



Control Algorithm with MPPT of Stand Alone Wind- Solar Hybrid Energy Conversion System

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Abstract- Solar and wind are the most popular resources due to its ease of availability and its ease conversion into electricity. Each renewable resource require DC/DC boost converter with MPPT control for power generation. To obtain high efficiency of photovoltaic (PV) system and wind energy system, the maximum power point tracking (MPPT) technology is employed. Perturb and Observe MPPT technique is used for PV system in which dc voltage is used as perturbation variable. While in wind energy system, perturbation variable as a dc current is used in modified perturb and observe MPPT algorithm. Modified perturb and observe algorithm is stable and tracks fast for sudden wind speed change conditions. Maximum Power Point Tracking (MPPT) technique used with boost converter extracts maximum power from the source when it is available. Simulation of both the renewable energy sources is carried out separately in PSIM 9.0 with different MPPT types of techniques.

Keywords- MPPT, Solar energy conversion system, Wind energy conversion system, Boost Converter, Simulation.

I. INTRODUCTION

There are different types of MPPT technique for PV and wind energy system. MPPT techniques for PV system like constant-voltage tracing, advanced intelligent, incremental conductance (INC) and perturbation and observation (P&O). The constant-voltage method tracks MPP rapidly but its accuracy is poor. P&O method has been widely used due to its simplicity and easy implementation, but its convergence is too slow. The INC technique improves the tracking accuracy but its tracking speed is also very slow [7]. MPPT techniques for wind energy system like TSR (tip speed ratio), perturb and observe (P&O) control, and optimum-relation-based (ORB) control. TSR algorithm relies on the accuracy of the wind speed measurement to maintain optimal tip speed ratio and ORB technique prior knowledge of accurate system parameters are required that can vary from one system to another. Since these MPP requires accurately knowing these parameters, continuous monitoring is needed to increase its efficiency. P&O algorithms has system variables as control inputs for the MPPT like the dc-link voltage and the duty cycle which reduces system cost and increases reliability by removing the need for shaft speed sensing [6].

In this paper, simulation of solar energy system and wind energy system with MPPT technique is done separately. MPPT technique is employed with DC/DC converter to turn on/off the controlled switch of the boost converter. Simulation is carried out in PSIM 9.0. MPPT algorithm used for the PV system is perturb and observe algorithm which is adopted from PSIM renewable examples while MPPT algorithm for wind energy system was programmed in visual C++ from the proposed modified perturb and observe algorithm in [6]. Results are compared by changing input conditions of sources like for PV system- irradiance and for wind system- wind speed, and output is observed. With different input conditions, power generated from these sources must be equal to power delivered to the load which is shown in simulation results.

II. MODELING OF WIND ENERGY SYSTEM

Generator is used with wind turbine which converts mechanical energy into the electrical energy. Electrical energy production mainly depends on the availability of wind. With variation in wind speed, electric energy production can be increased or decreased. So selection of area for wind energy system installation is important.

The mechanical power that is generated by the wind is given by:

$$P = 0.5 \times \rho \times A \times C_p(\lambda, \beta) \times v w^3$$

Where P= Power

ρ =Air density

A=Area perpendicular to the flow of wind

$v w^3$ =Wind velocity

$C_p(\lambda, \beta)$ = Power Coefficient

λ = tip speed ratio

β = blade pitch angle.

The tip speed ratio λ is defined as

$$\lambda = R\Omega / v_w$$

The maximum value of C_p is 0.48 at $\beta = 0$ and $\lambda = 0.16$. So we cannot convert all the wind energy into electrical energy; we can only convert 48%, according to Betz limit.

The schematic diagram of the wind energy system to which the MPPT applied is shown in Fig.1. Generator used is of permanent magnet synchronous generator type which is directly coupled to turbine due to its advantages like no need of gear box, small size, very less maintenance cost, no requirement of excitation current[6]. Instead of using three-phase controlled rectifier, diode bridge rectifier is used which converts the AC to a DC by rectifying voltage at constant level using boost converter.

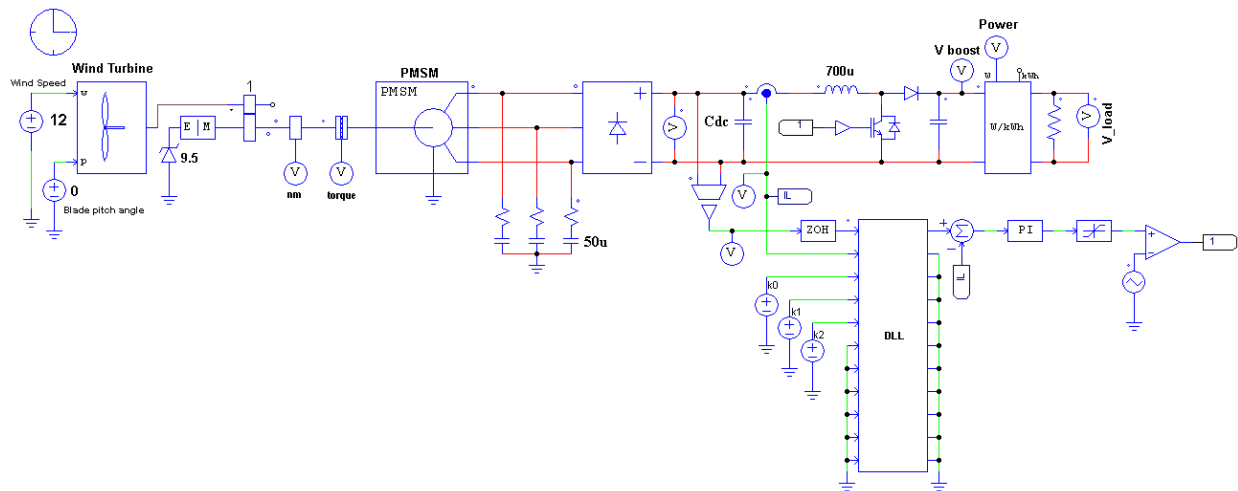


Fig. 1 Wind energy system

III. MODELLING OF SOLAR ENERGY SYSTEM

Solar energy is a renewable energy resource which can be converted into the electrical power using PV cells. There are two factors-radiations and temperature which can affect the output of PV panels. If irradiance increases then current increases but variation in voltage is very less. If temperature increases, open circuit voltage decreases while if intensity of solar radiation increases, short circuit current increases. Thus I-V and P-V curve changes with change in temperature and irradiance, which also changes maximum power point.

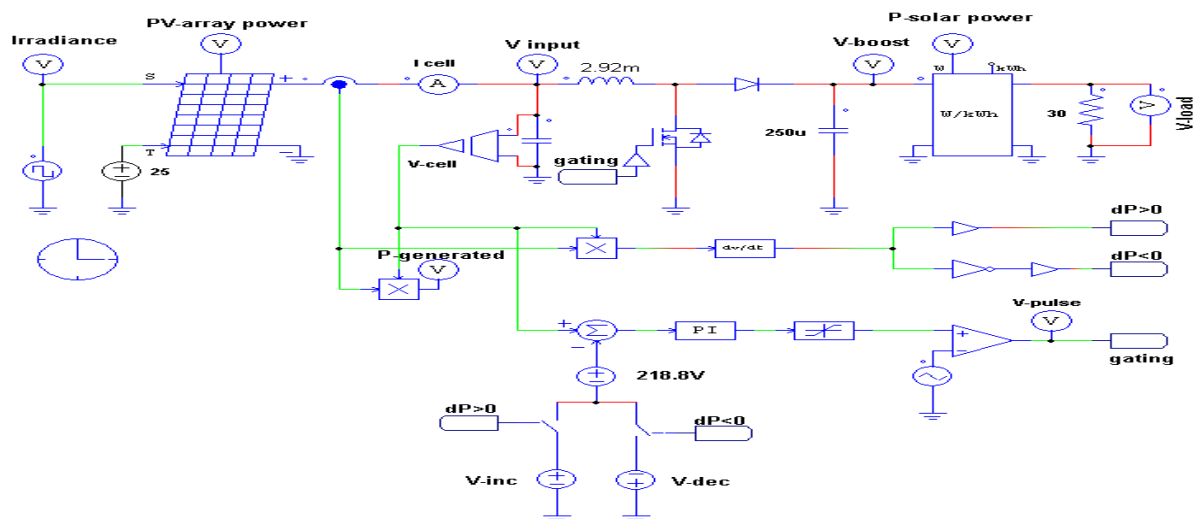


Fig. 2 Solar energy system

The power output from a solar photovoltaic system mainly depends on the nature of the connected load because of non-linear I-V characteristics [8]. The schematic diagram of solar system to which MPPT technique will be applied is shown in Fig.1. When PV panel is directly connected to the varying load its voltage keeps on fluctuating and thus voltage and current must be tracked continuously to achieve maximum power using MPPT technique. MPPT technique is used with boost converter to track maximum power and by extracting maximum power from the PV array using MPPT technique efficiency of the system can be increased.

IV. MPPT CONTROLLER

A. Perturb and Observe algorithm for solar energy system

The Perturb & Observe MPPT (maximum power point tracking) algorithm is shown in Fig. 3. There exists different MPP for different condition of temperature and irradiation which is tracked by MPPT technique and can be delivered to load. The P&O MPPT technique algorithm calculates the power $P(t)$ by measuring the instant voltage $V(t)$ and current $I(t)$ and then compares it with last calculated power $P(t-1)$. The algorithm continuously perturbs the system if the operating point variation is positive; otherwise the direction of perturbation is changed if the operating point variation is positive. The duty cycle of the DC/DC converter is varied till it reaches the maximum power point. With higher step size of perturbation, system may oscillate around MPP which results into wastage of energy. Perturb and Observe MPPT technique which is adopted from PSIM software. Voltage V_{cell} and current I_{cell} are measured from solar array to calculate power, P_o . Block dv/dt compares the present value of power with previous value. If increment in power is positive then perturbation variable voltage is incremented by predefined step size. Output voltage of solar panel is compared with this varied voltage value and steady state error obtained is eliminated by PI controller. To avoid over saturation, a limiter should be placed at the output of PI controller which is compared with carrier wave to generate pulse for controlled switch IGBT of DC/DC boost converter.

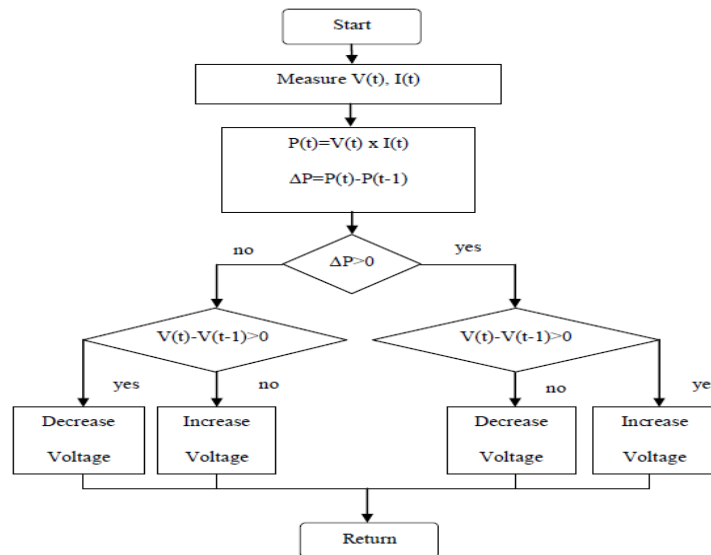


Fig.3 Flowchart of Perturb and Observe method

B. Modified Perturb and Observe algorithm for wind energy system

The flowchart for the proposed algorithm is shown in Fig. 4. The wind speed change detection through the dc-link voltage slope described earlier will be used to differentiate between the two modes. First, the system variables are initialized and samples from the dc-link voltage and the inductor current are taken. The samples of the voltage and current (and hence the power) are taken at a rate that depends on the system response time.

When the MPPT algorithm decides to increase the current command the system decelerates and reaches a new operating point. The rectified dc-link voltage will change according to the change of the speed. Slope variation of the dc-link voltage is continuously monitored to adjust the current as it varies with change in wind speed. A very steep slope will be observed, if there is sudden change in the wind speed algorithm will go into prediction mode with generation of interrupt during which dc-link voltage slope will be higher than threshold value k_0 and change in current $\Delta i_{Lref} =$

$k_2 \times \text{slope}$ is introduced to compensate change in wind velocity; where Δi_{Lref} is the reference inductor current step and slope will determine the increment or decrement in the inductor current, k_2 is determined based on the system characteristics by tuning its value.

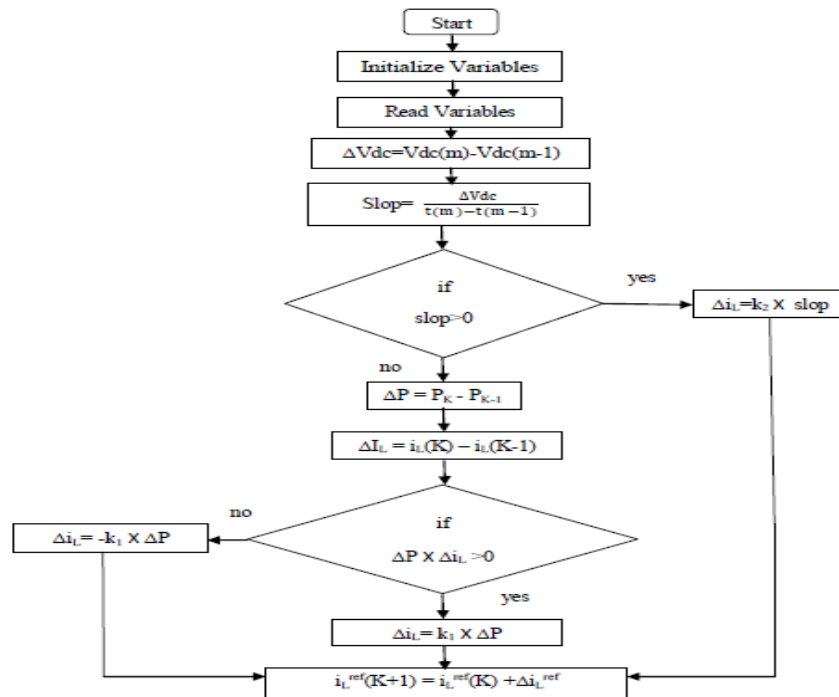


Fig. 4 Flowchart of the proposed MPPT algorithm for wind energy system

When the slope of the dc-link voltage is less than threshold value k_0 , the normal P&O technique is employed. In normal mode value of power at present state is compared with the previous value which is expressed as follows: $\Delta P = P_k - P_{k-1}$, then the reference inductor current of the current cycle is compared with the previous one $\Delta i_L = i_L(K) - i_L(K-1)$. To proceed further in algorithm comparison of $P \times \Delta i_L$ is done. When $P \times \Delta i_L$ is greater than zero current is increased by step size $\Delta i_L = k_1 \times \Delta P$ and when less than zero it is decreased by step size $\Delta i_L = -k_1 \times \Delta P$. In the implementation, value of $k_2 = 0.05$ is selected such that resulting step size avoids the stalling. The desired value of the scaling factor k_1 will not be the same for different wind speed range. [6]

After running the algorithm from normal P&O or prediction mode, inductor current changes by $\Delta i_{Lref}(K+1) = \Delta i_{Lref}(K) + \Delta i_{Lref}$. Thus the MPPT algorithm will run in normal prediction mode in normal wind speed and it will run in prediction mode in sudden wind speed change.

V. SIMULATION RESULTS FOR WIND ENERGY SYSTEM

MPPT control of wind turbine with boost converter is modelled using PSIM software. Simulation results from PSIM 9.0 are given for simulation of wind energy system with MPPT technique which is programmed using visual C++ 6.0 and linked to PSIM using DLL block. The DLL block receives values from PSIM as inputs and sends results back to PSIM by performing the calculations with program visual C++. The parameters are given in Table 1.

Table I: Parameters of Wind Energy System

Wind Generator		Wind Turbine		Boost Converter	
Parameters	Value	Parameters	Value	Parameters	Value
Power Rating	30 kW	Power rating	28 Kw	Input Voltage, V_{in}	8.74 V
Poles	8	Radius	1 m	Output Voltage, V_{out}	151 V
R_s	56 mΩ	Gear Ratio	1:1	Output Capacitor, C_{out}	400 μF
L_d	1.6 mH	Base rotational speed	180 rpm	Inductor	700 mH
L_d	1.6 mH	P	1.205 kg/m ²	Switching Frequency	5 kHz
Moment of inertia	0.02 kg.m ²	Moment of inertia	0.025 kg.m ²		

A. Output of Boost Converter

Permanent magnet synchronous generator is AC type. Uncontrolled rectifier generates 10V which is boosted to a higher level using boost converter. Output from boost converter obtained is 150 Volt. Switching of IGBT in boost converter is done using modified perturb and observe MPPT technique.

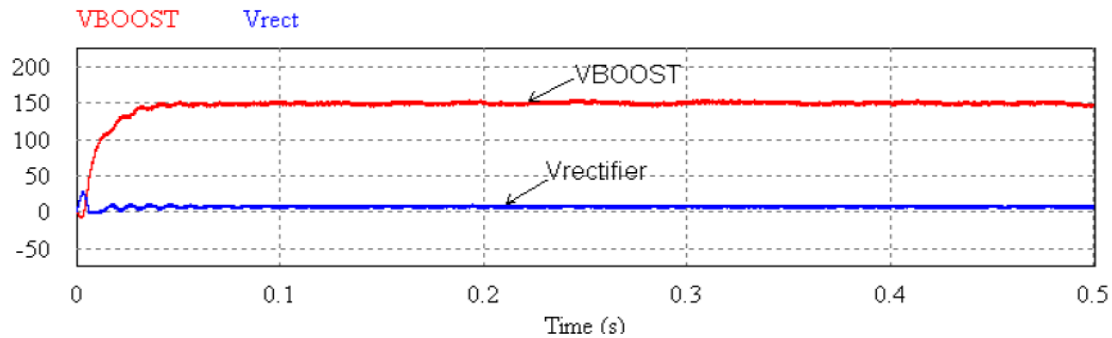


Fig.5 Output of boost converter

B. MPPT tracking for varying wind speed

Fig.6 shows variation in different parameters like power, voltage and current with change in wind speed. The system starts with 8 m/s wind speed at which power starts increasing and achieves MPP and becomes constant. Also load current and load voltage starts increasing as shown in Fig.6. Then wind starts increasing and its speed becomes constant 12 m/s after some time. During this sudden change in wind speed, dc voltage increases which leads to the algorithm in prediction mode where it proceeds by increasing current with larger steps. After sometime wind speed becomes constant which leads to the algorithm into normal perturb and observe algorithm. This mode is active till wind speed starts decreasing slowly from 12 to 9 m/s. The algorithm starts decreasing the current command with steps that are scaled by the measured slope.

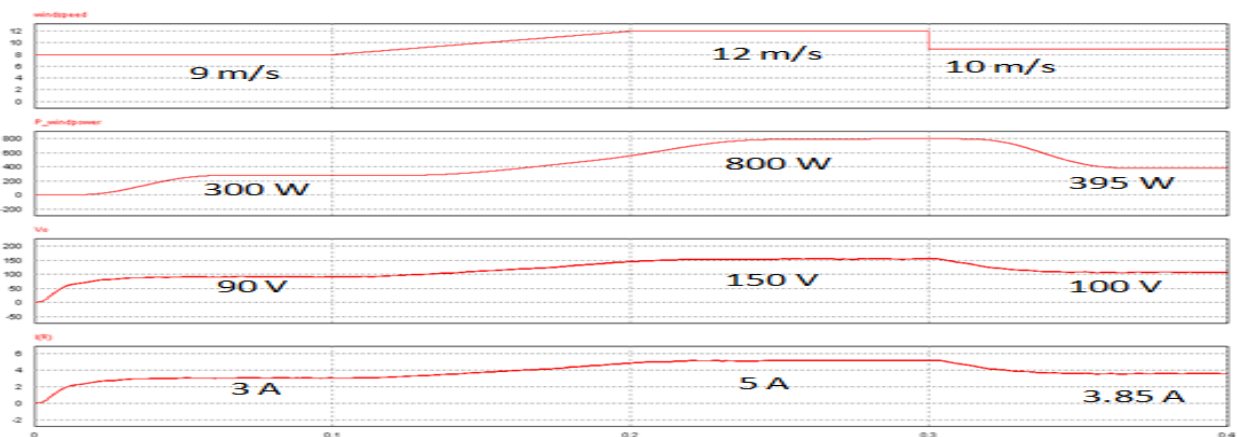


Fig.6 Variation of different parameters with sudden wind speed change

When the wind speed settles again at 9 m/s, the normal P&O mode is activated again by small variation in voltage slope. The current will vary with normal P&O mode during slow wind variation and will abruptly change to prediction mode when there is sudden change in wind speed. From the results proposed algorithm shows fast tracking performance with change in wind speed with minimum calculation and simple implementation. Under fast wind speed change, the proposed algorithm prevents the generator from stalling by comparing slope with threshold value which indirectly detects change in wind speed.

VI. SIMULATION RESULTS FOR SOLAR ENERGY SYSTEM

MPPT control of PV array with boost converter is modeled using PSIM software. Four Solar modules of Sun Power E19 of 320 W are connected in series, and a combined block is formed. Such type of two solar arrays are formed

and connected in parallel. When panels are connected in series voltage increases and when panels are connected in parallel current increases. Parameters of PV array are shown in Table II.

Table II: Parameters of Solar System

Parameters of solar array		Parameters of Boost Converter	
Parameters	Value	Parameters	Value
Number of cells N_s	384	Input Voltage, V_{in}	218.8 V
Maximum power P_{max}	2560 W	Output Voltage, V_{out}	260 V
Voltage at P_{max}	218.8 V	Output Capacitor, C_{out}	10 μ F
Current at P_{max}	11.72 A	Inductor L	2.92 mH
Open-circuit voltage V_{oc}	259.2 V	Switching Frequency f_s	5 kHz
Short-circuit current I_{sc}	12.48 A		
Temperature coefficient of V_{OC}			
Temperature coefficient of I_{SC}			

A. Simulation of Boost Converter

The simulation of boost converter with P&O MPPT control of solar array as input is taken and the input and output waveforms for voltage obtained are shown in Fig. 7. Parameters of boost converter are shown in Table II.

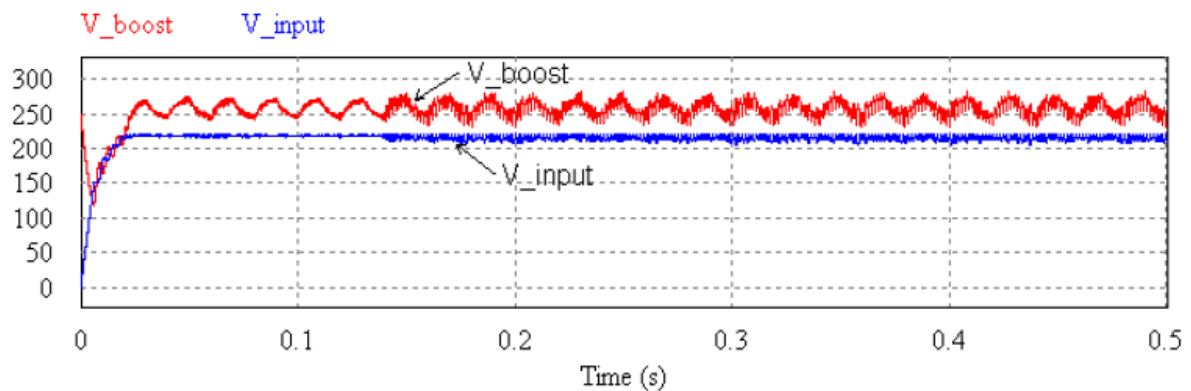


Fig.7 Voltage waveform of boost converter

B. MPPT tracking for different values of resistance

MPPT technique which tracks the power generated from solar panel for different resistance is shown in Fig. 8. For $R=20$ ohm, MPPT technique works efficiently as shown in results but for $R=10$ ohm MPPT tracking is inaccurate. Thus minimum value of resistance should be 20 ohm to track maximum power. For higher values of resistance i.e. more than 20 ohm MPPT tracking works efficiently. Power flowing through load with different resistance values is shown in Table II. As resistance increases power varies by small amount nearly 5-10%.

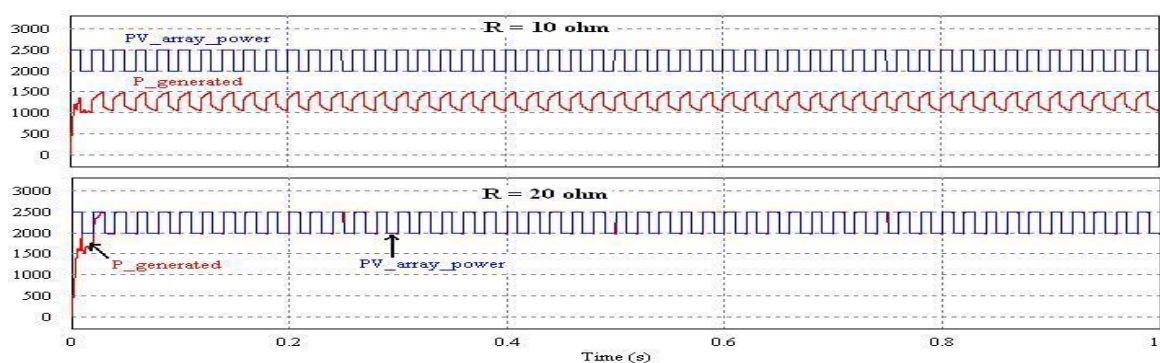


Fig. 8 MPPT tracking for 10 ohm and 20 ohm

VII. CONCLUSIONS

The simulation of the MPPT technique achieves the maximum power point for wind energy system as well PV system. For a particular irradiance level, maximum power generated by wind generator/PV system is delivered by using MPPT technique at the load. For PV system, perturb and observe MPPT technique is used which works efficiently. For wind energy system, modified perturb and technique adopted from IEEE transactions on energy conversion [6] is used in which with normal wind speed conventional perturb and observe technique is employed and with rapidly wind speed conditions prediction mode is employed. Under rapid wind speed condition, conventional P&O has the direction misleading problems while prediction mode reaches MPP faster.

The features of this simulation circuit are: 1) Both renewable sources are stepped up using boost converter; 2) Different MPPT technique is employed for each source; 3) individual operations are supported. Simulation results are presented in this paper.

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