Investigating the Intelligent MPPT Controller for a Stand-alone PV and Wind Hybrid System

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Abstract— The system consists of PV system, wind energy conversion system (WECS) and battery and intelligent MPPT controller. The PV/wind hybrid system can give fluctuating output that makes the system unstable, a battery is connected to the system to reduce the fluctuations in output voltage. To get the stable response for the system intelligent MPPT controller is used. The intelligent MPPT controller uses artificial neural network to extract maximum power point. PV and wind energy conversion system consists of MPPT algorithms. An Artificial Neural Network (ANN) based MPPT is proposed to get the maximum power from the system. The DC-DC boost converter is connected to the DC link. The output signal from MPPT controller is used as duty cycle of the DC-DC boost converter. The PV and wind block with intelligent MPPT controller are modeled separately in MATLAB/Simulink before connecting them together to build a hybrid system. The performance analysis is done under different wind speeds, solar irradiance and temperature in MATLAB/Simulink.

Key words: MPPT Controller, Wind Hybrid System

I. Introduction

The renewable energy resource does not have much effect on environment. Therefore, it can be a better option for fulfilling the escalated electricity demands [1]. The renewable energy sources are solar, wind, ocean, thermal etc. Solar and wind are two sources that can be thought as favorable power generating sources, as they are available for almost every time and are advantageous.

Because of their increasing trend, we can say that in the forthcoming years renewable energy sources will become the predominating sources of energy due to their ecological supremacy and the development of smart grids that are certainly the future of electrical power systems.

When compared to non-renewable energy sources such as thermal, nuclear and oil, the solar energy seems to be more favourable renewable energy source [2]. The solar energy is highly valued for its advantages of being clean, requires less maintenance, the power source is free of cost, and conversion of solar energy into any other form does not cause any pollution and power generation can be done by any individual user on their own conveniently without any risk [3]. Large wind turbines are designed for variable speed. Small wind turbines are simple and provide low cost power and speed control. Under transient windy conditions, the whole system is designed to tolerate the extreme speed [4]. When wind speed exceeds the design limit, yaw and tilt control is applied. Pitch and stall controls are used for the speed control.

There are two types of turbines; vertical axis turbine and horizontal axis turbine. Vertical axis turbines are less used because it covers more land area but they can produce power even at low velocities of the wind. Horizontal axis turbines are most commonly used, the shaft of such turbines is horizontal to the ground [5]. The turbine is attached with the generator. For changing the torque to the magnitude which is suitable for the generator, the gear box is used. The electricity produced by the generator can single phase AC, three phase AC or DC.

The Artificial Intelligence technique uses Fuzzy logic and Neural Network based approaches. Neural Network has three layers in which; first layer is input layer second in hidden layer and third layer is the output layer [6]. The no. of each layer can be varied. For the wind energy conversion system input variables can be wind speed, pitch angle and rotor speed. Both Artificial Intelligence technique and Adaptive technique may or may not use the sensors.

MPPT algorithms are applied for the captivation of maximum power for continuously changing wind conditions to attain better convergence of the control.

With the rapid rise in cost of the energy, wind- solar hybrid power generation system has great potential to supply various loads [7]. It can be used in city street lightning and distributed generation and water pumping for irrigation. It can supply the electrical power to the non-electrified rural areas. It can be used for stabilization of the grid to improve the power capacity.

Sensor based MPPT uses anemometer to find the speed of wind for Tip Speed Ratio (TSR) or Wind Speed Measurement technique (WSM). Sensor less MPPT technique is based on algorithms and they do not require any measurement devices. Sensor less technique is better than sensor-based technique, as it provides better result, more reliable and less costly. The MPPT algorithms can be classified into two types; Power Signal Feedback (PSF) or look-up table-based method and hill climb search method (HCS) or Perturb and Observe (P&O) method. Solar and wind are predominant power sources, and they can provide continuous power supply. The hybrid system is the combination of two or more power generation systems that fulfills the load demand [8,9].

Both wind and solar is uncertain in nature, because they rely on the climatic conditions. In summer days solar can work well and in winter there is more wind so wind plants serve better output, whereas in summer wind energy systems cannot give desired output and in winter solar is not able to produce sufficient power. So, we can say that individually they are not much reliable. Both the renewable sources can supplement each other in different weather conditions [10]. So, by taking both the systems together the desired output can be extracted in all weather conditions.

II. Artificial neural network based MPPT for PV and wind system

Artificial neural network based MPPT is proposed to extract the maximum power from PV and the wind energy conversion system [11].

A. MPPT for the PV System:

The neural network for a PV system consists of four input variables; temperature, irradiance, voltage and current. Hidden layer consists of 10 neurons. 704 data sets are used to get the duty cycle for the DC-DC boost converter.

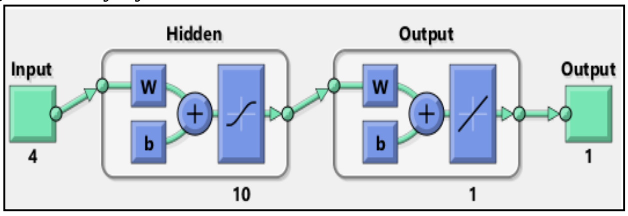


Fig. 1: Architecture of Artificial Neural Network Based MPPT for PV system

B. MPPT for the wind energy conversion system:

The neural network for the wind system consists of four input variables; wind speed, rotor speed, voltage and current. Hidden layer consists of 10 neurons. 220 data sets are collected to get the diverse duty cycle for the DC-DC boost converter.

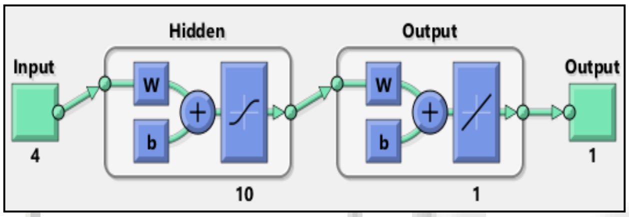


Fig. 2: Architecture of Artificial Neural Network Based MPPT for WECS

Levenberg-Marquardt algorithm is used for the training of the neural network for the MPPTs [12].

Implementation of Levenberg-Marquardt algorithm for training the neural network:

j and k =indices of neuron
nn = no. of neuron
i = index of neuron inputs
ni = no. of inputs
$y_{j,i}$ = ith input of neuron j

The output node of j neuron is calculated using:

$$y_j = f_j(net_j) \quad (1)$$

Here, f_j is the activation function of j neuron

Net value, slope and the output calculation for first layer

$$net_j^1 = \sum_{i=1}^{ni} w_{j,i}^1 I_i + w_{j,0}^1 \quad (2)$$

$$y_j^1 = f_j^1(net_j^1) \quad (3)$$

$$s_j^1 = \frac{\partial f_j^1}{\partial net_j^1} \quad (4)$$

Here, first layer is denoted by 1 in the above equations
I_i = network inputs
j = index of neurons in the first layer

the output of the neuron of first layer is input to neuron in the second layer.

Calculation for the second layer:

$$net_j^2 = \sum_{i=1}^{n1} w_{j,i}^2 y_i^1 + w_{j,0}^2 \quad (5)$$

$$y_j^2 = f_j^2(net_j^2) \quad (6)$$

$$s_j^2 = \frac{\partial f_j^2}{\partial net_j^2} \quad (7)$$

Calculation for the third layer;

$$net_j^3 = \sum_{i=1}^{n2} w_{j,i}^3 y_i^2 + w_{j,0}^3 \quad (8)$$

$$o_j = f_j^3(net_j^3) \quad (9)$$

$$s_j^3 = \frac{\partial f_j^3}{\partial net_j^3} \quad (10)$$

With results of forward computation backward computation can be done;

Calculation of error:

$$e_j = d_j - o \quad (11)$$

$$\delta_{j.j}^3 = s_j^3 \quad (12)$$

$$\delta_{j.k}^3 = 0 \quad (13)$$

Here, d_j = desired output
o_j = actual output taken in forward computation
$\delta^3_{j,j}$ = self back propagation
$\delta^3_{j,k}$ = back propagation from other neuron in output layer

III. Power Electronic Circuits

Selection Power electronic circuits are required in hybrid power system. The circuits that are used in the hybrid energy system are AC/DC rectifiers, DC/DC converters and DC/AC inverters. Effective average model for power electronic circuits will be studied in this section.

A. AC/DC Rectifiers

Rectifiers are used to convert AC voltage into DC voltage. Semiconductor diodes are used for the rectification process in power electronic circuits. A rectifier implementing diodes, is generally known as uncontrolled rectifier because the output that they provide is fixed DC voltage. Fig. 3.5 is showing a three-phase full diode bridge rectifier.

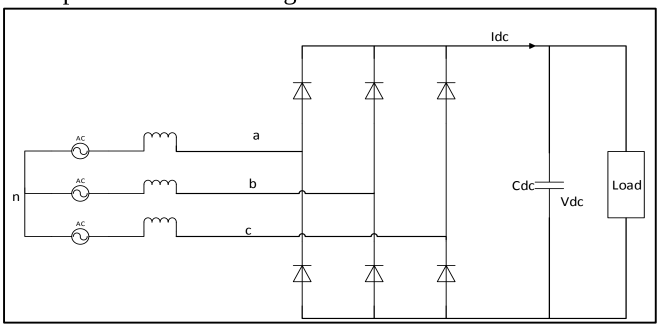


Fig. 3. Three-Phase Full Diode Bridge Rectifier

Average value of DC output voltage V_0 can be calculated by:

$$V_0 = \frac{3\sqrt{2}V_L}{\pi} \quad (14)$$

or

$$V_o = \frac{3\sqrt{6}V_P}{\pi} \quad (15)$$

Here,

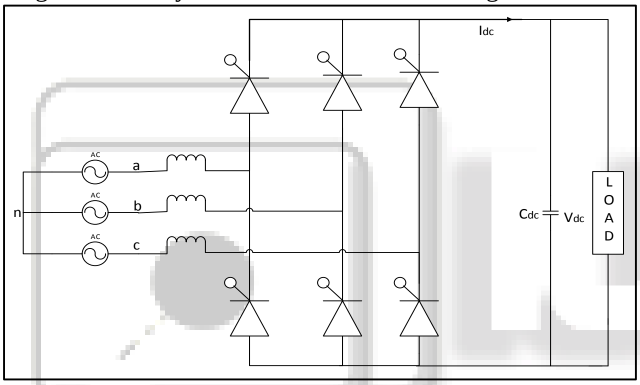
V_L = RMS value of line voltage

V_P = RMS value of phase voltage.

The ripple is within ±5% for the DC output voltage that is adequately good.

If the AC input current is distorted, the inductance on AC side increases and reduces the current distortion.

Controllable rectifiers are mostly controlled by the firing angle is controlled thyristors or pulse width modulation method. By replacing the diode with thyristor, the controlled output from the rectifier can be achieved. Fig. 3.6 shows the six-pulse thyristor rectifier. The DC voltage can be varied by controlling the firing angle of the thyristor. Firing angle is that phase angle of AC supply at which the current is applied to the gate of the thyristor and it starts conducting.



For a 6-pulse thyristor-controlled rectifier the DC output voltage can be calculated by the following equation:

$$V_0 = \frac{3\sqrt{2}V_L \cos\alpha}{\pi} \quad (16)$$

By taking 6-pulse or 12-pulse model for the same AC input source and same DC output load, it gives better results and provide accuracy.

B. DC/AC Inverter

A three phase 6pulse pulse width modulation (PWM) voltage source inverter (VSI) is used for the converting DC into AC. Fig. 3.7 showing the circuit diagram of a 3 phase PWM voltage source inverter.

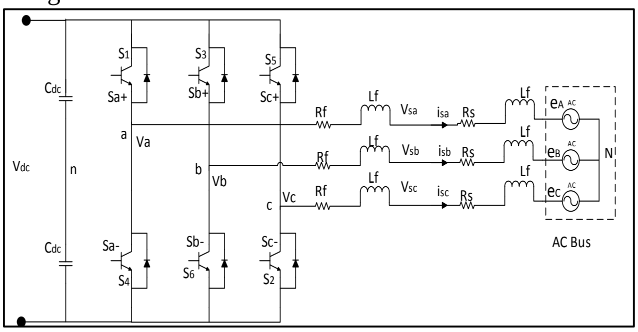


Fig. 5: 3-Phase DC/AC Inverter

IV. PV WIND HYBRID SYSTEM IN MATLAB

The description of the PV-Wind stand-alone hybrid system with connected battery is shown in Fig.4.17.

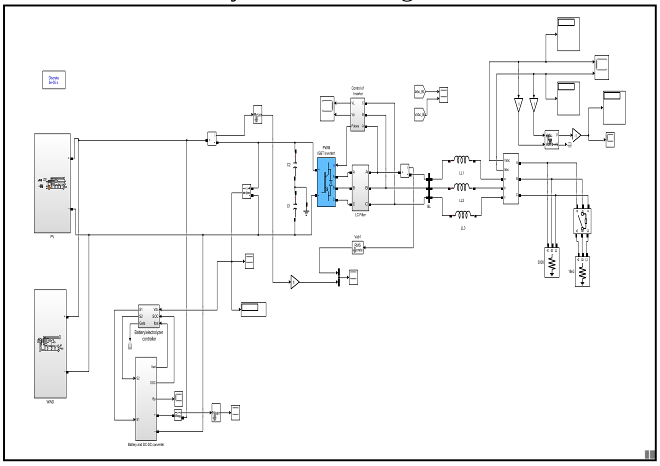
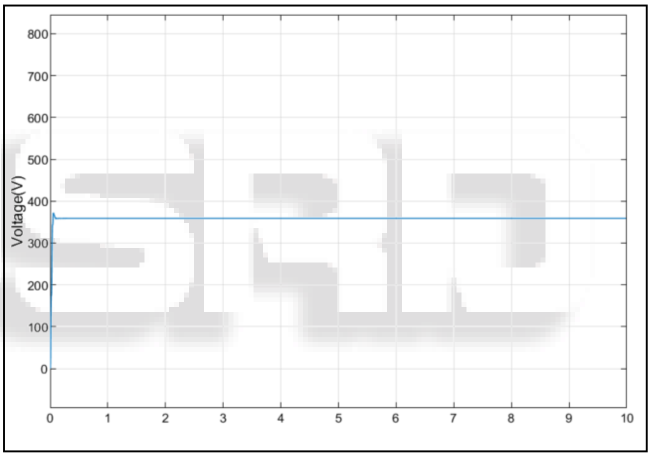
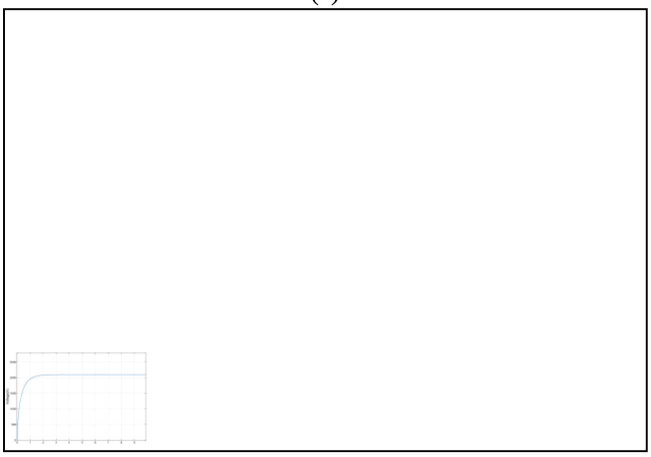


Fig. 6. Stand-alone Hybrid System Model

The output voltage of PV system with employing conventional P&O MPPT and proposed intelligent MPPT at 25 ˚C temperature and 1000W/m² irradiance is shown in fig 7.



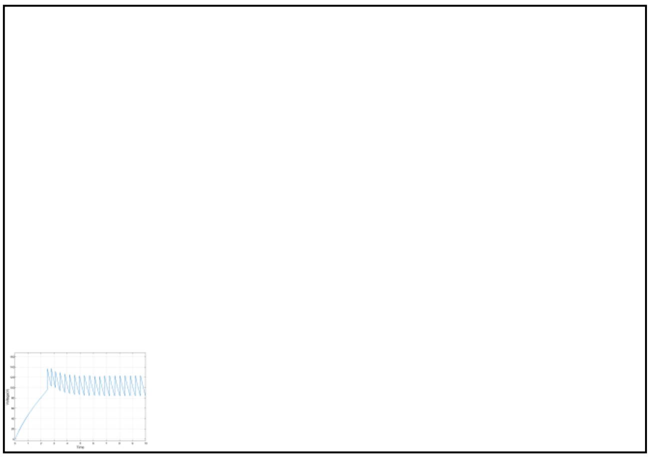
(a)



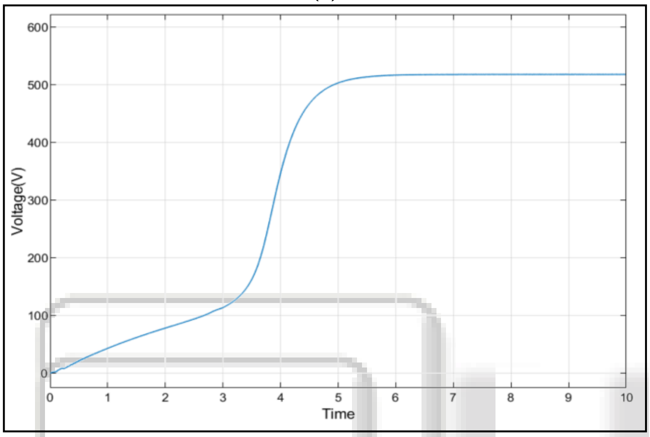
(b)

Fig. 7: Output Voltage of PV System at 25 ˚C and 1000W/m² With P&O MPPT (b) With ANN based MPPT

The output voltage of wind energy conversion system with employing conventional torque control MPPT and proposed intelligent MPPT at 8 m/s is shown in fig 8.



(a)



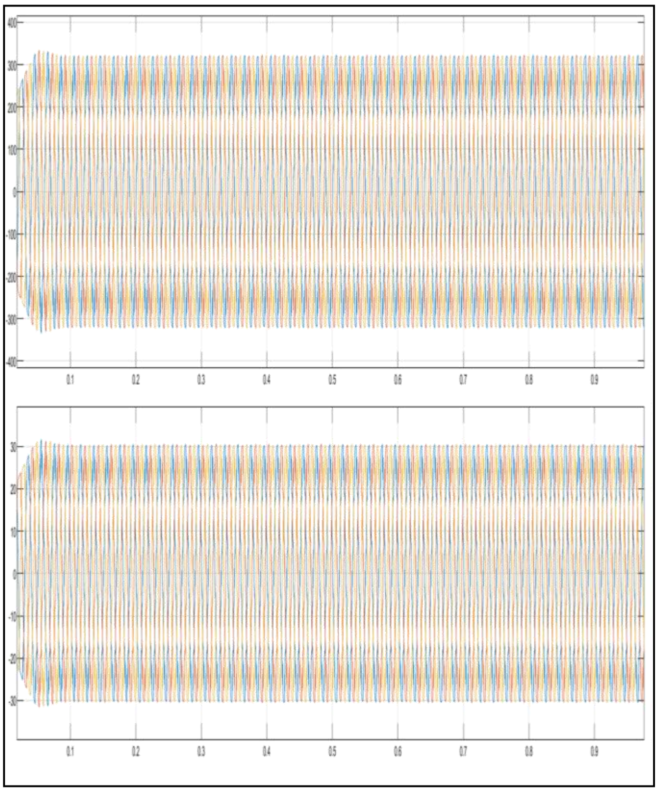
(b)

Fig. 8. Output Voltage of Wind Energy Conversion System at 8 m/s With Torque Control MPPT (b) With ANN based MPPT

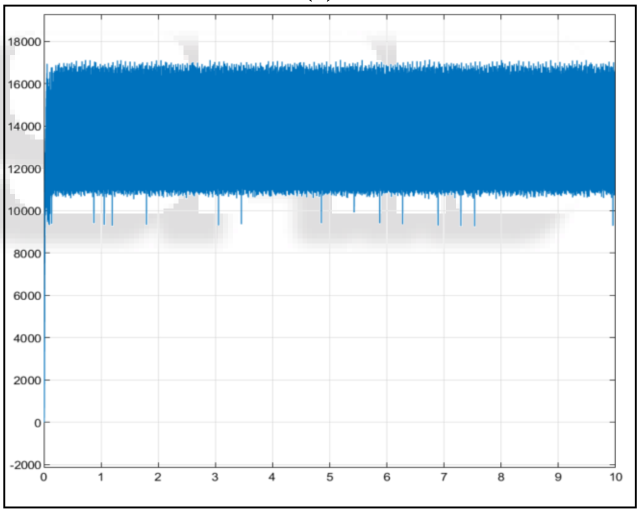
The analyzed outputs of the examined waveforms show that when temperature is 25˚C and irradiance is 1000W/m^2 for PV system and wind speed is 12m/s for WECS, the DC bus voltage is 640V, AC output voltage is 250V and AC output current is 3A and the output power is 11kW.

The output is constant under various conditions when the battery is connected with stand-alone PV/wind hybrid system.

(a)



(b)



(c)

Fig. 9: Behaviour of waveforms when temperature is 25˚C and irradiance is 1000W/m^2 for PV system and wind speed is 12m/s for WECS with Battery (a) Voltage at DC Bus (b) AC Output Voltage and current (c) Output Power

V. CONCLUSION

In this Project, the characteristics of PV, wind and hybrid scheme are analyzed under various conditions. The Hybrid system was examined with and without battery under different conditions.The results show that the hybrid system is more reliable when the battery is connected. It produces more output.The PV system and the wind system has improved outputs with the ANN based MPPT Controller in comparison with the connected MPPT Controller as the fluctuations are reduced.

APPENDIX

Experimental Parameters

Nominal Mechanical Output of Wind Turbine (W)	8.5e3
Base wind speed (m/s)	12
Stator Phase Resistance (Ω)	0.425
Inertia	5.5e-3
Maximum Power of PV Module (W)	250.1, 25˚C, 1000w/m^2
Irradiance Level (w/m^2)	500 – 1000
Voltage at Maximum Point (V)	30.5
Current at Maximum Point (A)	8.2
Open Circuit voltage (V)	37.8
Short Circuit current (A)	8.9
Nominal Voltage of Battery (V)	300
Rated Capacity of Battery (Ah)	6.5

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