Maximum Power Point Tracking Using Hill Climb Searching Method for Wind System

Mr. Dubal Krishnat Ramrao
BE, M Tech II (Electrical Power System)
Krishnat.dubal@yahoo.in

Mr. Chavan Dattatray S.
Associate Professor,Bharati Vidyapeet College Of Engineering, Pune .
Email:greenearth1234@yahoo.com

ABSTRACT-This proposed project develops a new Maximum Power Point Tracking (MPPT) technique for permanent magnet synchronous generator (PMSG) based wind energy conversion system (WECS). A mathematical equation of the wind power system also proved. For this implemented maximum power point tracking (MPPT) control, hill climb searching (HCS) algorithms are used. As an integral part of the max-power extraction algorithm, advanced hill-climb searching method has been developed to take into account the wind turbine inertia. The proposed control Algorithm allows the generator to track the optimal operation points of the wind turbine System under fluctuating wind conditions and the tracking process speeds up over time.

The developed maximum extraction wind power algorithm has the capability of providing initial power demand based on error driven control, searching for the maximum wind turbine power at variable wind speeds, constructing an intelligent memory, and applying the intelligent memory data to control the inverter for maximum wind power extraction, without the requirement of either knowledge of wind turbine characteristics or the measurements of mechanical quantities such as wind speed and turbine rotor speed. The effectiveness of this proposed algorithm was evaluated using MATLAB/SIMULINK.

Keywords-MPPT,PMSG,WECS,HCS,PSF ,TSR,SVPWM,WEGS.

1.Introduction-

The demand for electric energy is increasing very rapidly. Since the conventional fuels are depleting fast and their prices are going up and up, the attention has shifted to nonconventional energy sources, like wind, solar, fuel cell, etc. at that time; wind is a particularly attractive option. Electric energy is generated from wind using a wind turbine and an electric generator. The generated energy can be used either for standalone loads or transfer into the power grid through an appropriate power electronic convertor.

The wind turbine which converts rotating energy in to the kinetic energy and kinetic energy into mechanical energy & that mechanical energy is finally converts into electrical energy with the help of the electrical generator. For the generation of electrical power from the wind system different types of generators used such as induction generator, synchronous generator etc. Normally for that the equipments used for construction of wind system are wind turbine, gear box, generator & AC-to-DC convertor. As we know that the wind velocity does not remain constant continuously, it changes time to time so we do not get the maximum power point (MPP) under such condition. So to overcome this problem we can use the maximum power point tracking (MPPT) algorithm for the variable wind velocity condition. Some of them are as follows:-

Algorithm use for MPPT

1) Anemometer-based MPPT algorithm

   In the anemometer-based MPPT algorithm, a reference speed for the induction generator (IG) corresponding to the MPP of the present wind velocity is set. And the wind velocity is measured .Although this is a fast MPPT scheme, the overall cost of the system increases because anemometer is expensive.

2) Calculation based algorithm

   In this from available electrical Parameter, Speed is calculated and Electrical

International Journal of Advanced Information Science and Technology (IJAIST) ISSN: 2319:2682
Vol.3, No.6, June 2014 DOI:10.15693/ijaist/2014.v3i6.65-75

frequency produce by the generator is directly proportional to be acceleration of rotor.

3) Tip speed ratio control algorithm

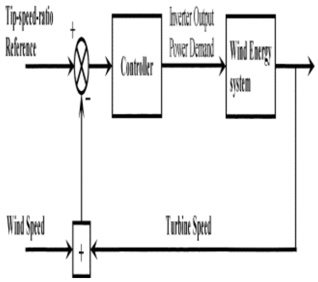


Fig 1. Block diagram of TSR control.

The above Fig. shows the block diagram of TSR. In which both the turbine speed and wind speed measured for TSR calculation. On the basis of this calculation, for the proper operation optimal TSR is given to the controller. In the TSR algorithm there are two disadvantages to implement on TSR control. The first is wind speed measurement with the help of anemometer which increases the system cost and creates complexity in practical implementation. Second one is for obtaining the optimal value of TSR, which is different from one system to another.

4) Power signal feedback (PSF) control algorithm

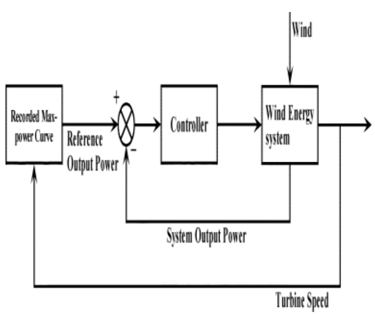


Fig. 2. Block diag ram of PSF control.

The above Fig. Shows the block diagram of PSF control. It needs the knowledge of the maximum power curve of the wind turbine, and to tracking this curve through its control mechanism. This maximum power curve can be obtained via simulations or data available for wind turbine, which makes the PSF control, is difficult and expensive to implement in practical Hill climb searching algorithm or Perturb and observe (P & O) algorithm

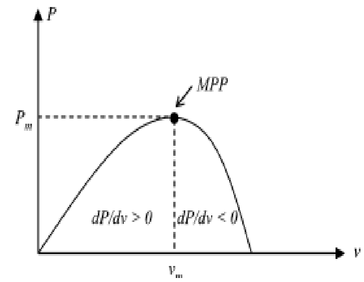


Fig. 3 Hill Climb searching.

The above fig. shows the ideal power verses speed characteristics. To implement the Hill Climb search (HCS) method, here one can check the signs of dv and dP/dv. The shaft speed is either incremented as long as dP/dv > 0, or decremented as long as dP/dv < 0. This is continued until the maximum power point is reached, i.e., dP/dv = 0. If incrementing the shaft speed results in dP/dv < 0 or decrementing shaft speed results in dP/dv > 0, the direction of shaft speed change must be reversed. This method search peak power of the variable wind velocity. For this method two basic advantages are

1 It does not required information of turbine characteristics.
2 It can be applied to any wind turbine.

2.Concept of maximum power point tracking

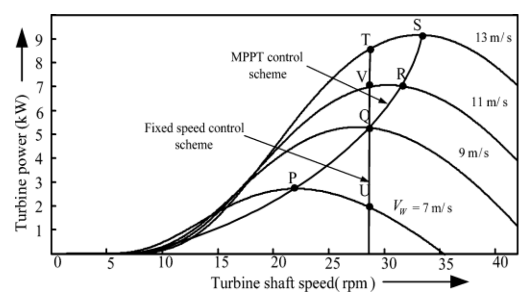


Fig: 4 Turbine power verses turbine speed for different wind velocities

The above fig.4 shows the turbine power(Kw) verses turbine speed(rpm) for different wind velocity like 7m/s, 9m/s, 11m/s, 13m/s etc. the energy from the wind extracted by using a constant speed wind energy conversion system (WECS). This extracted energy converted in to electrical energy to the generator and this generated power is fed into the grid or standalone load. The main drawback of overall system its poor efficiency because it cannot track maximum power [21] [5]. As the wind velocity change, this situation is dissipated by segment T-V-Q-U in the above figure. Let the constant speed system be set to correspond to MPP "Q" for a wind velocity of 9 m/s. This would result in the system running at points U, V, and T for other wind velocities, which are far away from the actual MPP points P, R, and S, respectively, for the corresponding wind velocities. With the advent of high speed, high power converters, variable-speed operation of the WEGS has now become possible and the system can be made to run at a speed corresponding to MPP for the current wind velocity, i.e., the system, represented by Fig 4 can run at P, Q, R, and S. The amount of energy captured from the wind in this case is much higher than a fixed speed system.

3. The proposed scheme of MPPT

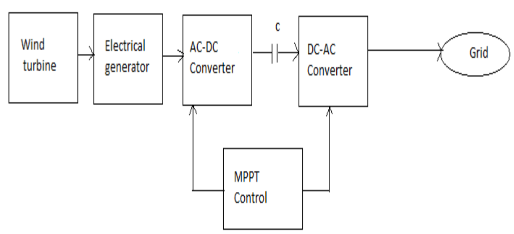


Fig 5: Block diagram of typical grid connected MPPT.

The wind turbine which converts the kinetic energy into mechanical energy & that mechanical energy is finally converts into electrical energy with the help of the electrical generator. For the generation of electrical power from the wind system different types of generators are used such as induction generator, synchronous generator etc. Normally the equipments used for construction of wind system are wind turbine, gear box, generator & AC-to-DC convertor.

In Fig.5 shows a block diagram of the proposed wind energy conversion scheme. As the entire power generated by the wind turbine is transferred through the AC-DC-AC converter. The HCS algorithm interfaces the PMSG AC-DC-AC converter to achieve maximum power point tracking with different wind velocities. Back to back converter is consisting of a rectifier (AC/DC) which is on the wind turbine generator side, DC energy storage and inverter (DC/AC) which is on the grid side. The rectifier rectifies the AC power source coming from the wind turbine generator to a DC power that is stored in the DC bus energy storage. Inverter converts the DC power coming from the DC bus to AC with specific voltage and frequency to meet the grid requirements. The rectifier and the inverter are made up of three arm bridges switch which are an IGBT .

4 Graphical Representation of MPPT

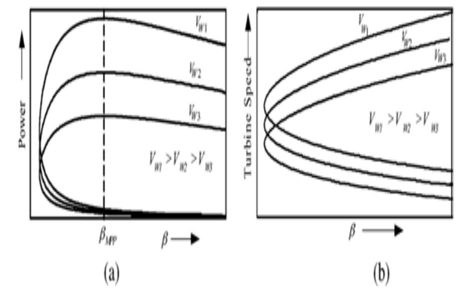


Fig.6 (a) Power versus β curves for different wind velocities. (b) Turbine speed versus β curves for different wind velocities.

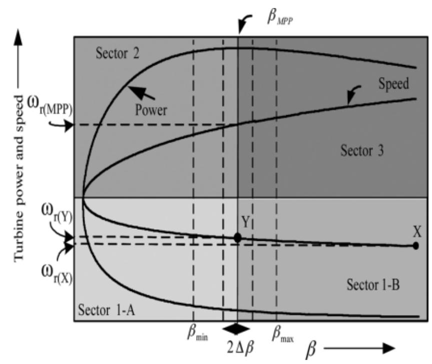


Fig7: Turbine power and speed versus β curves (not to scale). The various Operating sectors are shown in different shades.

The fig 6 (a) and (b) shows the graph of turbine output power vs β and turbine speed vs β respectively. From graph 6(a) we can conclude that as the wind velocity increases power increases, but when we look through value of β at MPP it remain constant irrespective of wind speed [10].

By comparing the graph shown in fig 6(a) and (b) for different wind speeds, gives a new set off curves as shown in fig 7. Let divide the complete working area in to three small sectors say sectors1, sectors 2 and sectors3 for more simplification by dividing sectors 1 in to it Subsectors as 1-A and 1-B as shown in fig. 7. By observing the fig. it can be easily conclude that β_{MPP} related to the MPP lies at the junction of sector 2 and 3. Some may conclude that the junction 1-A and 1-B is also related to β_{MPP} but it's not, because the slope of both curve negative in sector 1. The slope of both the curve are positive in sector 2 but in sector 3 the power vs β curve in negative slope whereas the speed versus β curve has a positive slope. By doing the proper observation a novel rapid MPPT algorithm is developed [10].

4 Proposed MPPT algorithm

1. Measure the speed of the wind turbine (ωrk) apart from voltage, current, and frequency (Fk) at stator terminal of the PMSG.

2. If the present frequency (Fk) at stator terminal at the stator terminals is equal to the reference frequency (Fk-1), calculate the present turbine output power (Pk), βk, ΔPk= Pk- Pk-1, Δωk =ωk – ωk-1, and Δβk = βk –βk-1.
3. Identify the operating sector (Fig.7) depending upon the value of ΔPk/ Δβk and Δωk/ Δβk and Δωk/ Δβk, if both are negative then the sector is 1, if both are positive then the sector is 2, and if ΔPk/ Δβk is negative but Δωk/ Δβk is positive then the sector is 3.
4. If the βk value (i.e., current value of β) lies within the "βMPP±Δβ" band and the operating sector is either 2 or 3, set the reference frequency equal to the present frequency, ie., Fk=fk.
5. If the current sector is 1 and βk > βMPP, set the reference frequency Fk=fk+ fmin 1.if βk > βMPP set the reference frequency Fk=fk+ fmin 2.
6. If the current sector is 2 and βk < βMPP, set the reference frequency Fk=fk+ (βMPP- βk) Gf, else set the reference frequency Fk=fk+ fmin 3.
7. If the current sector is 3 and βk < β_{max}, set the reference frequency Fk=fk+ (βMPP- βk) Gf, else set the reference frequency Fk=fk+ fmin 3.
8. If the current sector is 3 and βk >βMPP, set the reference frequency Fk=fk+ (βMPP- βk) Gf, else set the reference frequency Fk=fk- fmin 3.
9. Go to step 1) and start again. On this manner, continuously track the maximum power at any wind velocity.

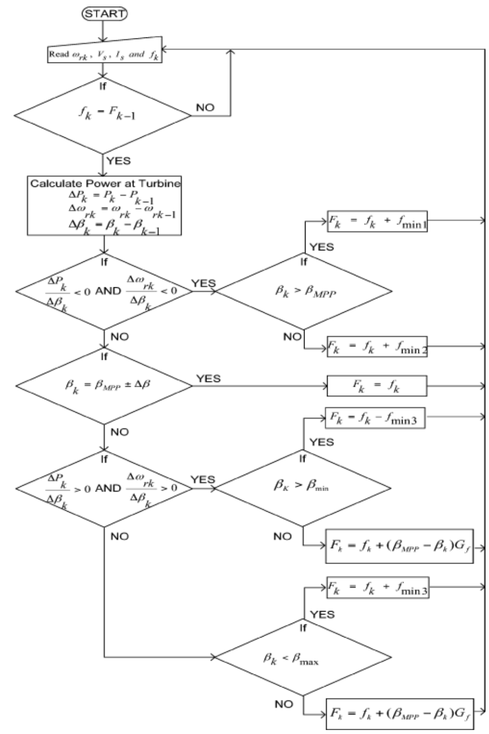


Fig.8: Flow chart of the proposed algorithm

In above fig.8 shows the flowchart for the corresponding algorithm, the operating point can lie on any sector as shown in fig.6. The Stator frequency is completely depends on the sector the sector where the operating point lies. If the operating point lie in sector 1 (sector 1-B), then the stator frequency, if F_{min1} to drive the operating point to MPP with βk> βMpp.Also the stator frequency is F_{min2} to drive the operating point to MPP if the operating point is in sector 1-B with βk< βMpp. If the condition occur where $\beta_{min} < \beta_k < \beta_{max}$ then F_{min3} is used the value of F_{min1} and F_{min2} is depend on the parameter of WECS and wind speed at given location. To start the algorithm approximate value are used. Let assume any point "X" on speed vs β curve which is longest one. For that point "X" chose the F_{min1} such as the turbine speed must be in between $\omega_{r\,(Y)}$ and $\omega_{r\,(MPP)}$. The frequencies of F_{min1} and F_{min2} need fine tanning at the time of installation Fmin3 is very fine frequency used to obtain MPP. If operating point lie between sector 2 and 3 then the stator frequency change is decided by G_f (βMpp- β_k), where G_f nothing but frequency gain factor used to reduced the number of step to achieve the MPP. The value of β_{min} and β_{max} are such a tuned so as to require minimum time to achieve MPP. Similarly if (β_{max} -β_{min}) is too small then system oscillates between sector 2 and 3 before entering the (β_{max} -β_{min}) band. Hence there must be some relation between MPPT and system stability at the

International Journal of Advanced Information Science and Technology (IJAIST) ISSN: 2319:2682
Vol.3, No.6, June 2014 DOI:10.15693/ijaist/2014.v3i6.65-75

time of selecting β_{min} and $\beta_{max.}$ In practice it is impossible to achieve extract βMpp point. Hence it requires a computational error which is nothing but Δβ around βMpp.

5. Simulation and results

5.1 Simulation of wind power equation

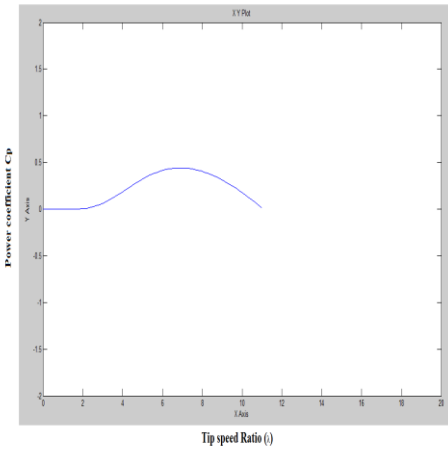
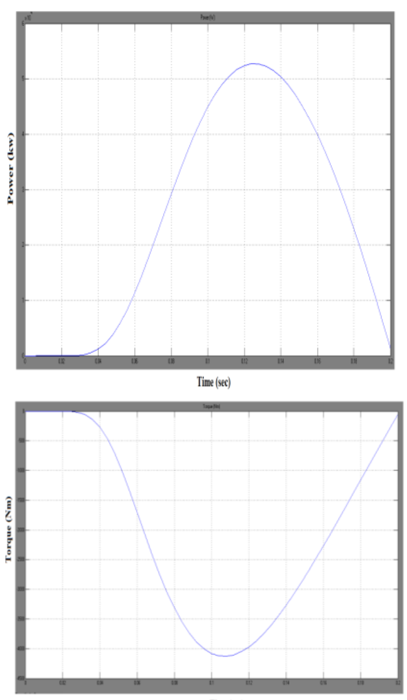


Fig 9: Cp versus tip speed ratio λ



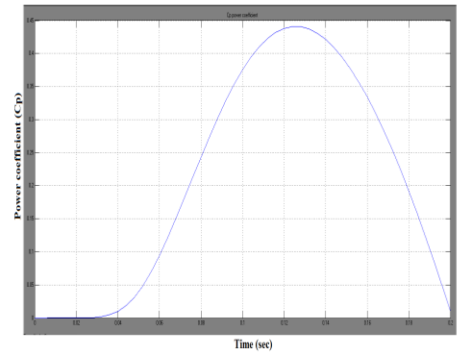


Fig 10: Simulation result of Power, Torque and Cp coefficient of power

5.2 Variable speed wind turbine system

5.2.1 Simulation for variable wind speed

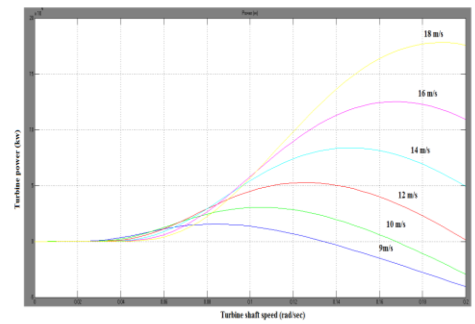


Fig 11: Simulation result of variable speed wind turbine system

5.2.2 Simulation of variable wind speed, power and torque

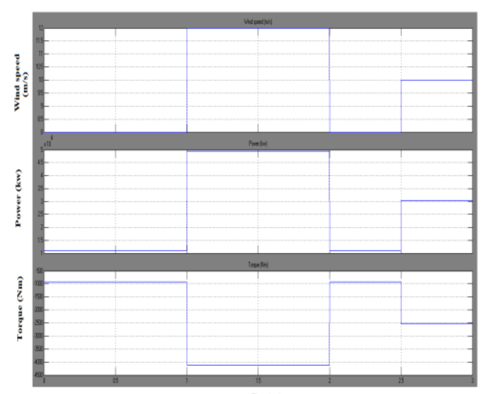


Fig 12 Simulation results of variable speed wind, power and torque

5.3 Simulation of wind power system connected PMSG

5.3.1 Simulation of constant wind speed profile

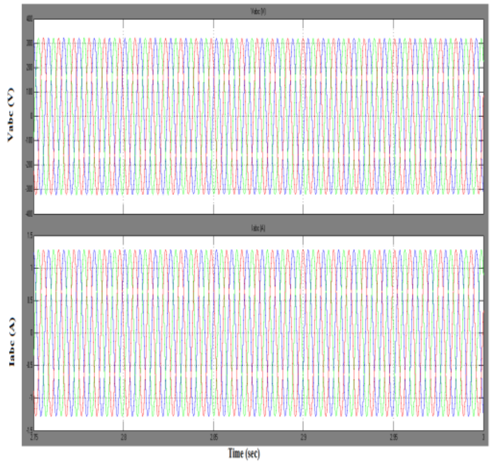


Fig 13 Output Vabc and Iabc for constant wind speed profile

5.3.2 Simulation of variable wind speed profile

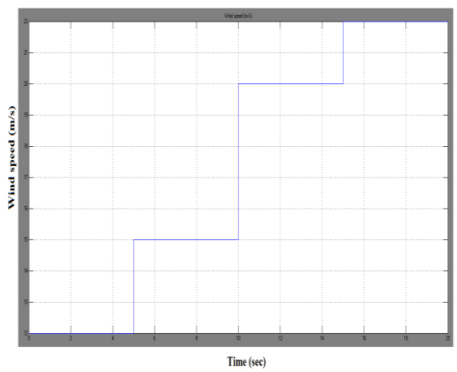


Fig14: Variable wind speed profile

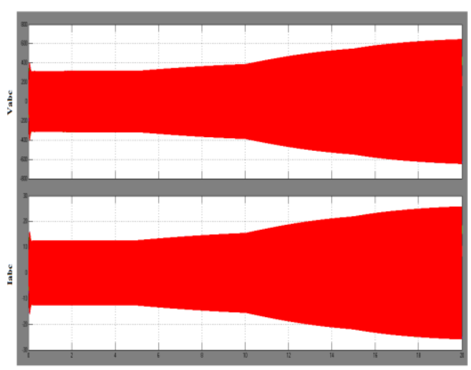


Fig 15: Output Vabc and Iabc for Variable wind speed profile

5.3.3 Simulation of rectifier connected to PMSG (AC-DC converter)

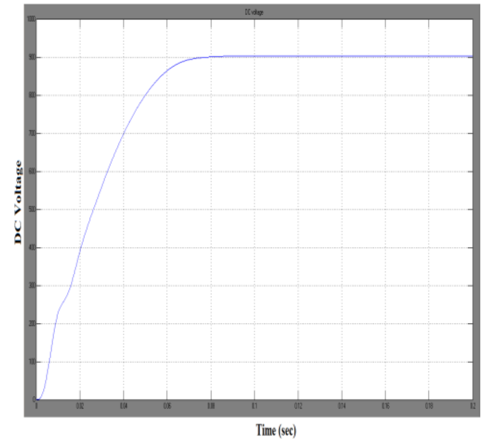
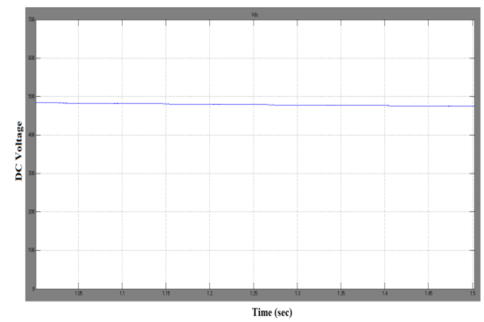
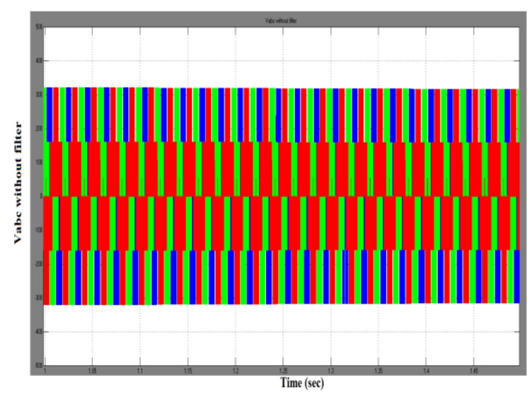


Fig 16: DC link voltage

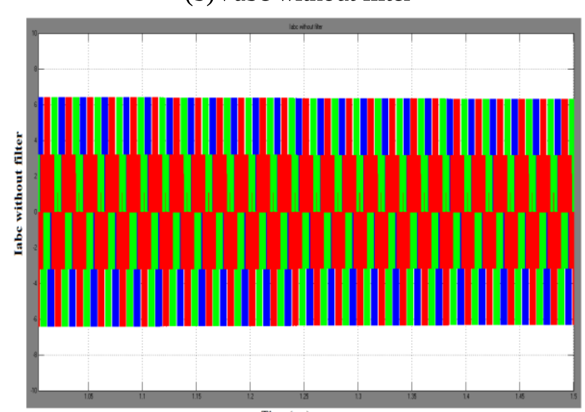
5.3.4 Simulation (AC-DC-AC) of PWM of inverter



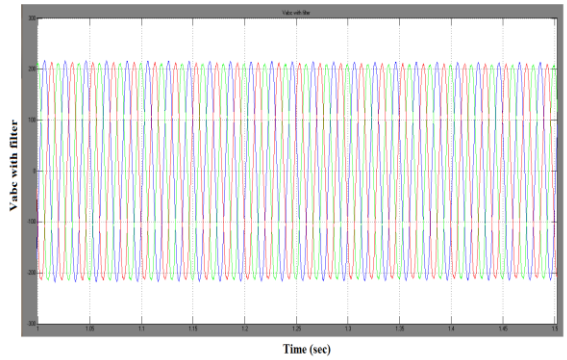
(a)Dc voltage



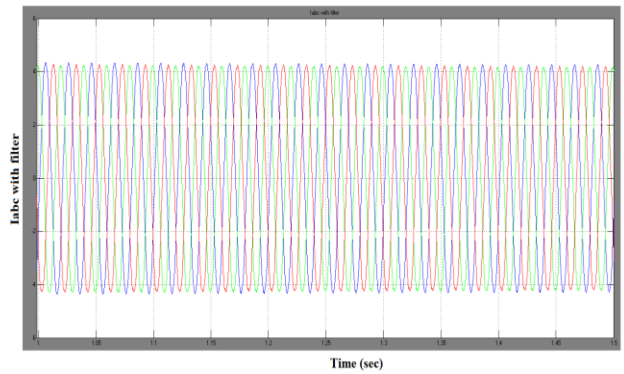
(b)Vabc without filter



(c)Iabc without filter



(d)Vabc with filter



(e)Iabc with filter.

Fig 17: Simulation results of (a) DC link Voltage. (b) Vabc without filter. (c) Iabc without filter. (d) Vabc with filter. (e) Iabc with filter.

5.4 Simulations of converter and their controller

5.4.1 Generator side controller (SVPWM)

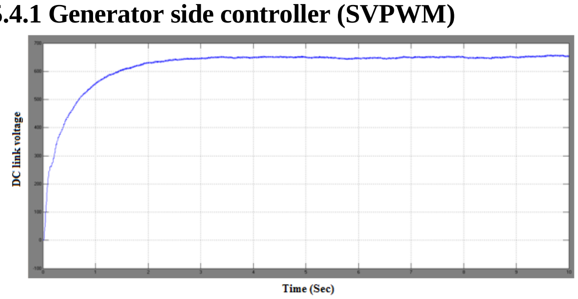


Fig 17: DC link Voltage

5.4.2 Grid side controller (SVPWM)

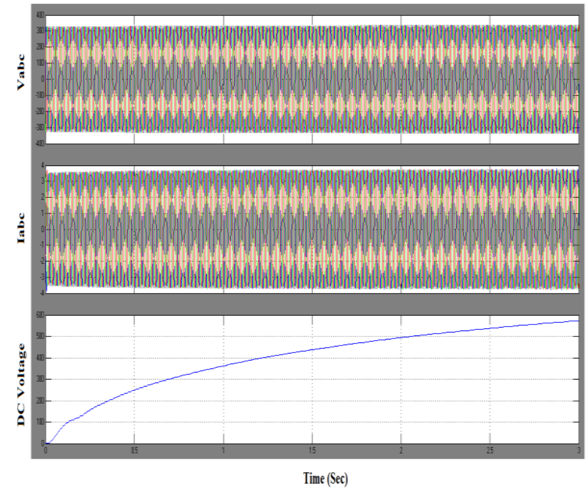


Fig 18: Simulation results of Vabc, Iabc and Vdc

5.5 Simulations result without MPPT

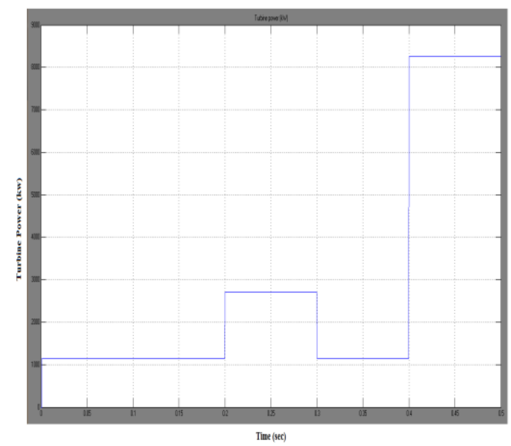
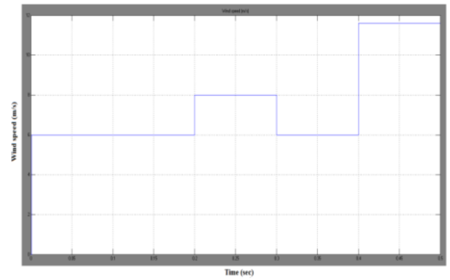


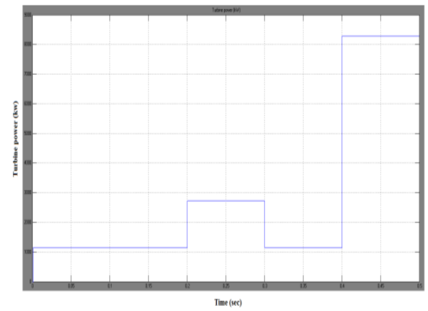
Fig 19: Simulation results turbine power without MPPT

Table No: 1 Variable wind speed turbine power without MPPT

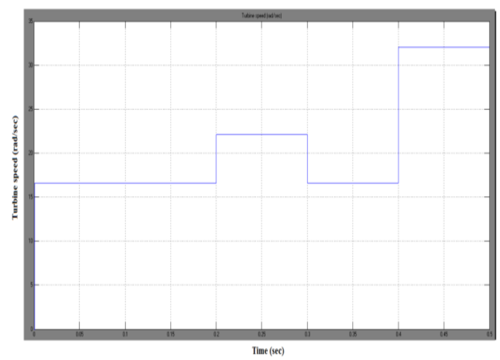
Wind speed (m/s)	**Turbine Power Without MPPT (kW)**	**Wind speed (m/s)**	**Turbine Power Without MPPT (kW)**	**Wind speed (m/s)**	**Turbine Power Without MPPT (kW)**
0	0	7	1813.78	14	14510.27
1	5.288	8	2707.45	15	17847
2	41.824	9	3854.95	16	21659.64
3	142.77	10	5288	17	25979.94
4	338.432	11	7038.32	18	30839.6
5	661	12	9137.66	19	36270.39
6	1142.20	13	11617.7	20	42304



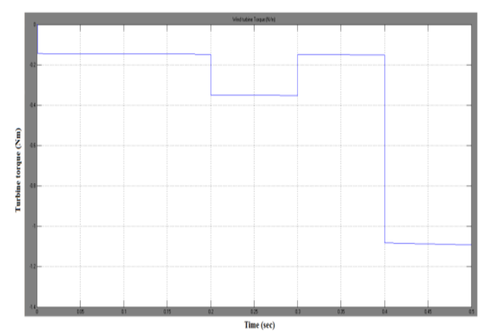
(a) Variable wind speed profile.



(b)Turbine Power (Kw).



(c)Turbine speed (rad/sec).



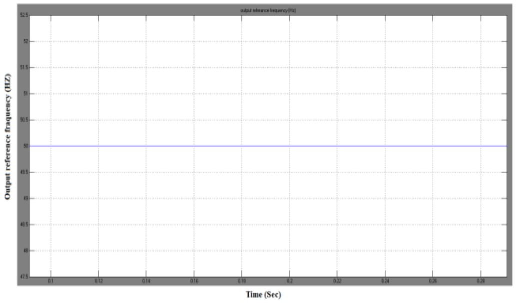
(d)Turbine torque (Nm).

5.7Simulations result with MPPT

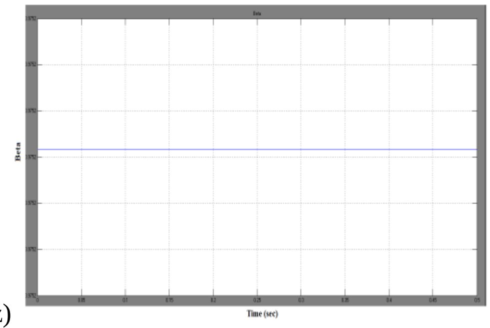
Table No:2 Variable wind speed turbine power with MPPT

Wind speed (m/s)	**Turbine Power Without MPPT (kW)**	**Wind speed (m/s)**	**Turbine Power Without MPPT (kW)**	**Wind speed (m/s)**	**Turbine Power Without MPPT (kW)**
0	0	7	1819.54	14	14556.34
1	5.3047	8	2716.05	15	17903
2	42.438	9	3867.19	16	21728.42
3	143.22	10	5304.79	17	26062.44
4	339.50	11	7060.67	18	30937.54
5	663.098	12	9166.67	19	36385.56
6	1145.83	13	11654.62	20	42438.33

International Journal of Advanced Information Science and Technology (IJAIST) ISSN: 2319:2682
Vol.3, No.6, June 2014 DOI:10.15693/ijaist/2014.v3i6.65-75

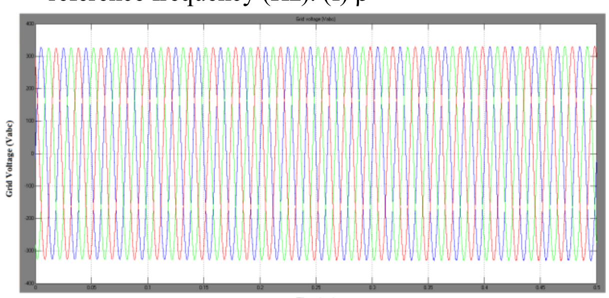


(e)Output reference frequency

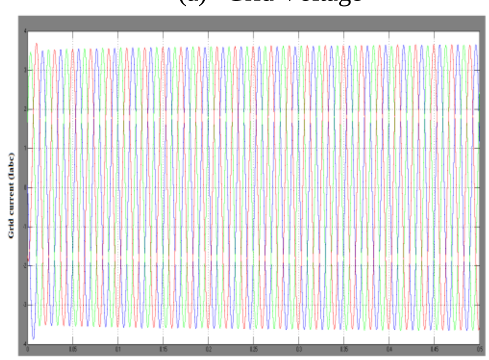


(Hz)
(f) β

Fig 20: Typical curves during the tracking of the MPP using the proposed MPPT algorithm. a) Wind speed. b)Turbine Power (Kw). (c)Turbine speed (rad/sec). (d)Turbine torque (Nm. (e) Output reference frequency (Hz). (f) β



(a) Grid Voltage



(b) Grid Current

Fig 21: Simulation result (a) Grid voltage and (b) Grid current

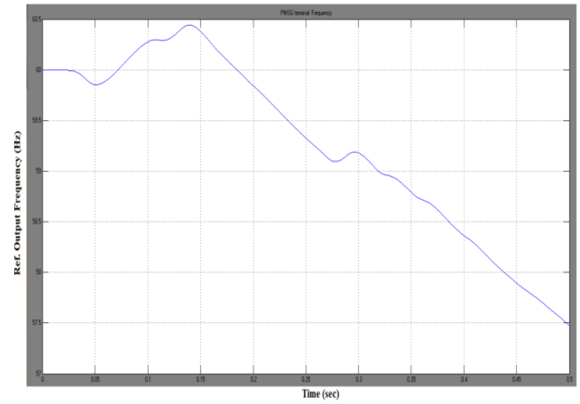


Fig.22: Frequency (fk) at stator terminals of the PMSG

Table No: 3 Comparison result without MPPT and with MPPT turbine power.

Wind speed (m/s)	**Turbine Power Without MPPT (kW)**	**Turbine Power With MPPT (kW)**	**Difference (kW)**
0	0	0	**0**
1	5.288	5.3047	**0.0167**
2	41.824	42.438	**0.6142**
3	142.77	143.22	**0.45**
4	338.432	339.50	**1.068**
5	661	663.098	**2.098**
6	1142.20	1145.83	**3.63**
7	1813.78	1819.54	**5.76**
8	2707.45	2716.05	**8.6**
9	3854.95	3867.19	**12.24**
10	5288	5304.79	**16.79**
11	7038.32	7060.67	**22.35**
12	9137.66	9166.67	**29.01**
13	11617.7	11654.62	**36.92**
14	14510.27	14556.34	**46.07**
15	17847	17903	**56**
16	21659.64	21728.42	**68.78**
17	25979.94	26062.44	**82.49**
18	30839.6	30937.54	**97.94**
19	36270.39	36385.56	**115.17**
20	42304	42438.33	**134.33**

6.Conclusions

A new maximum power point tracking (MPPT) algorithm for wind energy conversion system has been presented and implemented on a grid-connected system. The proposed algorithm was tested under different wind conditions including constant wind speed, abruptly changing wind speed, and randomly varying wind speed. In all the scenarios, the power extraction from the turbine was at the peak with respect to the wind curves for the turbine. The reduced ripple in power and increased efficiency are the biggest achievements of the Hill climb searching algorithm.

- By using this Hill climb searching algorithm (new P and 0), maximum power corresponding any wind speed can be captured. But time take to reach MPP is small as compared to P and O algorithm .So this algorithm used to reduce considerable amount of power loss during the tracking of MPP.
- The exact MPP is tracked using this hill climb searching algorithm, no extra hardware or measurement (sensor) are required compared to the other algorithm like calculation based, Anemometer- based, Tip speed ratio control , Power signal feedback control etc. hence the cost is not increased.
- This algorithm does not required information of turbine characteristics and wind speed measurement. It can be apply to any wind turbine system. Also this algorithm implementation in practical is simple as compared to other algorithm.

7 .REFERENCES

- [1] “World Energy Outlook,” International Energy Agencies, pp.303-338, 2010.
- [2] “World Wise energy report,” Conf. World wind energy Renew. Energy Exhib. WWEA, Cairo, pp.6-8, 2010.
- [3] “Global wind Report: Annual market update,” Global Wind Energy Council, pp.18-19, 2010.
- [4] G. D. Moor and H.J. Beukes, “Maximum power point trackers for wind turbines” in proc. 35th annu. IEEE Power Electron. Spec. Conf., Aachen, Germany, Jun.2004, pp. 2044-2049.
- [5] R. Datta and V. T. Ranganathan, “A method of tracking the peak power points for a variable speed wind energy conversion system,” in IEEE Trans. Energy Conversion., no. 1. vol. 18, pp. 163–168, Mar.2003.
- [6] Q. Wang and L.-C. Chang, “An intelligent maximum power extraction algorithm for inverter-based variable speed wind turbine systems,” IEEE Trans. Power Electron., vol. 19, no. 5, pp. 1242–1249, Sep. 2004.
- [7] Y. Xia, Khaled H. Ahmed and Barry W. Williams “A new maximum power point tracking technique for permanent magnet synchronous generator based wind energy conversion system” IEEE Trans. Power Electron., vol. 26, no. 12, pp. 3609–3620, Dec. 2011.
- [8] C. N. Bhende, S. Mishra, and S. G. Malla, “Permanent Magnet Synchronous Generator-Based Standalone Wind energy Supply system,” IEEE Trans. on Sustainable Energy Convers., vol. 2, no. 4, pp. 361–373, Oct. 2011.
- [9] H. Huang C. Mao J. Lu D. Wang “Small-signal modeling and analysis of wind turbine with direct drive permanent magnet synchronous generator connected to power grid” IET Renew. Power Gener., 2012, Vol. 6, Iss. 1, pp. 48–58.
- [10] Vivek Agarwal, Rakesh K. Aggarwal, Pravin Patidar, and Chetan Patki, “A Novel Scheme for Rapid Tracking of Maximum Power Point in Wind Energy Generation Systems” IEEE Trans. On energy conversion, vol. 25, no. 1, Mar 2010.
- [11] Mukund R. Patel, “Wind and Solar Power Systems” U.S. Merchant Marine Academy Kings Point, New York.
- [12] S.M.Barakati, M. Kazerani, andX.Chen, “A newwind turbine generation system based on matrix converter,” in *Proc. IEEE/PES General Meeting*, Jun. 2005, vol. 3, pp. 2083–2089.
- [13] T. Ackermann, “Wind power in power systems,” John Wiley and sons, England, 2005.
- [14] J. G. Slootweg, S. W. H. de Haan, H. Polinder and W. L. Kling. "General Model for Representing Variable Speed Wind Turbines in Power System Dynamics Simulations". IEEE Transactions on Power Systems, vol. 18, no. 1, 2003.

- [15] S. N. Bhadra, D. Kastha, S. Banerjee, "*Wind Electrical Systems*," Oxford University Press, New Delhi, 2009.
- [16] F. Mei and B. Pal, "Modal analysis of grid-connected doubly fed induction generators," *IEEE Trans. Energy Convers.*, vol. 22, no. 3, pp. 728–736, Sep. 2007
- [17] S.M.Barakati, M. Kazerani, andX.Chen, "A newwind turbine generation system based on matrix converter," in *Proc. IEEE/PES General Meeting*, Jun. 2005, vol. 3, pp. 2083–2089.
- [18] H. Polinder, F. F. A. van der Pijl, G. J. de Vilder, and P. J. Tavner, "Comparison of direct-drive and geared generator concepts for wind turbines," *IEEE Trans. Energy Convers.*, vol. 21, no. 3, pp. 725–733, Sep. 2006.
- [19] T. F. Chan and L. L. Lai, "Permanent-magnet machines for distributed generation: A review," in *Proc. 2007 IEEE Power Engineering Annual Meeting*, pp. 1–6.
- [20] Q. W. T. Tanaka, T. Toumiya, and T. Suzuki, "Output control by hill climbing method for a small scale wind power generating system," *Elsevier Int. J. Renewable Energy*, vol. 12, no. 4, pp. 387–400, Dec. 1997.
- [21] M.G. Simoes, B. K. Bose, and R. J. Spiegel, "Fuzzy logic based intelligent control of a variable speed cage machine wind generation system," IEEE Trans. Power Electron., vol. 12, no. 1, pp. 87–95, Jan. 1997.
- [22] Bagen and R. Billinton, "Evaluation of different operating strategies in small stand-alone power systems," *IEEE Trans. Energy Convers.*, vol. 20, no. 3, pp. 654–660, Sep. 2005.