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Hybrid Power Generation Using Intelligence Technique

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***Abstract*: -- Hybrid power generation is the need of the hour. Solar power and wind power are the best available non-conventional energy sources. To extract the maximum electrical power from these sources at various atmospheric conditions intelligent algorithm is the solution. This paper presents improved hybrid power generation by using the artificial neural network. ANN provides improved power generation by improving the maximum power point tracking of sun and with the available wind in the atmosphere. In this paper, an adaptive control using perturbs and observes method is proposed. Neural network controller gives the enhanced and improved power output. Operational analysis is carried out by using MATLAB Simulink.**

I. INTRODUCTION

Renewable energy resources play an important role in electric power generation. There are various renewable resources which is used for electric power generation, such as solar energy, wind energy, geothermal etc. Solar Energy is a good choice for electric power generation, since the solar energy is directly converted into electrical energy by solar photovoltaic modules. These modules are made up of silicon cells. When many such cells are connected in series we get a solar PV module. The current rating of the modules increases when the area of the individual cells is increased, and vice versa. When many PV modules are connected in series and parallel combinations we get a solar PV array, which is suitable for obtaining higher power output. There are two major approaches for maximizing power extraction in solar systems. They are sun tracking, maximum power point (MPP) tracking or both. Later on in this thesis, two MPP tracking techniques are studied and compared. The first technique is based on artificial neural networks and the second one is based on the P&O method. Also a complete grid connected scheme is proposed along with a DC-AC inverter control technique based on hysteresis current control.

II. RENEWABLE ENERGY FORM

1. Wind Power

Wind turbines are used to harvest the energy available in airflows. Current day turbines rated power range from 600kW to 7.5MW (see appendix A.1). The output power of a wind turbine increases with the increase of the cube of wind speed, thus turbines are always installed in high altitudes and especially in places known for high wind speeds [2].

2- Solar Power

Harvesting the power of the sun can be done with two major ways, the first one is to collect the solar heat with mirrors and concentrate it on pipes to exchange the heat of the sun with a certain fluid and then it can be used to generate electricity [3], see Figure 2.2. The second way is to generate electricity directly from the falling sun rays using static photovoltaic cells [4] as shown in Figure 2.3.

Fig 2.1: Parabolic trough systems using mirrors

Fig 2.2: PV panels to generate electricity directly from the sunlight

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2.3 Solar-Photovoltaic Energy

2.1 Growth of photovoltaic:
As Hydro and wind powers are limited to certain geographic conditions, solar power started to take over in the past few years as the solar energy is generously spread across our planet. Photovoltaic are spreading in a very fast way around the globe as it is an easy and fast method of producing electricity through solar energy. Figure 2.3 shows the average annual growth rates of renewable energy, it's obvious that photovoltaic has the highest growth rate among all other renewable energy resources in 2010. While one can notice that the world capacity of photovoltaic almost doubled in 2010

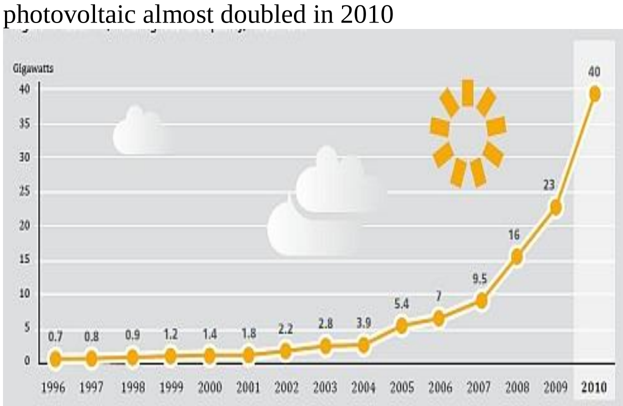

Fig 2.3: Solar PV existing world capacity 1995-2010

2.2 Equivalent Circuit And Mathematical Model

A current source type PV model is discussed in this section. The equivalent circuit is shown in Figure 2.4

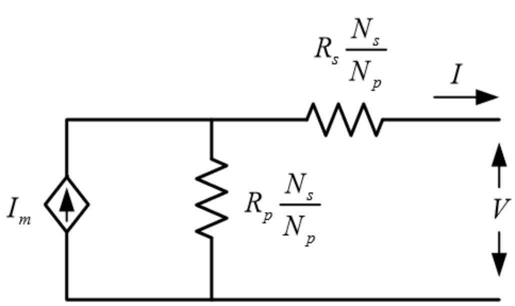

Fig. 2.4: PV module equivalent circuit.

Io is the reverse leakage current of the diode and can be calculated from:

$$I_0 = \frac{I_{scn} + K_i \Delta T}{\exp\left(\frac{V_{ocn} + K_v \Delta T}{a V_t}\right) - 1}$$

Where: Ipvn is the generated current at 25oC and 1000W/m2 (nominal conditions), Ki, Kv the current and voltage temperature confidents respectively, G is the irradiance and Gn is the irradiance at nominal conditions, Iscn ,Vocn are the short circuit current and open circuit voltage respectively at nominal conditions and delta T is the difference between the actual and the nominal temperatures in Kelvin's.

III. MAXIMUM POWER POINT TRACKING

The maximum power point of any PV varies with the variation of the atmospheric conditions (solar irradiance and temperature). This means that there is always one optimum terminal voltage for the PV array to operate at with each condition as shown in Figure 3.1, to obtain the maximum power out of it i.e. increase the array's efficiency.

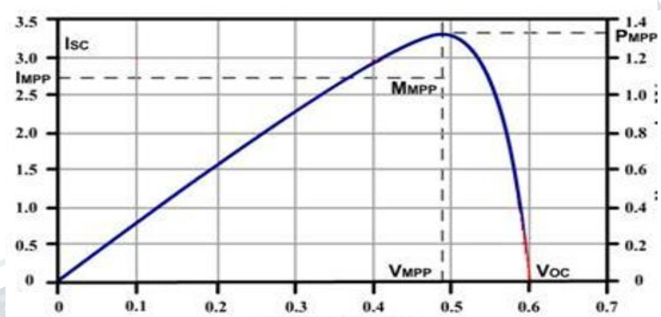

Fig. 3. 1: PV curve showing Maximum Power Point.

DC-DC converters play an important role in the maximum power point tracking process. As by connecting the array's output terminals with the DC-DC converter's input terminals, the array voltage can be controlled by varying the duty cycle of the converter and the voltage at which maximum power is obtained can be maintained. DC-AC inverter's main task is to convert the DC electricity to AC and hence it could be tied to the grid. The inverter has also a very important role in the MPPT process which is fixing the DC-link voltage at certain value. As varying the duty cycle of the DC-DC converter will change the array terminal voltage (the DC-DC converter's input voltage) only in case of fixing the output voltage of the DC-DC converter at a certain value, a control scheme for the DC-AC inverter is proposed to keep the DC link voltage constant (which is the DC-DC output voltage also) and thus, varying the duty cycle of the DC-DC converter varies the array terminal voltage.

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The complete system discussed in this thesis is shown in

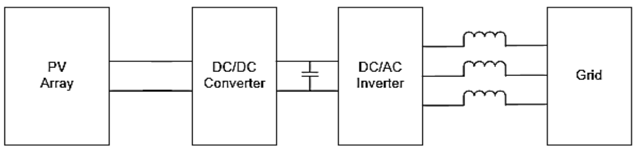

Fig. 3. 2: A complete Grid-Connected PV system.

IV. ARTIFICIAL INTELLIGENCE METHODS

There are two main AI methods, Fuzzy logic based MPPT and Neural Networks based ones. Both Conventional and artificial intelligence methods has their advantages and drawbacks. Conventional methods are famous for their easy implementation and compatibility to operate with any Photovoltaic array, While they're disadvantages is that they are considered relatively slower than the artificial intelligence methods and not only that they show slow response in sudden temperature and solar irradiance changes, but also they may fail in tracking the maximum power point [30]. On the other hand, artificial intelligence methods show very fast response under any operating condition changes, give very accurate results and they are able to work under instant temperature or solar irradiance changes efficiently. The drawbacks of the AI methods that they are complicated in design, they need very fast processors to be implemented physically or otherwise they will run very slowly. For each PV array type, a separate model should be designed to guarantee that it will perform well which is considered also a disadvantage [30].

4.1 Collecting Data

The first step in designing an ANN is to collect historical data on the problem that is being solved using the network. In case of MPPT lots of array solar irradiances and temperatures and their corresponding maximum power point voltages are required to in order to train the network. This obtained data is called (training points).

4.2 Case Studies And Simulation Results.

4.2.1 System Under Study

The complete system is to be simulated using the MATLAB/SIMULINK (as shown in Figure 4.1), and by varying the operating conditions (solar irradiance and temperature), both conventional P&O algorithm and artificial neural networks MPPT methods will be compared. In addition to the MPPT techniques, the proposed inverter hysteresis current control scheme is tested under step changes of the DC reference voltage. The PV array is composed of (15x2) series and parallel modules respectively with a total output power of 6kW.

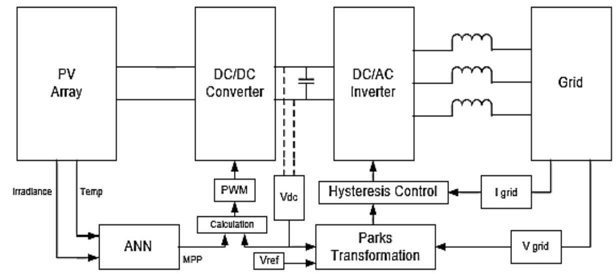

Fig. 4. 1: The complete integrated system under study using ANN.

4.3 PV Model Verification

The PV mathematical model is modeled and simulated using the MATLAB SIMULINK. The previously discussed module current SIMULINK model can be seen in Figure 4.2, while the reverse leakage and the photovoltaic currents (discussed in chapter 2, equations 2.4 and 2.3 respectively) simulation are in Figure 4.3.

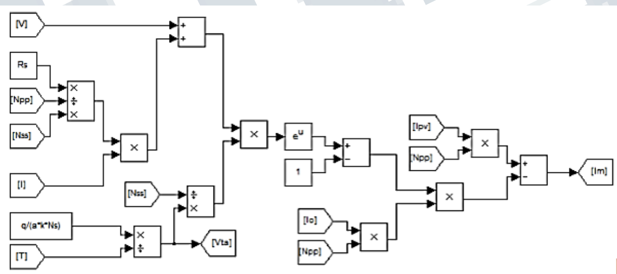

Fig. 4. 2: Simulation of module current in SIMULINK.

The MATLAB/SIMULINK model of the simulated PV is shown in Figure 4.4

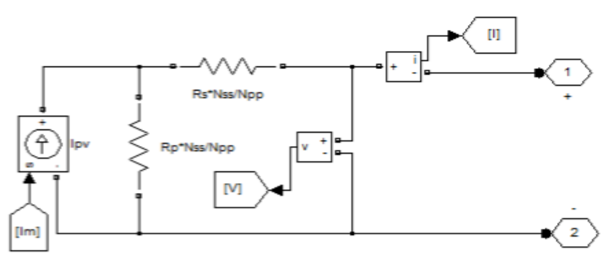

Fig. 4. 3: Simulation of the photovoltaic module.

The MATLAB/SIMULINK model is tested by inserting all the required data shown in Table 4-2 to simulate the KYOCERA KC200GT module. The data sheet of the simulated module is shown in appendix A.2. By comparing the KC200GT datasheet I-V curves at different values of solar irradiance and temperature with the one's obtained by the MATLAB model, shown in Figures 4.5, 4.6, 4.7 and 4.8,

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It is very clear that the curves obtained by the model are almost identical to the one's found in the module data sheet which proves that the model is reliable.

Table 4. 2 KC200GT module parameters

Quantity	Value
I max power	7.61 A
V max power	26.3 V
P max	200.143 W
I short circuit	8.21 A
V open circuit	32.9 V
I leakage	9.825*10^-3
I photovoltaic	8.211 A
Diode ideality constant	1.3
Parallel resistance	415.406 Ω
Series resistance	0.221 Ω

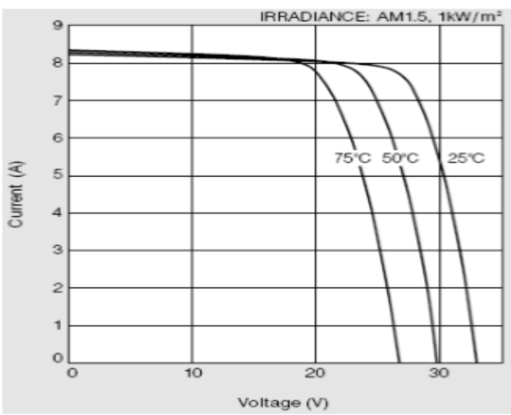

Fig. 4. 5: I-V curves at different temperatures found in KC200GT data sheet.

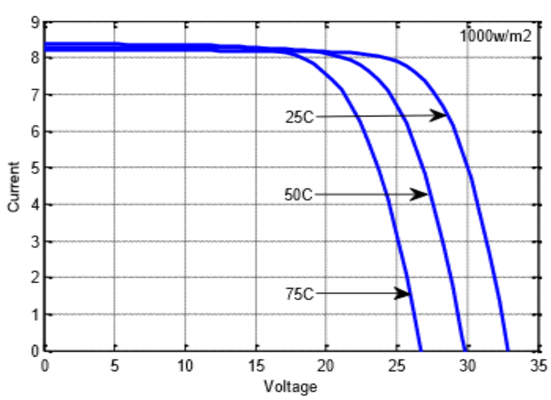

Fig. 4. 6: I-V curves at different temperatures obtained by MATLAB.

4.3 Neural Network Controller Model

As stated before in chapter 3, training points should be obtained in order to start our work with any ANN. The training points are obtained through varying the irradiance and temperature of the array and taking values of voltage and currents and maximum power. The training points obtained are shown in appendix B.1. ANN is formed using MATLAB M-FILE and the code is shown in appendix C.2. The proposed ANN has two inputs (solar irradiance and temperature) and one output which is the voltage at maximum power point. The network is trained using the MATLAB NNET tool box [35], see Figure 4.10

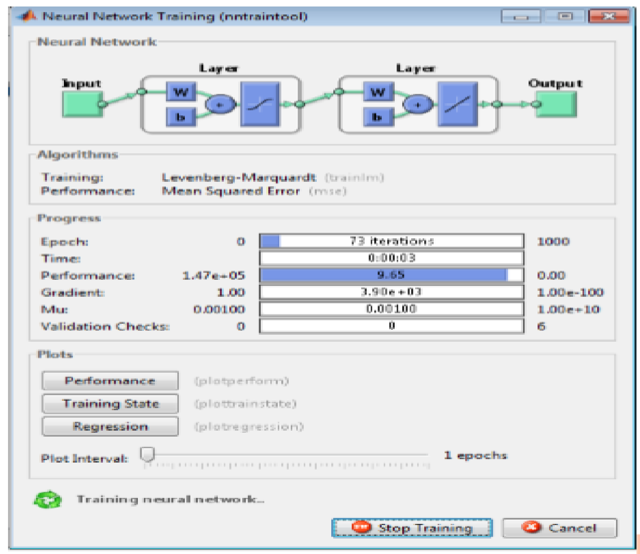

Fig. 4. 7: ANN training with MATLAB NNET toolbox.

This M-FILE is then transformed to SIMULINK blocks using the command (gensim) which facilitates the usage of the designed ANN with the whole SIMULINK system and the output of the ANN is used to calculate the duty cycle for MPPT, see Figure 4.11.

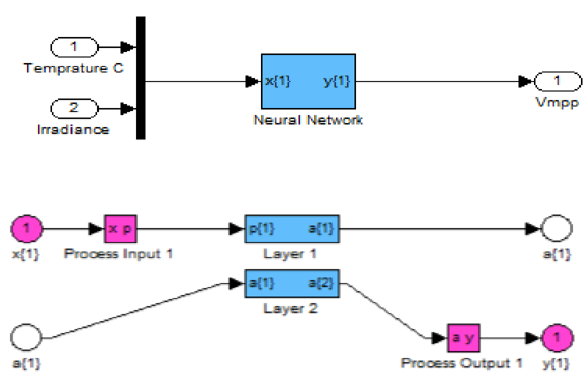

Fig. 4.8: Generated SIMULINK two layers ANN blocks.

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The generated ANN is then tested using some test points and the results can be shown in Table 4-3.

Table 4.3 ANN Test results

Test point	Temperature (oC)	Impedance (W/m2)	Vmpp (V)	Vmpp (V)	Pmax (W)	Pmax (W)
1	18	1000	404.6V	406.86	6208	6206
2	27	900	385.2	385.59	4130.5	4130.3
3	38	750	365.2	366.62	5322	5331

It is obvious that the ANN results are very close to the actual one's which implies the high accuracy of the designed network.

4.8 Simulation Results

All the discussed elements in this chapter are to be bound together to form a complete integrated grid-connected PV system as seen in Figure 4.17. This system is to be studied in different cases; without MPPT, with the artificial neural network controller, and with perturb and observe controller and then comparisons are made. The inverter control is set to 400V for the DC-link. A PV module KC200GT parameters are inserted into the PV model [34] and two P-V curves are obtained at two different operating conditions (temperature 44 and irradiance) as shown in Figure 4.18. An array of 15 by 2 series and parallel modules respectively is formed with a total output power 6004W at nominal operating conditions. Figure 4.18 shows that for each operating conditions there is a different voltage to operate at in order to obtain the maximum power out of the array.

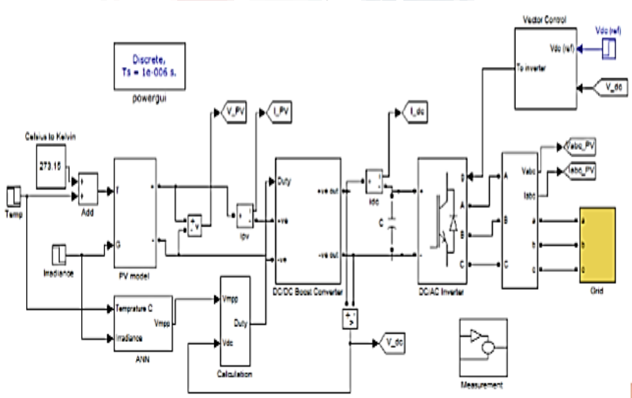

Fig. 4.9: The complete integrated system onSIMULINK.

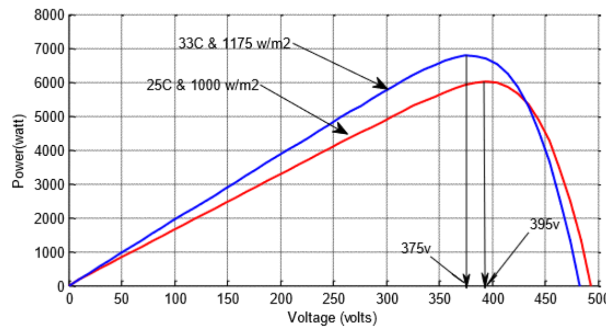

Fig. 4. 10: Two different operating conditions P-V curves.

V. CONCLUSION

An artificial intelligent maximum power point tracking technique using neural networks is proposed, which predicts the appropriate duty cycle for which the DC-DC converter can operate with and thus maximum power can be obtained from the PV system. The system is tied to the grid with a DC-AC inverter. A PV simulator is also developed using MATLAB/SIMULINK software which if supplied by the required data can simulate the behavior of any PV array. Also DC-DC boost converter model is simulated which is the key for changing the PV's terminal voltage to track the maximum power. DC-AC inverter control scheme is developed using hysteresis switching technique which gives fast dynamic response and accurate results. This scheme keeps the DC link's voltage constant at any desired value and that facilitates the role of the DC-DC converter in maximum power tracking. Also a complete integrated grid-connected scheme was proposed to simulate the real time cases. The conventional Perturb and Observe MPPT algorithm is developed through MATLAB code and tested and compared with the artificial neural network MPPT method under sudden temperature and irradiance changes and the ANN method gave very fast and accurate response.

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