

Design and Implementation Wind Power Using Hill Climbing Mppt Algorithm

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Abstract: This paper proposes a maximum power point tracking (MPPT) algorithm for small-scale wind energy conversion systems. The proposed algorithm uses the dc current as the perturbing variable. The algorithm detects sudden wind speed changes indirectly through the dc-link voltage slope. The voltage slope is also used to enhance the tracking speed of the algorithm and to prevent the generator from stalling under rapid wind speed slowdown conditions. The proposed method uses two modes of operation: A perturb and observe (P and O) mode with adaptive step size under slow wind speed fluctuation conditions and a prediction mode employed under fast wind speed change conditions. The dc-link capacitor voltage slope reflects the acceleration information of the generator, which is then used to predict the next step size and direction of the current command. The proposed algorithm shows enhanced stability and fast tracking capability under both high and low rate of change wind speed conditions and is verified using a 1.5 kW prototype hardware setup.

Key words: Hill climbing • Wind energy conversion system (WECS) • Maximum Power Point Tracking

INTRODUCTION

As smaller generation sources, off-grid wind power generator systems are so flexible that they are dispersed over wide areas, such as pasture regions, insular regions or highways. Given its low cost, the variable-speed fixed-pitch approach is the most common scheme for small wind turbines. However, this kind of system cannot capture the maximum power from wind, which leads to a low utilization ratio of wind energy [1].

In this structure we can add a dc-dc converter and control circuits to the generation system and use the control algorithm to change the characteristics of the generator for maximum power point tracking (MPPT). In this method, turbine speed is adjusted to maximum power points (MPPs) by regulating the dc-side voltage or current according to the comparison results between Successive wind turbine generator output power measurements. This method is called the perturbation and observation method, also called the hill-climbing searching (HCS) method. This system can track the MPP without using control circuits and it utilizes the saturation characteristic of the external reactors to improve the system performance. The proposed wind generator

system which has a compact structure and is able to automatically track maximum power from wind without using any electrical control devices [2-5].

Previous Research: Numerous related research works are already existed in literature which based on wind power generation circuit of the system. Some of them are reviewed here.

Maurizio Cirrincione *et al.* [6]. Presented a maximum power point tracking (MPPT) technique for variable-pitch wind generators with induction machines (IMs), which can suitably be adopted in both the maximum power range and the constant-power range of the wind speed. To this aim, an MPPT technique based on the growing neural gas (GNG) wind turbine surface identification and corresponding function inversion has been adopted here to cover also the situation of variable-power region. To cope with the constant-power region, the blade pitch angle has been controlled on the basis of the closed-loop control of the mechanical power absorbed by the IM. The wind speed is then estimated in the constant-power region on the basis of the actual position of the blade pitch angle. The proposed methodology has been verified both in numerical simulation and experimentally on a

properly devised test setup. In addition, a comparison between the proposed approach and the previously developed GNG-based MPPT has been performed on a real wind speed profile. Finally, the effect of the torsional stiffness of the mechanical transmission system has been analyzed.

Baoquan Kou *et al.* [7]. This paper presents a novel off-grid wind power generator system that consists of a permanent magnet (PM) generator, two rectifiers, a battery and loads. The PM generator has a novel stator structure and two Y-connected winding sets. The wind power generator system can automatically track the maximum power from wind without the need for converters and control circuits and has higher reliability and lower loss. This paper also describes the operational principle and mathematical model of the system. A prototype is manufactured and experiments prove that the new system efficiently captures maximum power from wind across a wide speed range.

Yuan-Chih Chang *et al.* [8]. This paper develops the operational control of two maximum power point trackers (MPPTs) for two-string photovoltaic (PV) panels in dc distribution systems. This dc distribution system is connected to ac grid via a bidirectional inverter. Two PV strings and two MPPTs are implemented in this system. The proposed MPPT topology consists of buck and boost converters to deal with wide output voltage range of PV panels. To accurately determine the input current of MPPTs, the PV-string configuration check is accomplished online. The perturbation and observation method are applied for maximum power point tracking. Moreover, the current balancing of two MPPT modules in parallel is achieved. In this paper, the system configuration and the operational principle of the proposed MPPT are first introduced. Afterward, the perturbation and observation method and the mode transition are demonstrated. Flowcharts of the online PV-string configuration check and current balancing are explained. The validity of configuration check and current balancing is verified via the experimental results. Maximum power tracking performance and power conversion efficiency are also obtained.

Sweeka Meshram *et al.* [9], presented simulation modeling of the grid connected DC linked PV/Hydro hybrid system has been done. The DC bus of the PV and hydro system has been common linked to reduce the cost and complexity of the hybrid system. The hybrid system acts as a dominant system and power grid will be acts as a standby to compensate the deficit in the hybrid system. In rainy days/night, the solar energy will be unavailable,

hence the power requirement will fulfilled by hydro system and power grid. In summer, the hydro power will be less; in that case the power requirement will be fulfilled by the PV system and power grid. In other days, the power will be fed by the PV/Hydro hybrid system. Thus, the power requirement throughout the year can be satisfied by the proposed system. The proposed system is tested under the linear resistive, RL and Induction Motor (IM) as a dynamic load.

E.M. Natsheh, *et al.* [10], Implemented the model of smart grid-connected PV/Wind hybrid system was developed. It comprises photovoltaic array, wind turbine, asynchronous (induction) generator, controller and converters. The model was implemented using MATLAB/SIMULINK software package. Perturb and observe (P and O) algorithm was used for maximizing the generated power based on maximum power point tracker (MPPT) implementation. The dynamic behavior of the proposed model is examined under different operating conditions. Solar irradiance, temperature and wind speed data is gathered from a grid connected, 28.8kW solar power system located in central Manchester. Real-time measured parameters are used as inputs for the developed system. The proposed model and its control strategy offer a proper tool for smart grid performance optimization.

Yann Riffonneau *et al.* [11], has presented an optimal power management mechanism for grid connected photovoltaic (PV) systems with storage. The objective was to help intensive penetration of PV production into the grid by proposing peak shaving service at the lowest cost. The structure of a power supervisor based on an optimal predictive power scheduling algorithm was proposed. The particularity of this paper was the consideration of batteries ageing into the optimization process then the “day-ahead” approach of power management. Simulations and real conditions application are carried out over one exemplary day. In simulation, it points out that peak shaving was realized with the minimal cost, but especially that power fluctuations on the grid are reduced which matches with the initial objective of helping PV penetration into the grid.

The main disadvantages of the above references are that the complexity in the design and cost. To overcome the drawbacks we propose a new model, control and simulation of a smart wind power generation system is proposed. Modeling and simulation are implemented using MATLAB/SIMULINK and Sim Power Systems software packages to verify the effectiveness of the proposed system.

Proposed Approach: According to the variations of the wind speed, the typical operation of a wind generator presents the following working regions:

- Below cut-in speed (zero power);
- Maximum generable power (MPPT);
- Constant rated power;
- Above cutoff speed (generator shut down).

The simulation circuit of proposed system implementation is shown in Fig.1. The system comprises of a wind model with boost converter power stage controlled by a hill climb searching to achieve highly efficient output.

The subsystem model of the WT is implemented as shown in Fig. 2. In this model, whereas the inputs are the wind speed and generator speed, the output is the torque applied to the generator shaft. The torque of the generator is based on the generator power and speed.

The wind turbine induction generator (WTIG) model is designed using the built-in SimPower System library. The rotor shaft is driven by the WT which produces the mechanical torque according to the generator and wind speed values. The electrical power

output of the generator (stator winding) is connected to the smart grid.

The hill climbing based techniques are so named because of the shape of the Characteristic curve. This technique is sub-categorized in three types:

- Perturb and Observe Algorithm (P and O)
- Modified Adaptive P and O Method
- Incremental Conductance Algorithm (INC)

The proposed hill climbing based algorithm consists of hybrid algorithm using a different algorithm technique along with the hill climbing method for faster and accurate tracking of MPP. The voltage and current controlled algorithms are more accurate and effective than most commonly used hill-climbing algorithms at low solar radiation. Therefore these algorithms are combined with P and O and Incremental conductance algorithms to increase their effectiveness. The hill climbing based algorithms used to track the maximum power point in slow varying atmospheric conditions. Therefore to decrease losses due to oscillations, the hill climbing based algorithms are suitable in only rapidly changing atmospheric conditions and the constant voltage method is fast and sufficient for constant conditions.

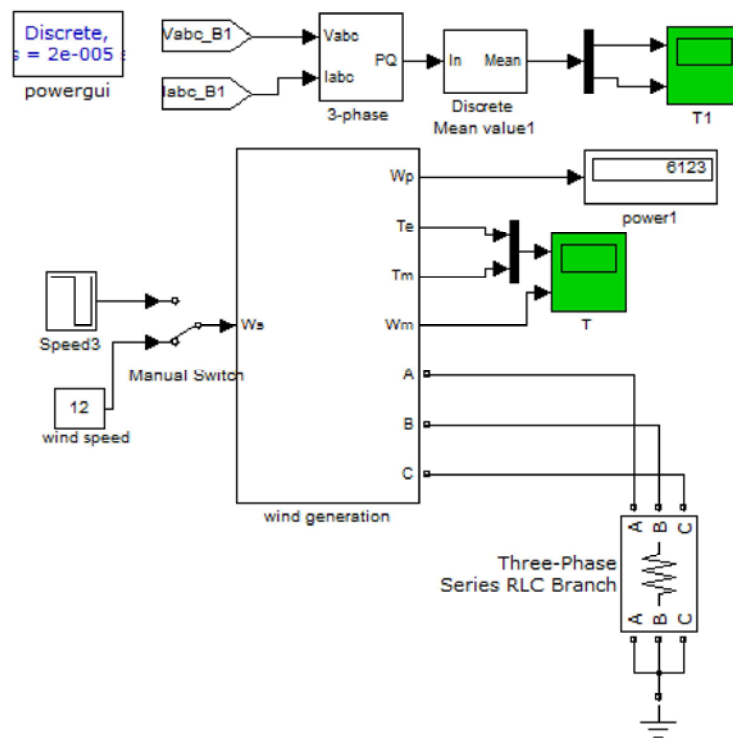


Fig. 1: Simulation circuit diagram of proposed wind power generation system.

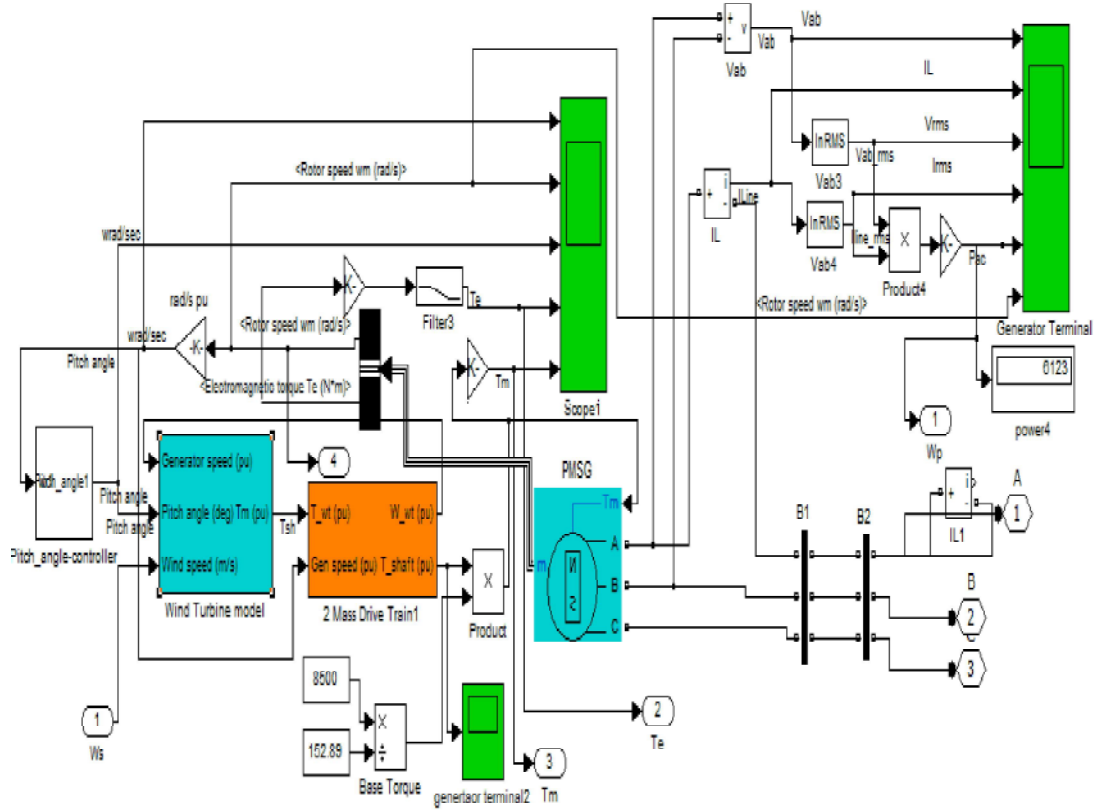


Fig. 2: Subsystem Circuit for Wind generation system.

Mathematical Model: Several studies have been reported regarding to WT and wind generators. In this study, the proposed WT model is based on the wind speed versus WT output power characteristics. The output power of the wind turbine is given by

$$P_m = c_p(\lambda, \beta) \frac{\rho A}{2} v_{wind}^3 \quad (1)$$

Where P_m is the mechanical output power of the turbine, c_p is the performance coefficient of the turbine, λ is the tip speed ratio of the rotor blade, β is the blade pitch angle, ρ is the air density, A is the turbine swept area and V_{wind} is the wind speed.

The performance coefficient model $c_p(\lambda, \beta)$ used in this paper is taken from and given by

$$c_p(\lambda, \beta) = c_1 \left(\frac{c_2 - c_3 \beta - c_4}{\lambda_i} \right) e^{\left(\frac{-c_5}{\lambda_i} \right)} + c_6 \lambda_i \quad (2)$$

Where constants c_1 to c_6 are parameters that depend on the wind turbine rotor and blade design and λ_i is a parameter given as follows

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08 \beta} - \frac{0.035}{\beta^3 + 1} \quad (3)$$

Furthermore, (1) can be normalized and simplified for specific values of A and ρ , as in (4)

$$P_{m-pu} = k_p c_{p-pu} v_{wind-pu}^3 \quad (4)$$

Where P_{m-pu} is the power in per unit (p.u.) of nominal power for particular values of ρ and A , c_{p-pu} is the p.u. value of the performance coefficient c_p , k_p is the power gain, $v_{wind-pu}$ is the p.u. value of the base wind speed. The based wind speed is the mean value of the expected wind speed in (m/s).

The hill climbing Algorithm of MPPT technique is used as a derivative of conductance to determine the maximum power point (MPP). The MPP is determined by comparing instant conductance I/V to the incremental conductance $\Delta I/\Delta V$. This algorithm performs better than P and O algorithm in rapidly varying environment Conditions. From the above equations the duty ratio responses under various conditions are declared using hill climbing algorithm [12].

RESULTS AND DISCUSSIONS

The major inputs for the proposed wind model were wind speed, rotor speed and pitch angle. The generated output power, torque values of generator, pitch angle, rotor speed and rms value of output V and I for the Proposed model are shown in following simulation results.

The following simulation result shows that the output power of proposed wind model. The output power of wind generation is 6123 Watts.

Fig.5 shows the simulated result for Pitch angle for wind blades, Rotor speed, T_e and T_m values with respect to time.

From Figure 5 and 6 shows that the result of wind generated output power is 6123Watts. The simulation result show that the rotor speed is fluctuated before it is

regulated at 100 volt. The duration for the time of operation to regulate is about 10 millisecond.

Hardware Setup: A motor was used for driving the generator system in order to test the characteristic of the new system. The experimental setup which consists of the novel generator, a PMS motor as prime motor, two diode rectifiers, a 24-V battery and loads. In this experiment, the motor drives the new generator system form a low rotational speed (120 r/min) to the rated rotational speed (400 r/min). The Experimental setup is shown Fig.7 [13].

From the comparative analysis, it is revealed that the proposed Hill climbing MPPT algorithm is better when compared to the Existing algorithm. The proposed converter efficiency is deviated more than the Existing system. Hence, the proposed Hill climbing MPPT is better than other methods that produces maximum output power is produced at high efficiency for the application[14-16].

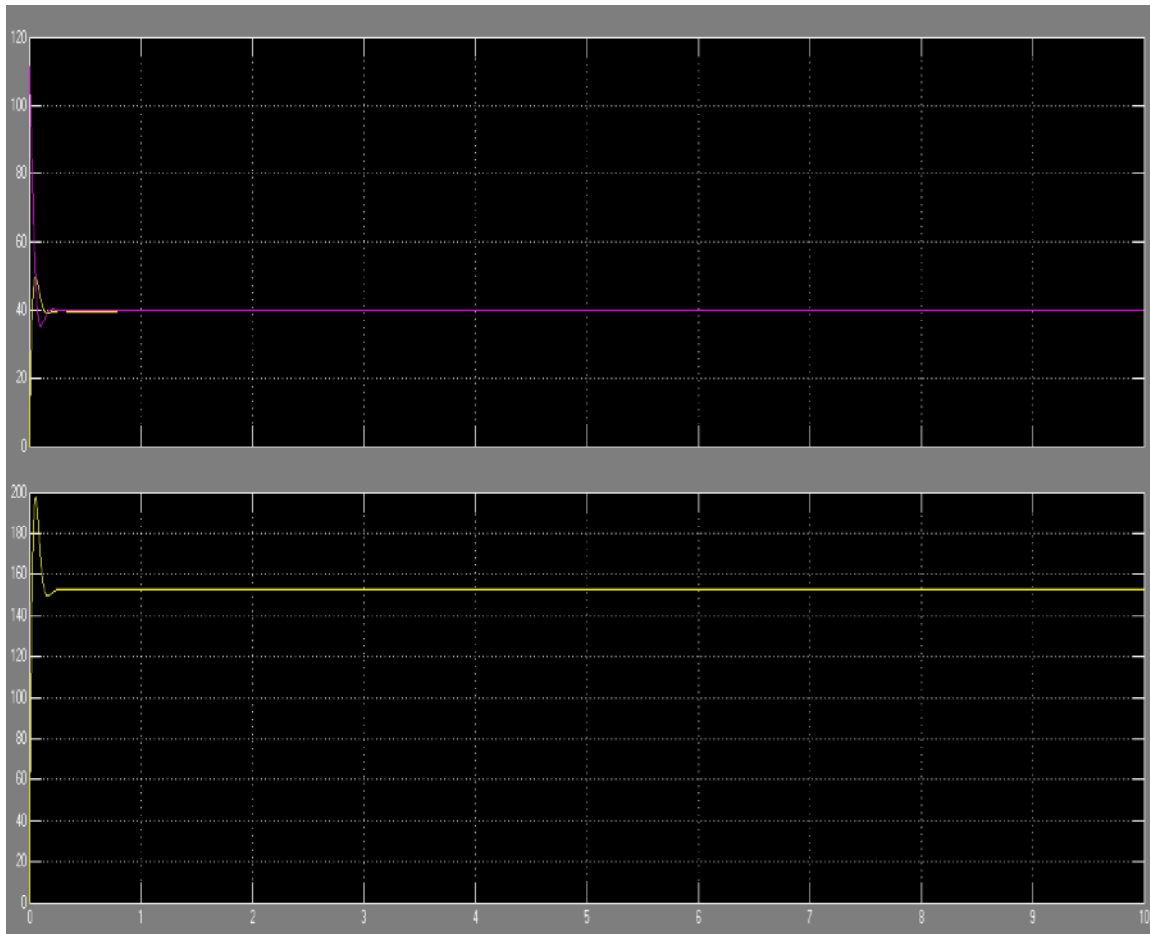


Fig. 3: Simulation result for Rotor Torque (T_e) and Electromagnetic Torque(T_m).

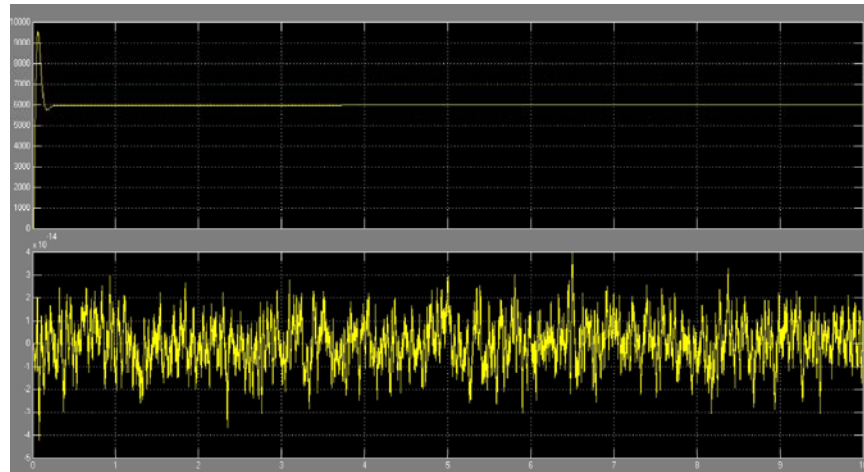


Fig. 4: Simulation result for proposed MPPT output Power respect to Time.

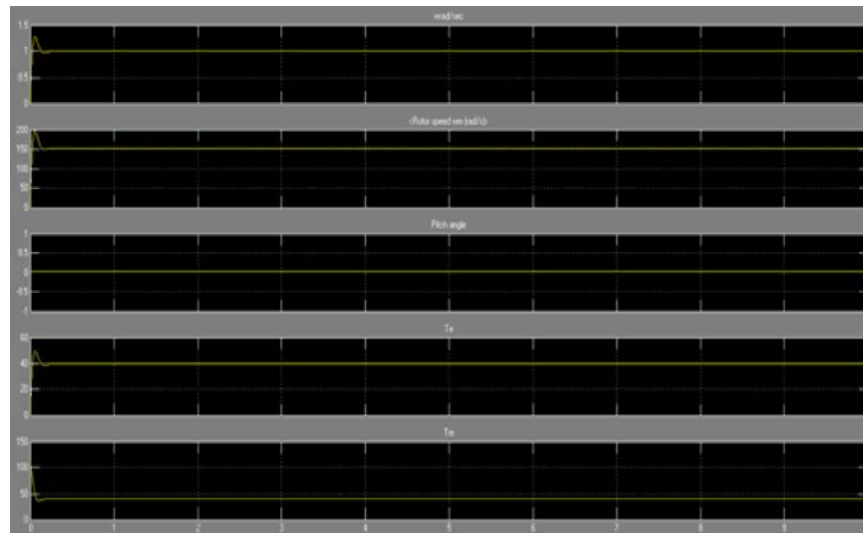


Fig. 5: Simulation result for Rotor speed, T_e , T_m , W_{rad} , pitch angle with respect to time.

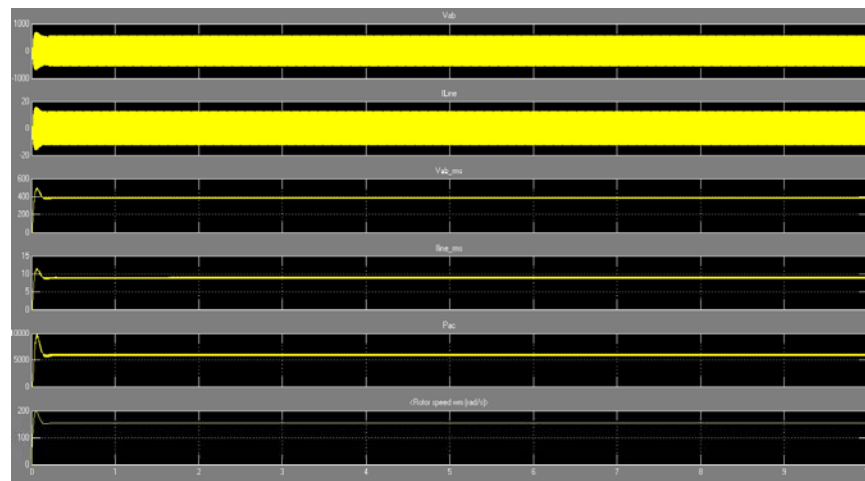


Fig. 6: Simulation result for V_{rms} , I_{rms} and power with respect to time

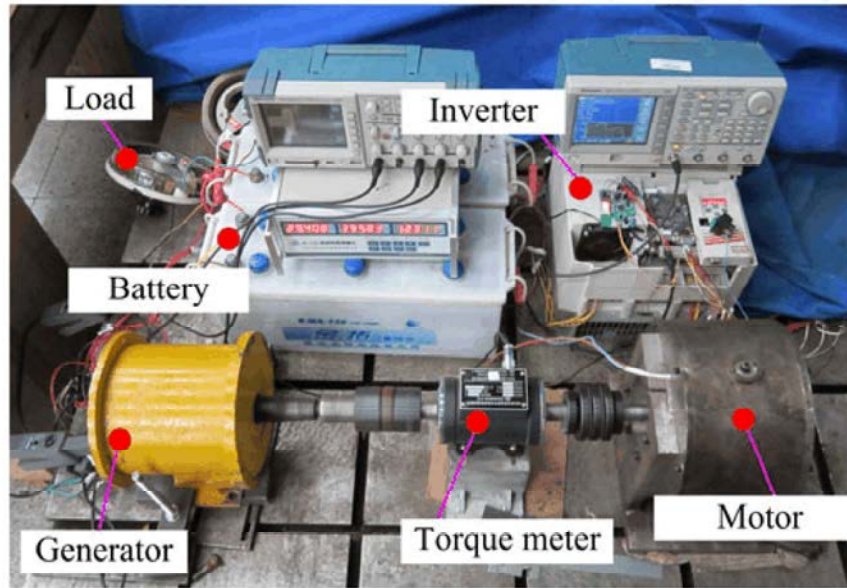


Fig. 7: Experimental setup for the proposed Wind generation.

Table 1: Comparison of parameter values

Parameters	Existing method	Proposed method
Maximum Power	300W	6123watts
source	solar	wind
Topology	Boost	Boost
Cost	moderate	high

CONCLUSION

In the present study, a review of Hill Climbing maximum power point tracking techniques with Simulation and hardware results have been described to provide the High power output. From the study, it can be concluded that highly efficient output power for a fast and linearly increasing power. Compared with conventional systems, the novel wind power generator system can eliminate the loss of electrical control devices and improve the system reliability. The emulation experiment showed that the new system can efficiently capture wind energy across a wide wind speed range.

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