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APPLICATION OF RBF-NN ON POWER OPERATION OPTIMIZATION OF PHOTOVOLTAIC STAND ALONE SYSTEM WITH VARIABLE LOADS

B. CHUCO P., J.L. R. ORTIZ, J. O. P. PINTO, K.S. C. LINARES, L. C. LEITE

BATLAB, DEL, Universidade Federal Mato Grosso Do Sul
DEL/CCET/UFMS – CP 549 -79070900 – Campo Grande – MS - Brasil, CIEEP-Perú
E-mails: `bchuco@batlab.ufms.br`

Abstract— This work presents the application of Artificial Neural Network to a maximum voltage estimator and control system to maintain the photovoltaic (PV) generator in the maximum power point, independent of load variations. A Radial Basis Functions Neural Network (RBF-NN) controller is implemented, to estimate, from irradiation and temperature data, the maximum voltage of operation of PV generator. The charge and discharge of the battery and the SOC battery are controlled too with RBF-NN.

Keywords— RBF-NN, Maximum voltage, Maximum power, Photovoltaic Generator

1 Introduction

In stand alone PV systems, is desired to take advantage of the maximum solar irradiation energy for feeding loads. Usually, the maximum power point is found by tracking systems [1-3]. Power flow, due to instantaneous irradiation, depends on load, and could not be using maximum voltage/current, wasting the maximum power generated [3]. This work proposes a maximum voltage estimator, considering the load variations and weather conditions. The estimator is based on RBF-NN [4], trained with real solar irradiation and temperature data and maximum voltage output target data. This maximum voltage is conditioned by a buck-boost [5] to the nominal and fixed load operation dc voltage, producing a maximum current. Exceeding current generated to the battery, when there a current deficit, this is extracted from the baterry to the load. A RBF-NN, too estimates state of charge (SOC) and control the charge charge/discharge [6-7]. RBF-NN, For SOC battery estimation and buck-boost control was trained considering the typical operation conditions parameters, load variations, voltage level, and desirable power flow.

2 System Configuration

2.1 Stand Alone Photovoltaic system

The proposed stand alone system is composed by a PV-array generator, Buck-Boost converter, RBF-NN maximum votage, SOC estimator and control, battery bank, inverter and AC/DC variable loads, as seen in Fig. 1. The solar cell is modeled by an electric circuit [8], and consist on a current source *Iph*, a diode and a series resistance *Rs*, which represents the internal resistance of each cell and conections. The output current ***I*** is calculated by (1).

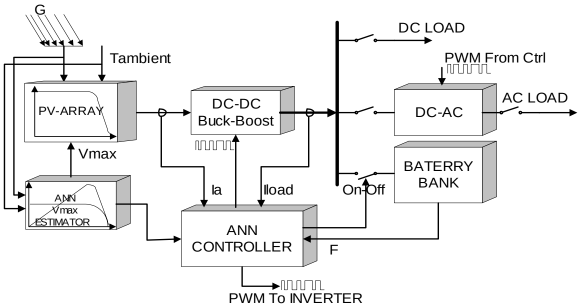

Figura 1. Stand Alone Photovoltaic System Configuration.

$$I = I_{ph} - I_D = I_{ph} - I_0\left(e^{q(V\max + IR_S)/mkT_c} - 1\right) \qquad (1)$$

Where:
m is an ideal factor
k is the Boltzmann's constant
Tc is the absolute cell temperature
q is the electron charge
Vmax is the imposed cell maximum voltage
Io is the saturation current.

2.2 RBF-Neural Network.

RBF-NN present attractive solutions possibilities. It uses Euclidean distance for finding similarities and grouping in its neighborhood, its hidden layer is non linear and the output layer is linear. Then, the theory of linear system can be applied [4].

The basic algorithm is represented in (2):

$$y(x_i) = w_0 + \sum_{j=1}^{m} w_j \phi_j\left(\left\| x_i - \mu_j \right\|\right) \qquad (2)$$

Where: j indicate the hide layer and

$$w_0, w_j, \phi_j, x_i, \mu_j, \|.\|$$

Are:

The initial weights, input weights, non-linear functions, input vector and, Euclidean distance respectibily. The ouput function is given by (3), where x ,is the input vector, μ is the radial function center and σ is the radial function lengh.

$$h(x) = \exp\left[\frac{(x-\mu)^2}{2\sigma^2}\right] \quad (3)$$

3 Proposed Controller and Voltage Estimator Model

3.1 Maximum Voltage Estimator for Maximum Power Point Operation (MPPO)

The RBF-NN was trained with real irradiations and temperature data (Fig.2). The output is the maximum voltage in the PV-array terminal. For testing and validating the RBF-NN output, is compared with mathematical model solutions outputs during 72 hrs, as seen in Fig. 3.

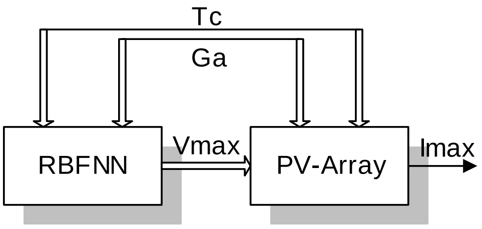

Figura 2. Maximum Voltage Estimator.

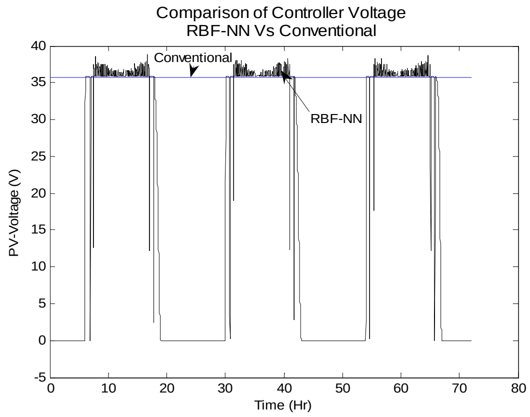

Figura 3. Ouput Voltage Comparison Between Mhatematical Model and RBF-NN Estimador.

3.2 Control Strategy

Fig. 4 shonws PV V-I ouput waveform for a particular instantaneus irradiation. When RBF-NN estimator impose Vmax, for any irradiation value, two cases could occur:

A.- In the load of case 1 (point 1), the load current demand is higher than Imax, this deficiency is compensated from the battery.

B.- In the load of case 2 (point 2), the Imax is lower than load current, at these moments the exceeding current is injected to battery. See that, MPPO does not occur in cases showed above, this is only possible when Vmax is imposed by the RBF-NN. For testing and validating, the RBF-NN was simulated for an unit of solar panel and results are shown in Fig. 5.

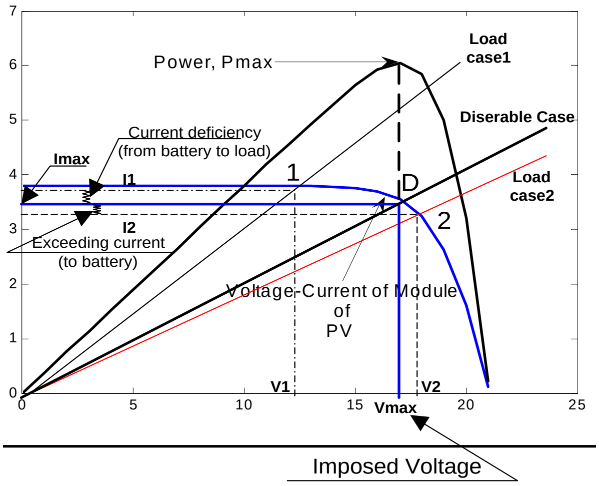

Fig. 4. Control Strategy

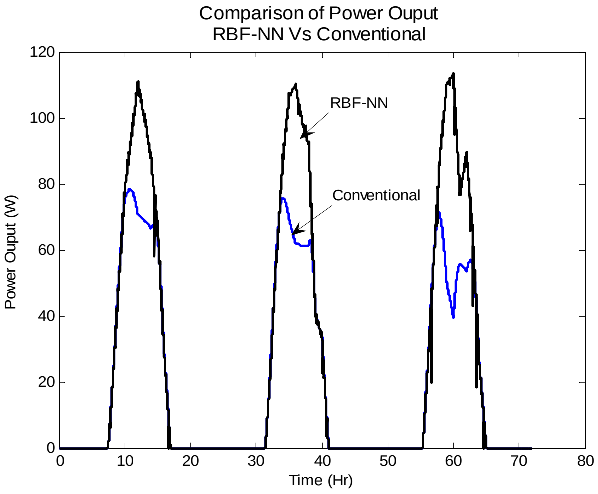

Fig. 5. Maximized Power Ouput.

3.3 Controller and SOC Estimator for Optimal Battery Control.

For optimal battery charge/discharge control, is estimated the battery SOC, Fig. 6. For this, the RBF-NN is trained using characteristic values of voltage, current and battery temperature under different conditions of charge or discharge [7]. Also, buck – boost and inverter control generated. The typical current and voltage discharge behavior of the battery shown in the Fig. 7-8.

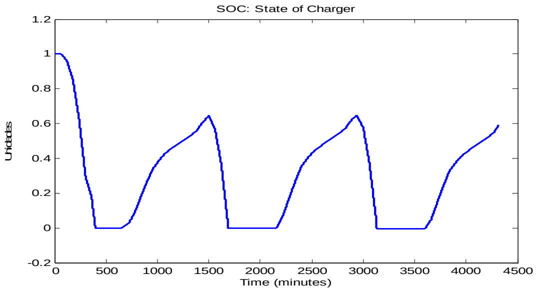

Fig. 6 SOC estimator output

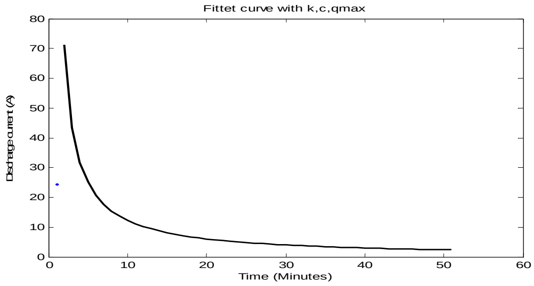

Fig. 7 Battery discharge current

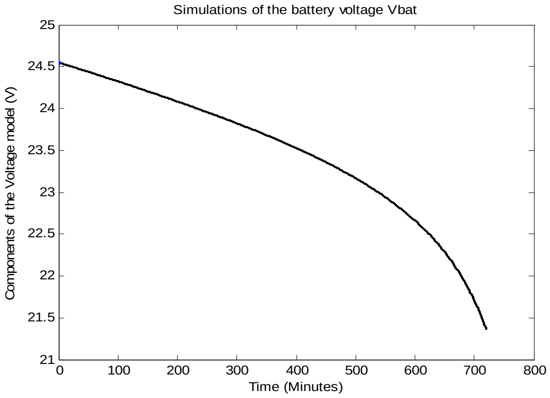

Fig. 8 Battery discharge voltage

4 Results

It was simulated the stand alone PV system of Fig. 1, with three-phase loads in AC and DC bus. PV-array is composed of 32 parallels panels of 160W each. Mean irradiance measured was 0.7 Suns. For this, is required an installed power of 5.12 KW, calculated for 1 suns. DC loads operates at 24V, AC load operates in 120V. It was made a 72 hour simulation, with an increasing solar irradiation. Initially the battery is discharged. The load is fed and battery begins the charge process. The system behaviour is shown in Fig. 9-14. It can be seen AC and DC loads behavior together with maximum power, the charge and discharge periods depending on maximum generated and consumed current. In periods where there is no solar energy, battery must attend the loads demand, varying the battery SOC.

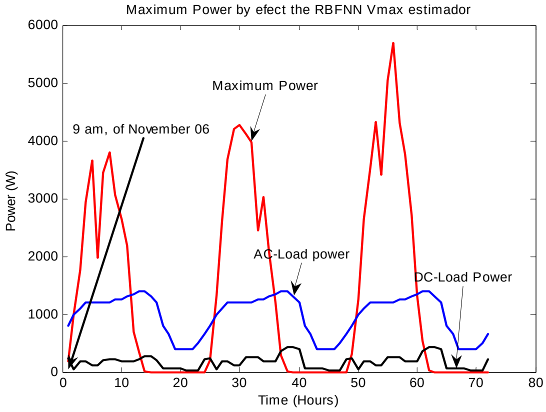

Fig. 9. Power distribution

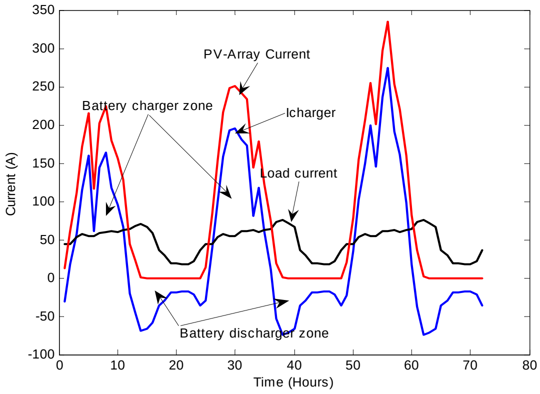

Fig. 10. Currents Distribution

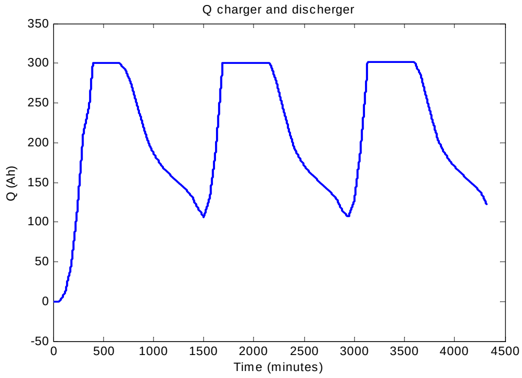

Fig. 11. Battery charge/dischargel level.

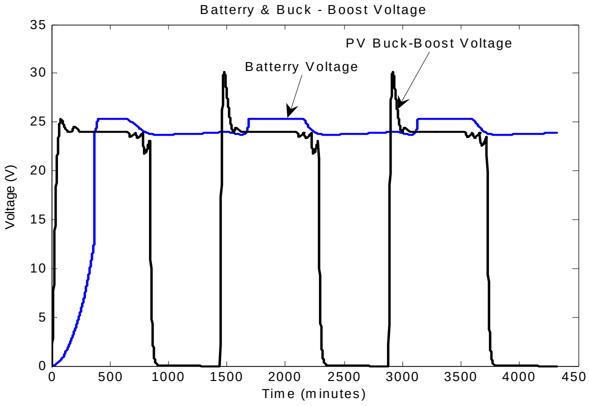

Fig. 12. Battery and buck-boost voltage

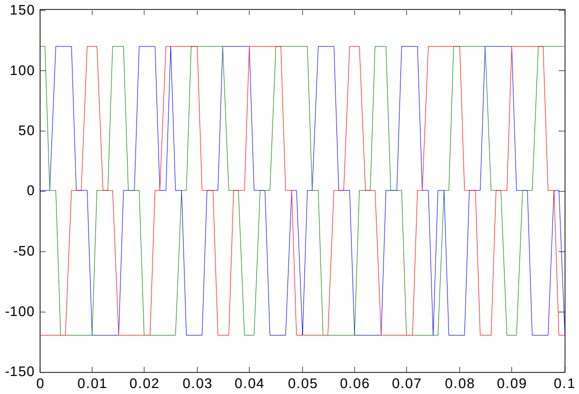

Fig. 13. AC load voltage.

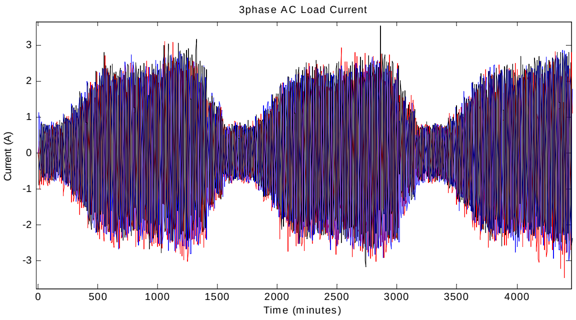

Fig. 14. AC load current.

5 Conclusion

This work shows a stand alone PV system simulation with the optimization of maximum energy extracted. It can be verified that results obtained are advantageous compared with models already proposed. With the use of maximum voltage estimator by RBF-NN it is possible to maintain the system operating in the maximum power point, such can be see in the Fig. 5. SOC estimation is based on all system voltage, current and battery temperature levels.

The advantages to use the system are to guarantee the extraction of the maximum power at all time and its robust behavior forehead to any disturbance.

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