WIND ENERGY CONVERSION SYSTEMS FOR HYBRID ALGORITHM OF MPPT

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***Abstract** – Under a given wind speed when the load impedance matches with the source impedance there is a possibility of generating maxi mum power by wind energy conversion system.*

(MPPT) Maximum Power Point Tracking will be complex due to the dynamic behavior of load and wind which keeps varying.

In the present work (MPPT) Maximum power-point tracking related to (WG) Wind Generator currently exists, which consists of efficiency buck-type dc/dc converter and a control unit running the MPPT functions with a high efficiency

(WG) Wind Generator which operates at a variable speed, great advantage of Maximum Power Point Tracking is it does not require any knowledge of Wind Generator's high potential feature of measurement of the wind speed. Higher reliability, lower complexity and less mechanical stress of the WG which results as different features (MPPT) Maximum Power Points Tracking and its methods like perturbation and observation (PAO) method and incremental conductance method are conventional.

Positive change in power is noticed in respect to correct flow direction of duty cycle of the converter in the power conditioning unit of conversion system of wind energy which is regardless, a part of POA method.

According to POA method, under rapidly changing load conditions or atmosphere, maximum power operating point will be slow and there is a possibility of tracking maximum power operation (MPOP) in an incorrect method.

The incremental conductance and the negative of present conductance value are compared as per the incremental conductance method. The duty cycle is increased, when the incremental conductance is outstanding when compared to the value of existing conductance, other it will be decreased.

Conditions of environment do not permit to feel the variations with this method abnormally, because at steady state its tendency to vary the system condition is very poor. To track the maximum power, a hybrid algorithm is used in order to overcome the above drawbacks.

On power variation, according to this method, duty cycle is adjusted based on the variation in rectifier output voltage.
Keywords: MPPT, MPOP, WECS,VSCF, CSCF,

INTRODUCTION

In the process of overcoming the power demand, renewable and clean energy is attaining more attention globally. With exhausting of traditional energy resources and increasing concern of environment, renewable and clean energy is attracting more attention all over the world to overcome the increasing power demand. Out of all the renewable energy sources, Wind energy and solar energy are reliable energy sources.

Lot of significance is gained by Wind power, as it is a cost-effective, wind power is proved to be environmentally clean and renewable power source which is safe compared to power generated by nuclear source and fossil fuel. Size of Wind Energy conversion system (WECS) may vary from hundred kilowatts to several megawatts. Generator and converter systems' choice is determined by the (WECS) Wind Energy conversion system.

For the systems which require power up to 2MW, Asynchronous generators are used very frequently; in this scenario machines of direct driven permanent magnet synchronous are preferred. As determined by the grid, Wind Energy Conversion System should be able to generate power with constant electrical frequency In medium power level grid-connected systems, generally Squirrel cage rotor induction generators are used

When connected to constant frequency network, generators with induction draws the magnetizing current from mains and runs at near synchronous speed and it results into Constant Frequency (CSCF) operation of generator and with the certain speed constantly. Having the flexibility in varying the shat speed, wind speed can be substantially improved by captured power due to the fluctuating wind speed.

Wound rotor induction machine will be an attractive solution for rotor side control of grid which is application like (VSCF) variable Speed Constant Frequency when the keeps varying very frequently The stator is directly connected. The stator is straightly connected to the three phase grid and the rotor is supplied by back-to-back Power Wind Machines converters in the double fed induction generator as shown in Figure1.

Such an arrangement in induction generators, the operations will be flexible at sub-synchronous and super synchronous as well with speeds [1] [2].

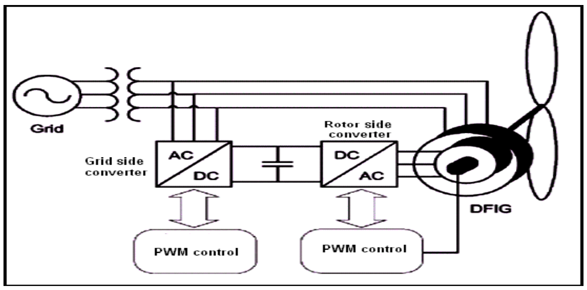

Figure I: (WECS) Wind Energy Conversion System

II. (MPPT) MAXIMUM POWER POINT TRACKING MODEL.

A. Maximum Power Point Tracking: Load impedance being connected differs with power output. Wind speed is not continuous as well; there is difference in load impedance

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So the system by itself cannot reside in the region of maximum power operating region, which is more desired.

For the system to operate at the (MPOP) maximum power operating point complexity and significance have been increased. Maximum power point tracking (MPPT) is a technique which helps to maintain or to operate in MPOP which runs a system.

A converter mainly called as a maximum power point tracker which is connected in between Wind Energy Conversion system source and the load. Maximum power is tracked from the source, due to the change of duty cycle which is changed continuously and operated at a particular value.

When the source impedance matches the load impedance, according to maximum power transfer theorem, maximum power will be delivered by the source.

Effective impedance which is seen by the (WECS) Wind Energy Conversion System and will be equal to the impedance of internal source and there will be scope for the delivery of maximum power, all this happens due to the maintenance of duty cycle of a converter.

To get the maxi mum wind power, an investigation helps us to understand the probable re-arrangement of the operating point of wind turbine in two different zones.

We can see from Figure 4 that according to the operating voltage which shows that there are two operating zones, which represents the typical curve of wind power variation.

Firstly It is located at the right side of the MPP $dp/d\Omega < 0$ and the secondly to the left side of the MPP where $dp/d\Omega > 0$. For searching the maximum wind power operating point and tracking this point, in order to reduce the error between the operating power and the maximum power,

The operating point of the wind turbine is disturbed periodically by control of the buck converter during the event of the change of the wind speed..

In decreasing or decreasing the duty cycle of the buck-boost converter to changer operating point of the wind turbine, information of acquiring the output voltage and current of PMSG will be used as its control..

movement of operating point comes into picture from (k-1) to (k), this happens After the perturbation. Four cases of perturbation from operating point are distinguished.

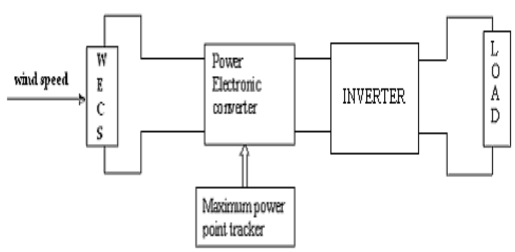


Figure 2.(MPPT) Block Diagram for maximum power point tracking

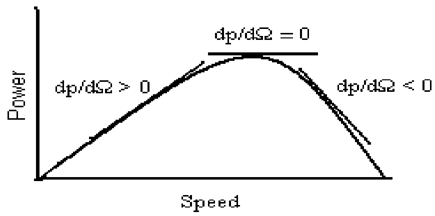


Figure 3. Probable displacement of the operating point

If P(k)>P(k-1) and Ω (k)> Ω(k-1),the power increases after perturbation. Reach of MPOP shows that it oriented toward good direction.

So, the search of the MPOP continues in the look –alike direction in reaching reaches the (OP) operating point (k+1) by increasing the duty cycle by ΔD. If P(k)<P(k-1) and Ω(k) < Ω(k-1), when we observer that the power is decreased perturbation, it clearly states that search of (MPOP) Maximum Power Operating Point is travelling towards bad direction.

The MPOP search direction must be changed and the duty cycle is increased by two ΔD to reach the operating point (k+1). If P(k)>P(k-1) and Ω (k)< Ω(k-1), the power increases after perturbation. This indicates that the MPOP search is oriented to the good direction.

Search direction of (MPOP) Maximum Power Operating Point must be maintained due to this, the duty cycle is decreased by one AD in order to reach the (OP) operating point,
(k+1). If P(k)<P(k-1) and Ω (k)> Ω(k-1), the power is decreased. This is an indication of the MPOP search which is oriented to bad direction. By changing the search direction of Maximum Power Operating Point, increased duty cycle by two AD helps in reaching the operating point (k+1).

Search rules of the various cases of operation are summarized in the table1.

Table1. Operation modes of buck converter

ΔD_i	$\Delta D > 0$		$\Delta D < 0$	
ΔP	> 0	< 0	> 0	< 0
$\Delta P/\Delta D$	> 0	< 0	< 0	> 0
region	I	II	II	I
$\Delta\Omega$	-	—	+	+
$\Delta\alpha_{i+1}$	+	-	-	+

B. (MPPT) *Maximum Power Operating Point is a process in* wind energy conversion system which is directly based in adjusting the dc/dc converter duty cycle, based on the result of the comparison of successive Wind Generator (WG) WG-output-power measurements.

Because of the slow dynamic response of the with the interconnected wind-turbine/generator system power absorption is directly proportional to the wind speed. When the wind speed is high then the power absorption is relatively slow .

According to the control law, there is a sharp method to solve the problem of maximizing the (WG) Wind Generator power by using the converter duty cycle as a control variable.

Control Law:

$$D_k = D_{k-1} + C_1 . \frac{\Delta P_{k-1}}{\Delta D_{k-1}} \qquad (1)$$

where D_k and D_{k-1} are the duty-cycle values at iterations k and k - 1, respectively ($0 < D_k < 1$); $\Delta P_{k-1}/\Delta D_{k-1}$ is the (WG) Wind Generator power gradient at step k - 1; and C_1 is a quick change.

Convergence to the (WG) Wind Generator maximum power point at any wind-speed-level should be ensured as per the method.

it is appropriate to prove that the function P(D), relating the WG power P and the dc/dc converter duty cycle D, has only one exceptional point coinciding

with the (WG) Wind Generator and its (MPPs) Maximum Power Point Tracking. It is clear that at the points of maximum power production

$$\frac{dP}{d\Omega} = 0 \qquad (2)$$

Where Ω is the (WG) Wind Generator speed?
Chain rule is applied while writing the above equation as

$$\frac{dP}{d\Omega} = \frac{dP}{dD} . \frac{dD}{dV_{WG}} . \frac{dV_{WG}}{d\Omega_e} \frac{d\Omega_e}{d\Omega} = 0 \qquad (3)$$

Where V_{WG} is the rectifier output voltage level and Ω_e is the generator-phase-voltage angular speed. In this situation of a buck-type dc/dc converter, its input voltage is related to the output (battery) voltage and the duty cycle as follows:

$$D = \frac{V_0}{V_{WG}} \qquad (4)$$

$$\frac{dD}{dV_{WG}} = -\frac{1}{V_{WG}^2} V_O \neq 0 \qquad (5)$$

Battery voltage level is indicated by the term Vo. Generator speed is indicated by wind-turbine rotor speed which is as follows::

$$\Omega_e = p.\Omega \quad (6)$$

$$\frac{d\Omega_e}{d\Omega} = p > 0 \quad (7)$$

Number of generators for pole pairs is p. The rectifier output voltage V_{WG} is proportional to the generator phase voltage V_{ph}. Considering Fig. 4, it is concluded that

$$\frac{dV_{ph}}{d\Omega_e} > 0 \quad (8)$$

$$\frac{dV_{WG}}{d\Omega_e} > 0 \quad (9)$$

Considering above, it holds that

(10)

Thus, the function P (D) has a single extreme point, co-existence with the WG MPOP, and the dc/dc converter duty-cycle adjustment according to the control law ensures convergence to the WG MPOP under any wind-speed condition. The power maximization process is shown in Figure 4. Since the duty-cycle and its adjustment follows the direction of dP/dD, high speed side of Wind Generator characteristic is increased due to the duty cycle value is increased,

Which results into Wind Generator-rotor-speed reduction and increase in the power, until it reaches MPOP (Maximum Power Operating Point.

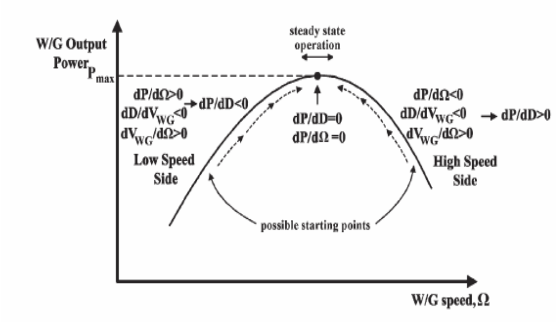


Figure 4.MPP tracking process.

Uniformly when the starting point is in the low-speed side, following the way of dP/dD results in duty-cycle reduction and the subsequent convergence at the MPOP, as the (WG) Wind Generator's rotor speed is progressively increased.

III..PERTURBATION AND OBSERVATION METHOD

According to this method, for each and every switching period, duty cycle of the converter keeps varying continuously.

The direction of variation of duty cycle is decided in the following manner. The output power of (WECS) Wind Energy Conversion System is continuously monitored and checking the similarity with the earlier value of measured power. If the existing power is more than the previous one, the duty cycle variation is continued in the same way, otherwise in the reverse direction.

Figure. 5 describes the observation algorithm and perturbation. First, the values of voltage and current are measured. Multiplication of current and voltage are found to be value of the power.

This present power is compared with the previous one. If both are equal, then no change in duty cycle is needed. i.e., the system is already operating in maximum power operating region. Next, if present power is higher than the earlier power, then it is an indication that the existing variation of duty cycle approaches to maximum power operating region. So the variation of duty cycle for the next iteration is done as same as the previous one. i.e., the step value given for the next duty cycle is the same step value with the same direction as the present one.

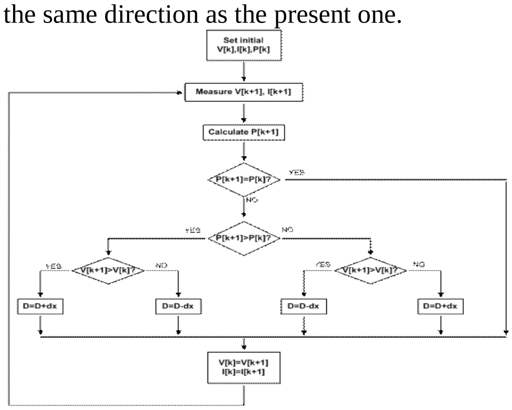


Figure 5.Flow chart for the perturbation and observation method

If the value of present power is found to be less than the previous power, then it is a symptom that the difference of duty cycle leads to an operating point, which is moving away from the maximum power point. So the duty cycle is varied in the other side of the way to the previous one. i.e., the step value given for the next duty cycle is the same step value but with the negative direction to the previous. To do this, simply (-1) can be multiplied to the step value.

Thus the algorithm is very simple in mathematical calculation but with proper logical decisions. Hence it is considered as one of the easiest algorithm available for (MPOP) maximum power point tracking.

Merits of this method are, it is easy to implement because the algorithm involves less mathematical calculation and involves more logical decisions. Also it works in the region of maximum power point region. Drawbacks of this method are, this algorithm is unsuitable for the conditions of atmosphere which changes very quickly. It is slow in the process of tracking maximum power point and at steady state, oscillations are unavoidable.

IV . INCREMENTAL CONDUCTANCE METHOD

According to this method, Incremental conductance comes into picture when the value of the conductance is calculated and compared with the previous value.

We will find any variation in the duty cycle, when the value is found equal to the negation of the present conductance value. When the value found to be more in respect the negation of present conductance, the is a scope of increase in duty cycle, if not it is decreased

The Incremental conductance algorithm is shown graphically in the Figure 7. First of all,, measurement of values for voltage and current. The change in conductance gives the consideration with which we need to proceed further. If the value of change in voltage is equal to zero, then no change in duty cycle is needed.

The basic strategy of Incremental Conductance MPPT control algorithm is equation (2). These equations can be written in terms of the current and voltage.

$$\frac{dP}{dV_{dc}} = \frac{d(V_{dc}I_{dc})}{dV_{dc}} = I_{dc} + V_{dc}\frac{dI_{dc}}{dV_{dc}} \quad (11)$$

Above equation can be written in the form of the conductance ($G = I_{dc}/V_{dc}$) and incremental conductance ($dG = dI_{dc}/dV_{dc}$). Under the constant voltage source region, the value of *dP/dV* is negative. But the value of conductance can be calculated positive or negative value as the direction of voltage variation. So the determination of MPOP can be failed for this reason. In this case, the $G + dG$ Incremental Conductance method is

$$G + dG = \frac{I_{dc1}}{V_{dc1}} + \frac{I_{dc1} - I_{dc2}}{V_{dc1} - V_{dc2}} \quad (12)$$

We have two possibilities, provided if value of the change in the voltage is not proportionate to zero. If the value of change in voltage is greater than zero, then the value of change in current is considered. If the value of change in current is equivalent to zero, then no change in duty cycle is needed. If the value of change in current is greater than zero, then it is an indication that the system is operating in constant voltage source region.

In order to increase the voltage, duty cycle is increased. Otherwise it is an indication that the system is operating in constant voltage source region. In this situation, voltage will be decreased to decrease the duty cycle. Now if the incremental conductance value is proved to be higher than the negation of present conductance value, it results into the system which is operating in constant current source region. Voltage should be increased to reach the maximum power operating region.

Otherwise it is an indication that the system is in constant voltage region. So we need to decrease the voltage to reach the maximum power-operating region. The merits of this method are, it is more suitable for the conditions of atmosphere which changes very quickly and it is having response characteristics in which the oscillatory part at the steady state when there is no change in environmental conditions is absent. As the high-end mathematics is involved and it is more forced towards wrong decision of maximum power point, it is a major drawback and also it is more complex.

Figure 6..Flow chart for the Incremental conductance method

Where D is duty cycle for the converter, V_{dc}, V_{dc1}, V_{dc2} are voltages corresponding to the respective duty cycles at the consecutive changes, I_{dc}, I_{dc1}, I_{dc2} are currents corresponding to the respective duty cycles at the consecutive changes and P_1, P_2 are powers corresponding to the respective duty cycles at the consecutive changes

The conventional algorithm Perturbation and Observation method has the disadvantageous that it is not suitable for rapidly changing atmospheric conditions. And the incremental conductance method proved to be very difficult for implementation.

V. HYBRID METHOD

Hybrid method helps us with a simple control method which is new, for maxim um power tracking at a variable speed wind turbine permanent magnet synchronous generator by using a buck converter.

Output voltage of the Permanent magnet generator is connected to a fixed dc-link through a three-phase rectifier and the dc-dc converter. Voltage command that corresponds to maximum power output of the turbine is calculated by the maximum power point algorithm.

The dc-dc converter uses this Voltage command to control the output power of the permanent magnet generator, such that the voltage of generator tracks the command voltage.

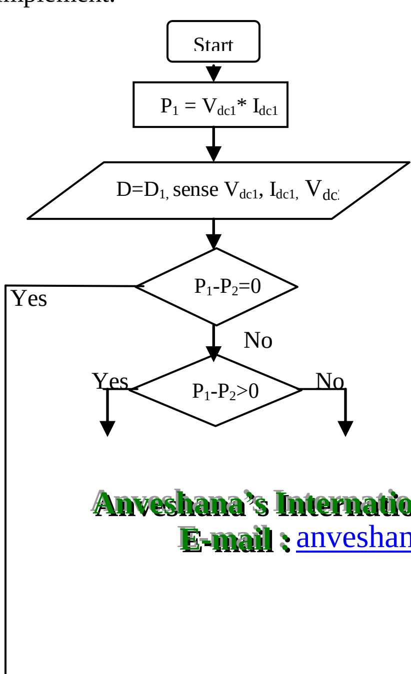
This algorithm is hybrid to overcome the disadvantages of the above-mentioned conventional methods of maximum power tracking, and it also incorporates the advantages of both the methods. The Perturbation and Observation method is erroneous because it does not consider whether the present operating value of duty cycle is correct or not. But it always concerns the next duty cycle to which it has to change. When the wind speed changes slowly the algorithm varies the duty cycle with its own speed whether the present operating condition is at maximum power operating region or at least nearer to it. So the value of power output will be always less than that it could have yielded.

Choose the initial reference rotor speed and generator output power will be measured. As per the value of measured DC output voltage of generator the reference voltage of wind generator increase or decrease by one step and measure the output power again. Calculate Sign (ΔP) and Sign (ΔV). Moreover the difference of duty cycle at a particular instant might cause an increase in power.

In order to overcome these disadvantages here, the voltage generated at a particular wind speed is considered initially. Speed of the wind will be affecting voltage, generator output is generated at this point. Voltage in permanent magnet synchronous generators wind speed is directly proportional to the generator output.

The drawback of incremental inductance method is the implementation of the algorithm is very difficult since we require more accurate sensors, which will calculate the effective impedance of the system at the particular instant. So, For calculating power variations in hybrid algorithm, we are taking the voltage as the control measure.

in this hybrid algorithm we are taking the voltage value as the control measure and calculating power variations, which will be given to the duty cycle of the converter. This method is always operating at MPPT algorithm is easy to implement.



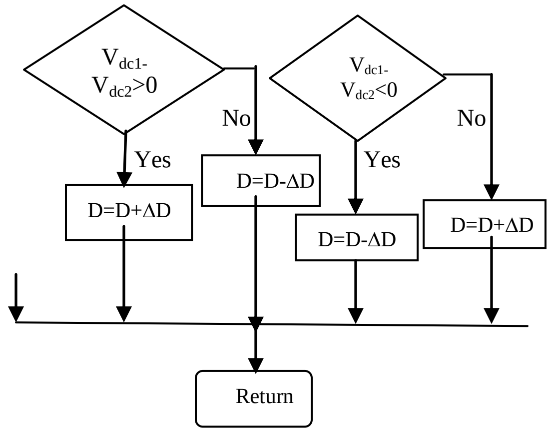


Figure 7.Flow chart for the hybrid method

VI. SIMULATION RESULTS

Simulation of the system with Hybrid method is carried out in simulink with the control circuit as shown in the following Fig. . First of all the power is measured and it is provided a transport delay with which we can obtain the previous value of the power output. Both are compared. Then voltage is measured and it is provided a transport delay with which we can obtain the previous value of the voltage output. Both the voltage and power outputs given to MATLAB embedded block. In which initially the power is compared with Previous power and if the variations between them exists then the voltage of consecutive intervals is compared. If the voltage is compared to the previous value the outputs block either the positive or negative depend on the power variation. The compared output is given to the comparator. Output of the Comparator is added to the previous output of the comparator by means of zero order hold circuit. The output is compared to the saw tooth wave form of switching frequency in order to get PWM of duty cycle. The difference is compared with 0. If the result is greater than zero then the output is 1, which indicates the switching on of the switch, MOSFET otherwise gives a 0, which indicates the switching off of the MOSFET.

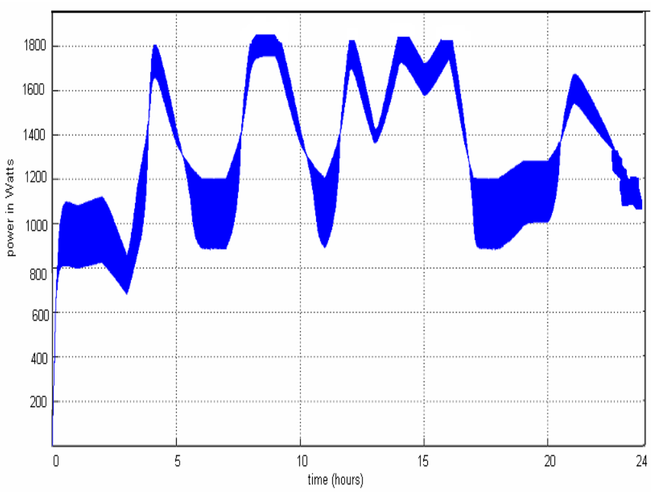


Figure 8. Power output without MPPT.

Without MPPT unit Maximum power is 1835W, Average power is 1.21kW and energy taken from the WECS on complete day is 29.11kWh

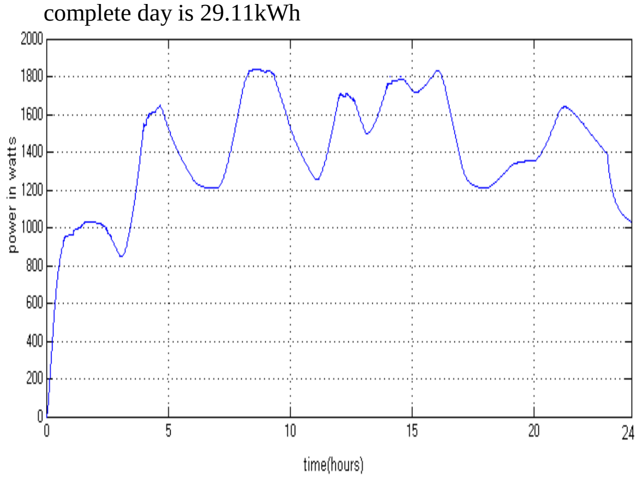


Figure 9.*PAO method output power(constant load)*

When PAO method is used for the MPPT for constant load, Maximum power is 1810 W, Average power is 1.6kw Wind energy taken from the WECS on complete day is 32.71kWh

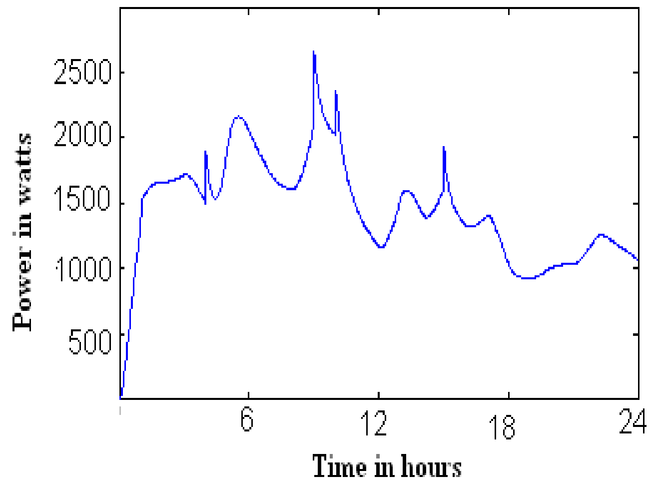


Figure 10.*PAO method output power(Variable load)*

When PAO method is used for the MPPT for variable load, Maximum power is 2540 W, Average power is .992kWand energy taken from the WECS on complete day is 23.82kWh

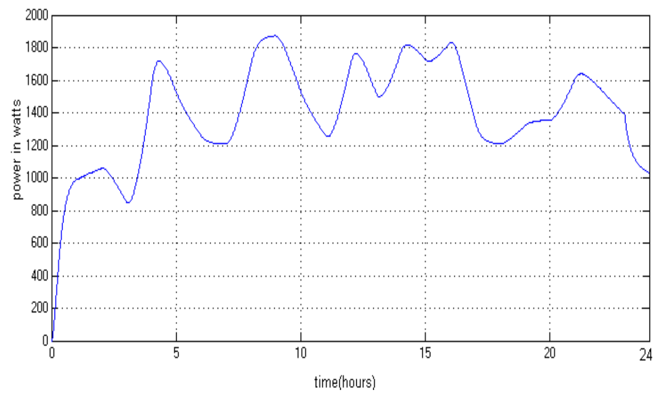


Figure 11.*Power output using IC method (Constant load)*

When IC method is used for the MPPT for constant load, Maximum power is 1835 W; Average power is 1.38kW and energy taken from the WECS on complete day is 33.2kWh

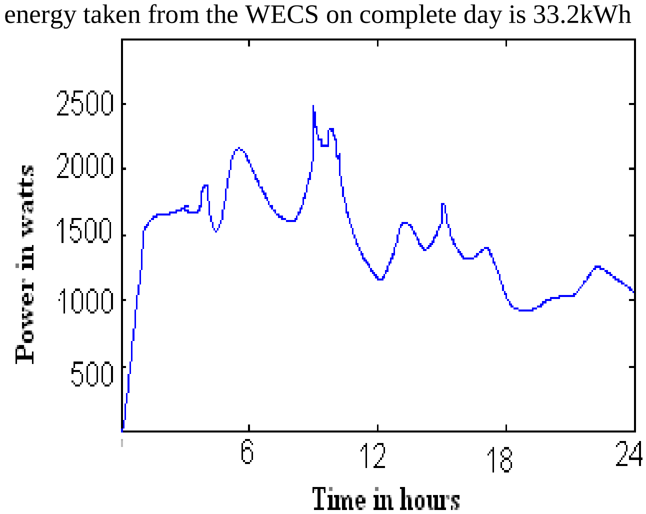


Figure 12. ***Power output using IC method (Variable load)***

When Incremental conductance method is used for the MPPT for variable load, Maximum power is 2546 W, Average power is 1.006kW and energy taken from the WECS on complete day is 24.15kWh

When Hybrid method is used for the MPPT for constant load, Maximum power is 1835 W, Average power is 1.6kW and energy taken from the WECS on complete day is 33.91kWh

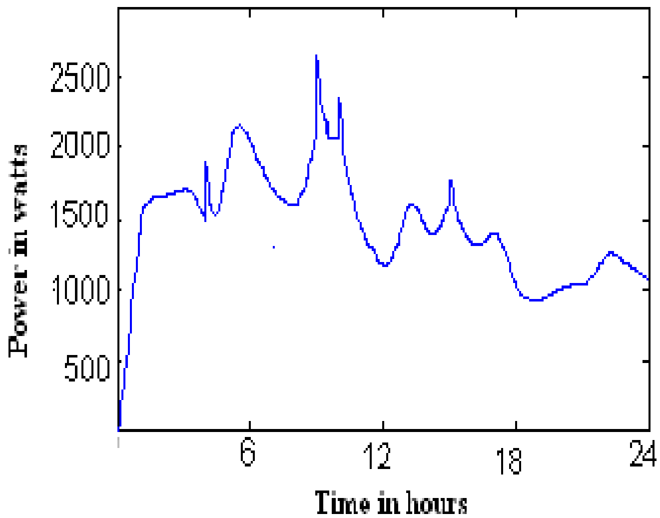


Figure 13. ***Power output using Hybrid Method(Variable Load)***

When Hybrid method is used for the MPPT for variable load Maximum power is 2548 W, Average power is 1.025kW and energy taken from the WECS on complete day is 24.62kWh.

VI. CONCLUSION

Maximum power point controls of Wind Generator are specified in this paper, which consists of of a high-efficiency buck-type dc/dc converter and control unit.

(MPPT) Maximum Power Point Tracking methods and its advantages have no knowledge of the (WG) Wind Generator's optimal power characteristic or measurement of the wind speed which is required, thus the Wind Generators operator operates variable speed a hence results into suffering lower stress on the shafts and gears.

The methods of (MPPT) Highest power Point Tracking does not depend on (WG) Wind Generator's wind and rotor speed rating or the dc/dc converter power rating..

For the Highest power point tracking of the wind energy conversion systems, in this project, a hybrid algorithm is used. In PAO method, the positive change in power is observed regardless of the correct flow direction of duty cycle of the converter in the power-conditioning unit of the wind energy conversion system.

To track the Highest power and may also to track the maximum (MPOP) power operating point, POA method proved to be slow. It could also track wrongly under quickly changing atmospheric or load conditions, as per the POA method. According to this thesis, hybrid algorithm is presented to track the Highest power from wind energy conversion system in or to eliminate the drawbacks

Using conventional methods, average output of power is increased by 14%

From the above mentioned results it is clear that using the hybrid method the power output is increased by 3.54% in case of constant load condition compared to the conventional PAO method. For variable load condition it is increased by 4.2%, output of power is increased in case of the load condition which is consistent when compared to the incremental conductance method. 2.11% under variable load condition is 1.98%.

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