad (7)$$

Where $x_n^{(l)}$ and $f_n^{(l)}$ are the output and the activation function of the n-th node in the l-th layer respectively. $x_i^{(l-1)}$ is i-th input of n-th node, w_i is the connection weight from i-th input to the n-th node, and *N* is the number of inputs to the l-th layer. The training process aims to minimize the cost function *E* expressed as,

$$E=\frac{1}{2}\textstyle\sum_{n=1}^{m} e_n^2 \quad (8)$$

Where,

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$$e_n = \begin{cases} x_n^{(l)} - d_n & \textit{for output node} \\ 0 & \text{otherwise} \end{cases}$$

Where m is the number of the output neurons. d_n is the desired output of the n-th output neuron. The weights of the NN can be dynamically updated according to the AI law as follows:

$$\Delta w_i f_n^{(l)'} \pi r^2 \left(net_n^{(l)}\right) \frac{x_n^{(l-1)}}{x_n^{(l)}} \sum_{j=1}^{P} w_{oj} \Delta w_{oj} - \gamma f_n^{(l)'} \left(net_n^{(l)}\right) x_i^{(l-1)} e_n \qquad (9)$$

Where $\gamma>0$ is the adaptation coefficient and *P* is the number neurons in the next layer. w_{oj} is the weight connecting o-th with j-th neuron. The Tangent-Sigmoid Activation Function (TS-AF) of neurons is defined as:

$$x_n^{(l)} = f_n^{(l)}\left(net_n^{(l)}\right) = \frac{2}{1+e^{-net_n^{(l)}}} - 1 = \frac{1-e^{-net_n^{(l)}}}{1+e^{-net_n^{(l)}}} \qquad (10)$$

$$f_n^{(l)'}\left(net_n^{(l)}\right) = \frac{1}{2}(1-(x_n^{(l)})^2) \qquad (11)$$

IV. RESULTS AND DISCUSSION SIMULINK DIAGRAM

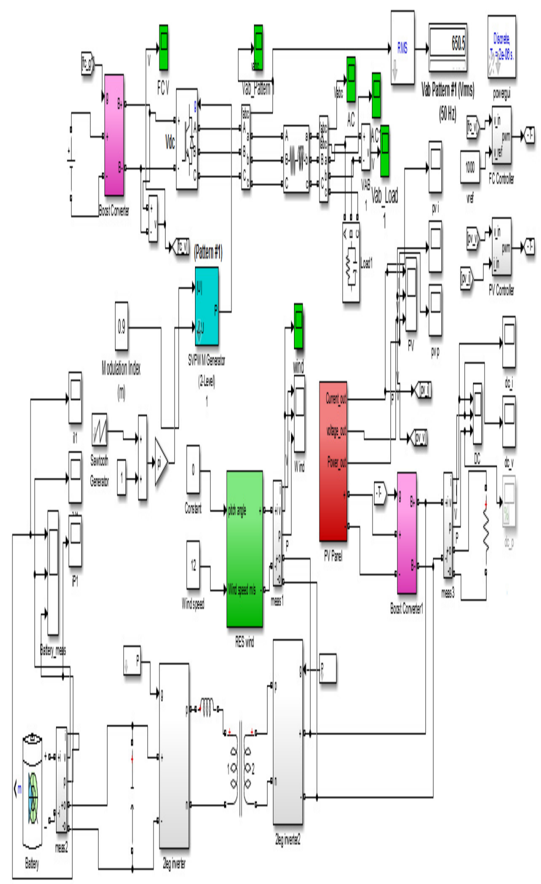

Fig.2 Simulink diagram of proposed method

The proposed method is implemented using MATLAB software. The simulink diagram of proposed method is shown if fig 2. The Simulink diagram consists of PV panel, wind source, fuel cell, battery and neural network controller.

V. SIMULATION RESULTS

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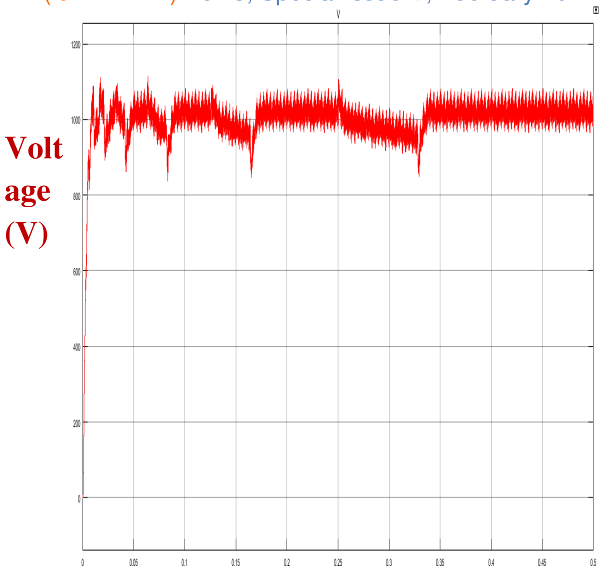

Fig. 3.Fuel cell voltage

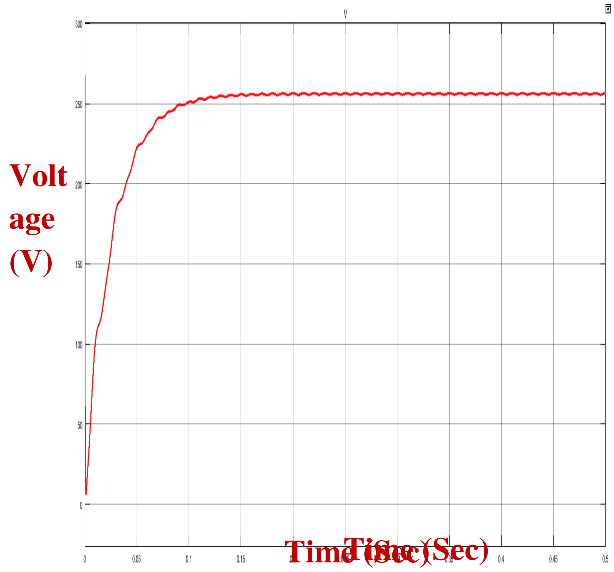

Fig. 5 PV panel voltage

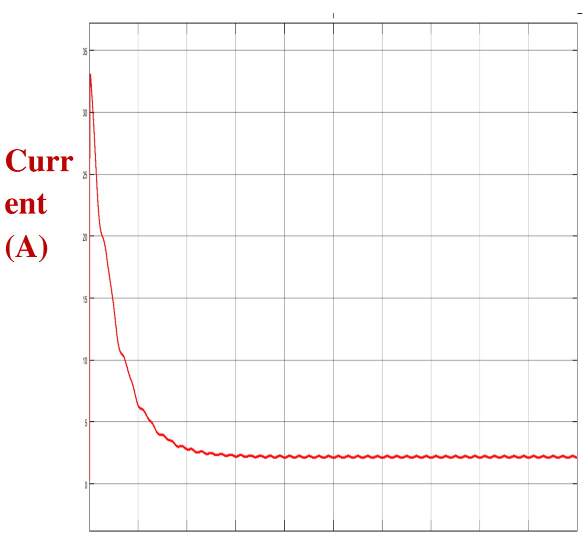

Fig .4 PV panel current

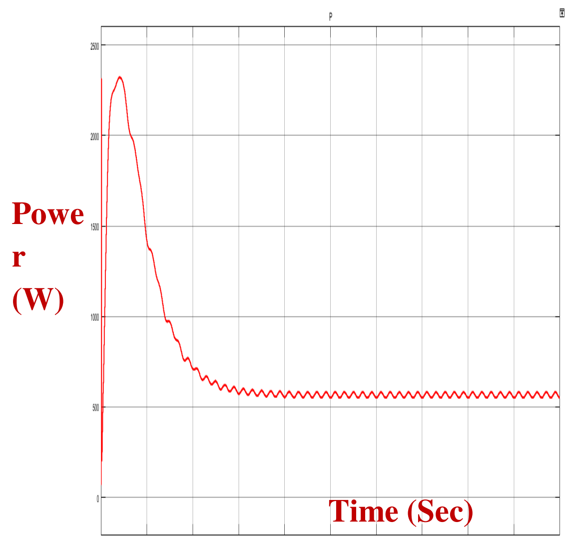

Fig. 6 PV panel power

The waveform of fuel cell voltage at boost converter stage is shown in fig 3. The waveform of PV panel current is shown in fig 4.

The waveform of the PV panel voltage is shown in fig.5 and the waveform of the PV panel power shown in fig. 6.

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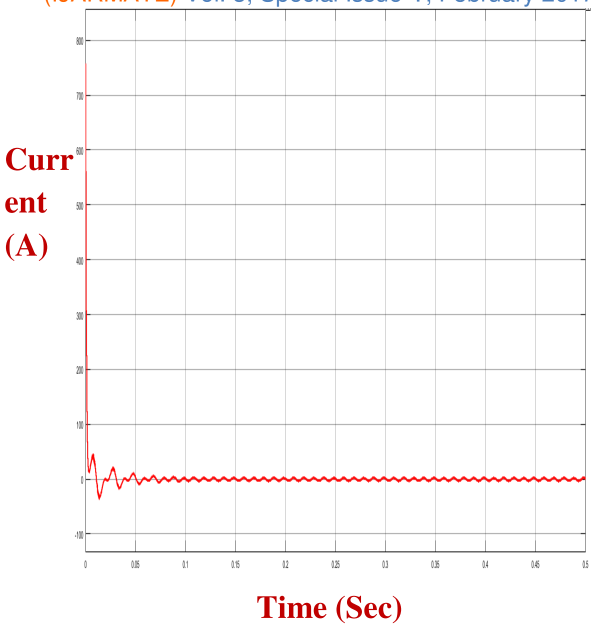

Fig .7 Battery current

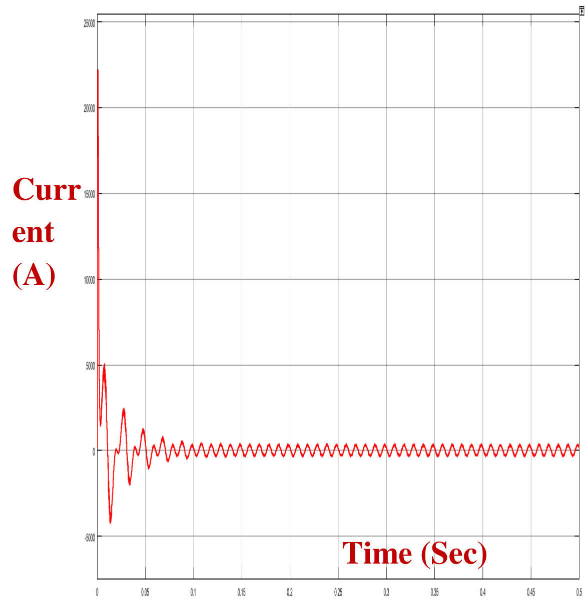

Fig.9 Battery power

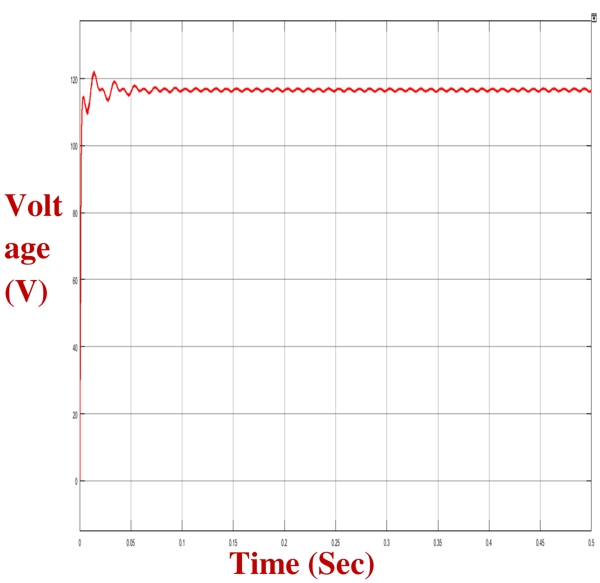

Fig .8 Battery voltage

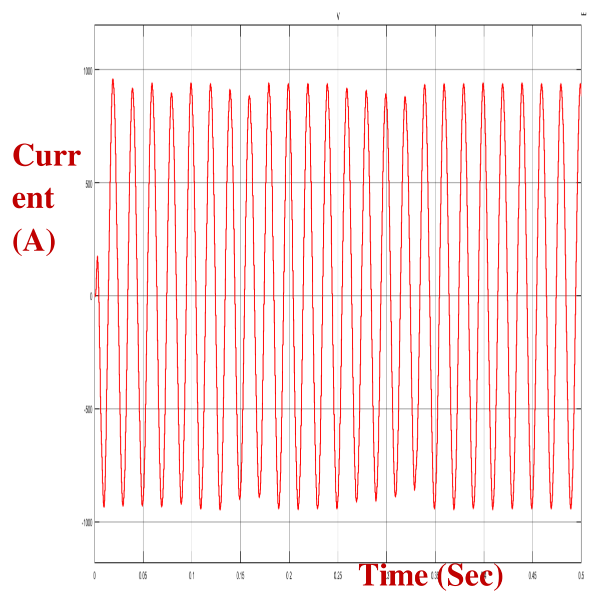

Fig.10 AC load single line to line current

The waveform of the battery current is shown in fig.7 and the waveform of the battery voltage is shown in fig.8.

The waveform of the battery power is shown in fig.9. Single line to line current of AC load is shown in fig.10.

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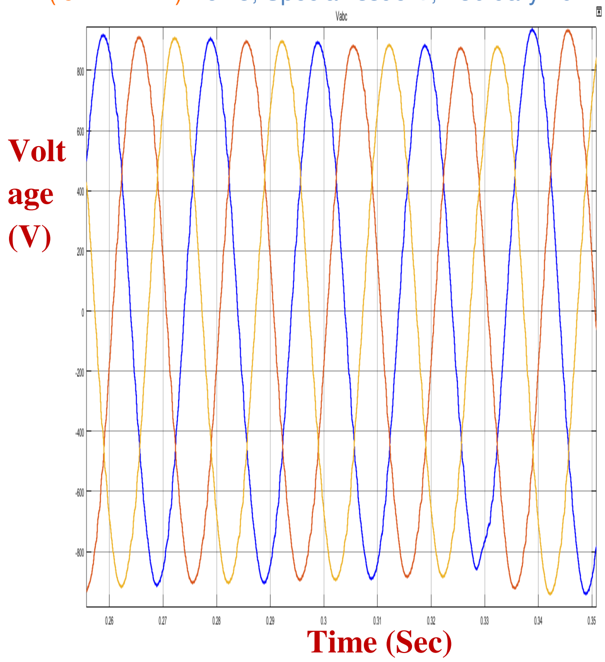

Fig.11 AC load voltage

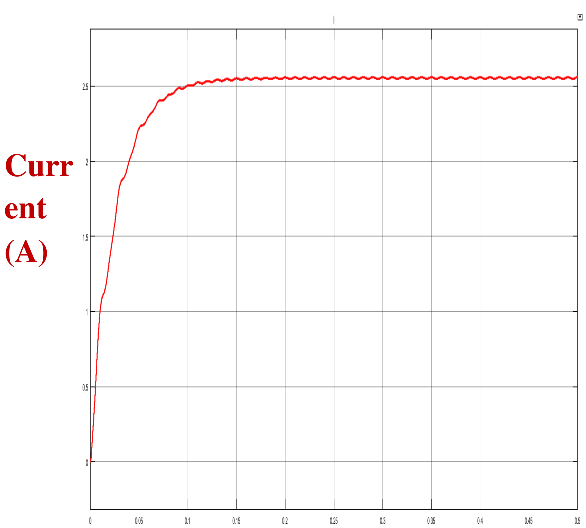

Fig.11 DC load current

The waveform of 3 phase load voltage is shown in fig.10. The waveform of DC load current is shown in fig.11.

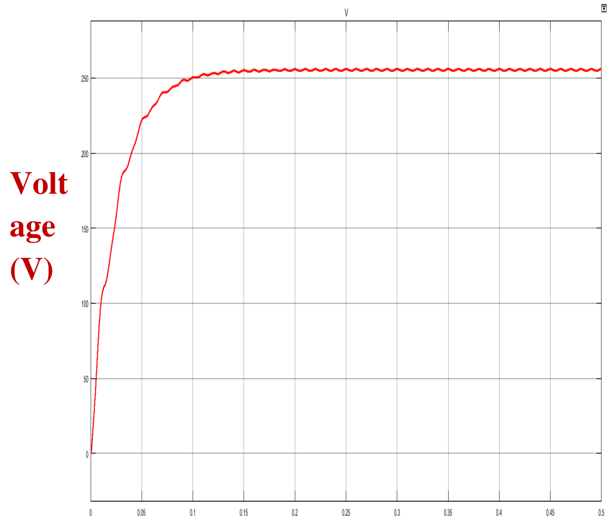

Fig.12 DC load voltage

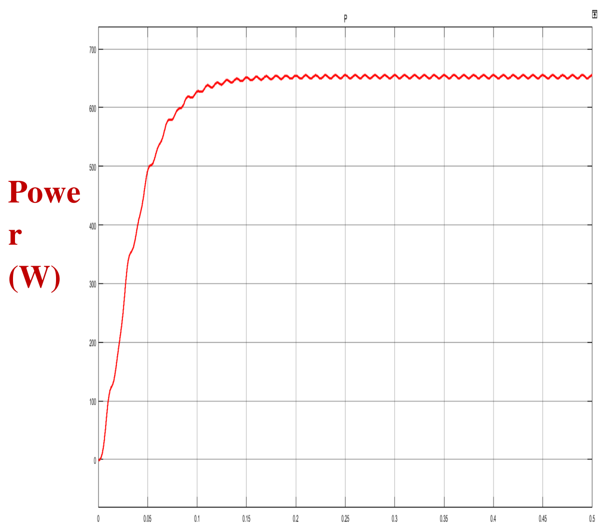

Fig.13 DC load power

The waveform of DC load voltage is shown in fig.12. The waveform of DC load power is shown in fig.13.

VI. CONCLUSION AND FUTURE WORK

This work is on the design and validation of an online trained neural network based control system for a grid-connected hybrid AC/DC microgrid. A number of artificial intelligence based controllers have been developed to follow the maximum power point of the renewable energy sources available in the microgrid, to control the power flow between the front-end converter and the electric grid, and to minimize the purchased energy optimizing the utilization of the battery energy storage system. The performance of the proposed control system has been tested for different situations: variable climate conditions, variable loads demand, and perturbed grid conditions. The obtained results show the possibility to control complex non-linear systems without the availability of precise models. Moreover, the proposed techniques are flexible, adaptable, require low computational costs, and are easy to implement in real-time applications. The simulation runned for a number of different conditions of power generation and demand demonstrate the effectiveness, robustness and self-adaptation ability of the proposed control system. This project can be extended to the level in which space vector modulator or neuro fuzzy controller can be implemented to improve the performance of the system

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