Incremental Conductance Technique for a Hybrid Wind - Solar Energy System

T. Salma[1], R. Yokeeswaran[2]

[1]P. G Student [PSE], IEEE Member, Department of Electrical and Electronics Engineering
V.S.B. Engineering College, Karur-639111, Tamilnadu, India

[2]Assistant Professor, Department of Electrical and Electronics Engineering
V.S.B. Engineering College, Karur-639111, Tamilnadu, India

Abstract*:* ***In recent years, wind and solar energy has become one of the most important and promising sources of renewable energy. Wind energy demands additional transmission capacity and better means of maintaining system reliability. The variations of the maximum power point with solar irradiance level and temperature and the nonlinear behavior of Photo Voltaic systems complicate the tracking of the maximum power point. This paper proposes the maximization of the power output in a hybrid wind-energy system by the Pitch control of a Doubly Fed Induction Generator based wind energy system and by controlling the reference voltage in solar energy system by Incremental Conductance technique. The proposed method is highly efficient and can be implemented in real-time. This system is modeled using MATLAB/Simulink. Simulation results prove the efficiency of this technique.***

Keywords: MPPT, PV System, Wind turbine, Pitch angle, DFIG, INCCOND.

1. Introduction

In recent years, there is increase in the fuel prices due to which the renewable source of energy is gaining importance. Solar as well as Wind energy has become the most significant and promising sources of renewable energy. These sources are combined to form a hybrid system as it provides the non-polluting, safe energy.

The technology development related to wind systems lead to the development of a generation of variable speed wind turbines like Doubly Fed Induction Generator (DFIG) based wind energy system which is advantageous when compared with the fixed speed wind turbines.

The Maximum Power Point Tracking (MPPT) techniques increases the power output from PV system as well as supports the lifetime of the system. The power obtained from hybrid Wind-Solar energy systems depends on the power set point traced by maximum power point tracking.

2. Overview

The main objective is to implement the Incremental Conductance Method in a Wind and Photo Voltaic energy system (Hybrid system) for the purpose of Maximum Power Point Tracking.

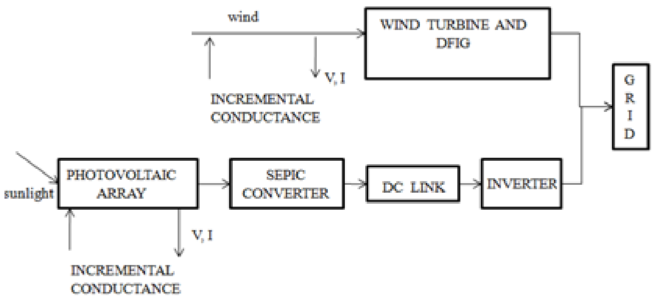

Figure 1: Block diagram of Hybrid System

3. MPPT Techniques

Wind turbine system has the major MPPT techniques like Tip Speed Ratio (TSR) control, Power Signal Feedback (PSF) control, Hill climbing search (HCS) method. TSR, defined as the ratio of turbine rotor tip speed to the wind speed.

TSR calculation requires the measured value of wind speed and turbine speed data. Wind speed measurement increases the system cost and also leads to practical difficulties.

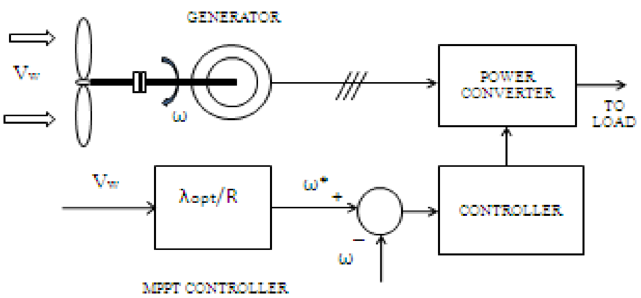

Figure 2: Block diagram of TSR control

Power Signal Feedback (PSF) needs the details of maximum power curve of the wind turbine and it is tracked by the control mechanisms. For every wind turbine, this curve is obtained from simulation or tests. This control method increases cost of implementation and is difficult. Fig.2. shows the logic for the power signal feedback control.

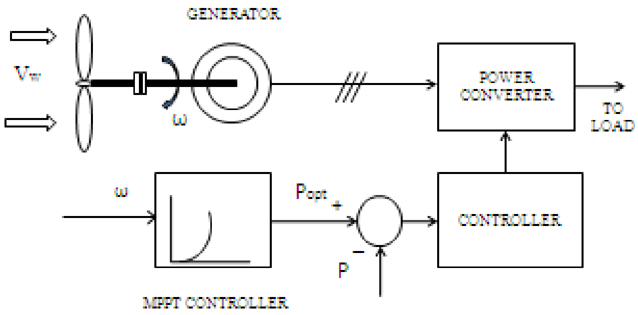

Figure 3: Block diagram of PSF control

Hill climbing search (HCS) method continuously searches for the peak power of the wind turbine. It dynamically modifies the speed command in accordance with the magnitude and direction of change of active power in order to reach the peak power point.

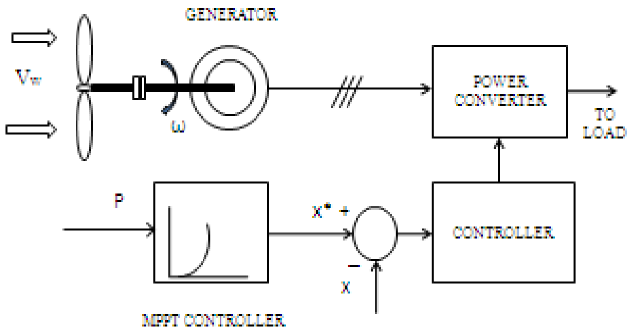

Figure 4: Block diagram of HCS control

Incremental Conductance Technique (INCCOND) method searches for the peak power of the Hybrid system individually. Thereby it modifies the reference voltage in solar system and pitch in the wind system. It offers effective solution under varying atmospheric conditions. The tracking algorithm, depending upon the location of the operating point computes the desired optimum signal in order to drive the system to the point of maximum power.

2.1 INCCOND in Solar System

The incremental conductance (IncCond) method employs the slope of the PV array power characteristics to track MPP. This method is based on the fact that the slope of the PV array power curve is zero at the MPP, positive for values of output power smaller than MPP, and negative for values of the output power greater than MPP. The slope of the PV array power curve (dP/dV) or (ΔI/ΔV)

zero at the MPP

$$(dP/dV = 0) \text{ or } (\Delta I/\Delta V = -I/V)$$

positive for values of the output power smaller than MPP

$$(dP/dV > 0) \text{ or } (\Delta I/\Delta V > -I/V)$$

negative for values of the output power greater than MPP

$$(dP/dV < 0) \text{ or } (\Delta I/\Delta V < -I/V)$$

The MPP can thus be tracked by comparing the instantaneous conductance (I/V) to the incremental conductance (ΔI/ΔV).

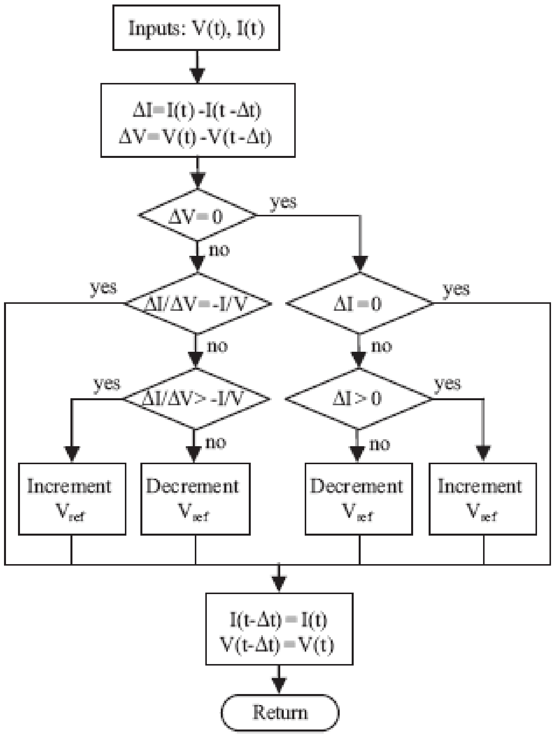

Figure 5: Block diagram of INCCOND for PV system

2.2 Pitch Control Using INCCOND

Wind turbine consists of three blades, a servomotor, a controller, rotor rotation sensor, a generator, and some mechanical components. The blades are developed based on NACA (National Advisory Committee for Aeronautics). A Servomotor is used to control the pitch angle of the blade. Fig. 5 shows a diagram block of pitch angle control of wind turbine using INCCOND. The pitch angle of the blade is controlled to maximize the rotational speed of wind turbine and thus the output mechanical power of wind turbine. The wind turbine mechanical power (P) is maximized.

Figure 6: Pitch angle control

To maximize the wind turbine mechanical power, the power coefficient of the wind turbine is optimized by controlling the pitch angle of the blade. Pitch angle (β) is the angle between the direction of wind and the direction perpendicular to the plane of blades. The wind turbine mechanical power (P) can be expressed as

$$\mathbf{P=1/2\rho_{air}Av^3C_P(\lambda, \beta)}$$

Where, ρ_{air} - air density

A - area swept by the blades

v - wind speed velocity

$C_P(\lambda, \beta)$ - coefficient of the wind turbine with the tip speed ratio of λ and blade pitch angle of β.

4. Doubly Fed Induction Generator

The studied system here is a variable speed wind generation system based on Doubly Fed Induction Generator (DFIG). The DFIG technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed, while minimizing mechanical stresses on the turbine during gusts of wind. The stator of the generator is directly connected to the grid while the rotor is connected through a back-to-back converter.

The AC/DC/AC converter is basically a PWM converter which uses sinusoidal PWM technique to reduce the harmonics present in the wind turbine driven DFIG system. Here Crotor is rotor side converter and Cgrid is grid side converter, Where Vr is the rotor voltage and Vgc is grid side voltage. To control the speed of wind turbine gear boxes or electronic control can be used.

Power flow of the rotor is bidirectional. When $\omega_r > \omega_s$, the power flows from the rotor to the power grid and when $\omega_r < \omega_s$, the rotor absorbs the energy from the power grid.

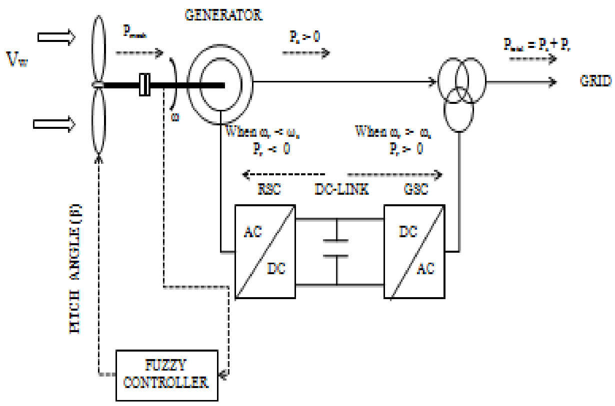

Figure7: Power flow of DFIG

Power electronic converters between the rotor and grid adjust the frequency and amplitude of the rotor voltage. The control of the rotor voltage allows the system to operate at a variable-speed while still producing constant frequency electricity.
Where, ω_r is the rotor rotational speed.
ω_s is the synchronous speed.

5. Simulation

A 9 MW wind farm consist of six 1.5 MW wind turbines is connected to a 25 kV distribution system. The effect of change in wind speed and change in supply frequency are also taken into consideration for the performance analysis of DFIG. The PV array is connected to the grid through the SEPIC converter. The change in irradiation and temperature is also considered. The wind turbine with pitch controlled by ICCOND for variable low rated wind speed and reference voltage with which the solar array operates also controlled by INCCOND is developed and demonstrated. The performance analysis is done using simulated results obtained from scope, which are found using MATLAB software.

6. Simulation Results

The voltage, current and the power produced in a hybrid system is shown below. The pitch angle of the turbine blades is zero degree. Then the pitch angle is increased from 0 deg in order to limit the mechanical power.

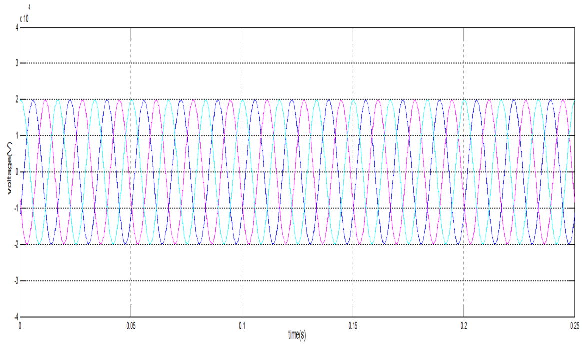

Figure 8: Simulated Output Voltage Waveform (INCCOND)

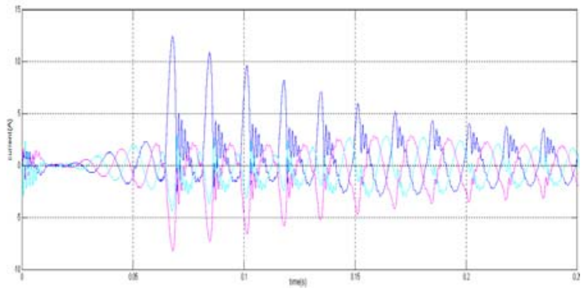

Figure 9: Simulated Output Current Waveform (INCCOND)

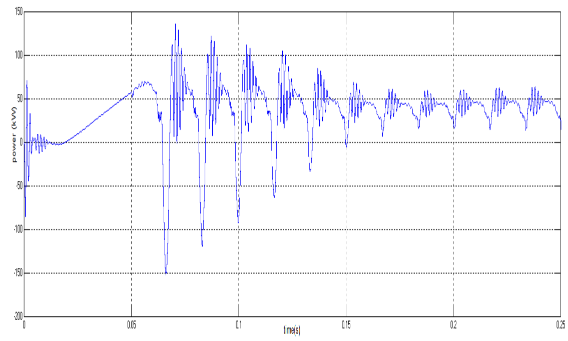

Figure 10: Simulated Output Power Waveform (INCCOND)

The wind turbine with pitch control for variable low rated wind speed has been developed and demonstrated. The use of pitch control can improve mechanical power response performance of wind turbine compared to the use of a fixed pitch angle or without control.

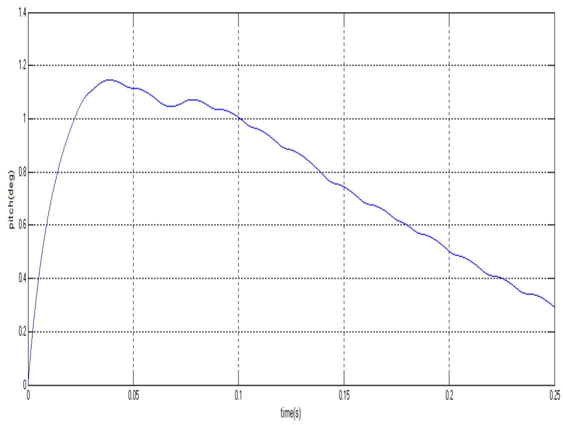

Figure 11: Simulated Output waveform for Pitch Angle

With the INCCOND approach, it shows the fine tuning and the values range around 1 degree. It improve mechanical power response performance of wind turbine compared to the use of a fixed pitch angle or without control.

7. Conclusion

Incremental Conductance technique offers effective solution under rapidly changing atmospheric solutions in a PV system. INCCOND tracks the MPP rapidly and does not oscillate around the MPP. The INCCOND proves the effectiveness in providing the optimum pitch, such that the maximum power is tracked.

References

[1] Ali Reza Reisi, Mohammad Hassan Moradi and Shahriar Jamasb, "Classification and comparison of maximum power point tracking techniques for photovoltaic system: A review", Renewable and Sustainable Energy Reviews 19, pp. 433–443, (2013).
[2] Ashwani Kumar and Sanjay K. Jain, "A Review on the Operation of Grid Integrated Doubly Fed Induction Generator," International Journal of Enhanced Research in Science Technology and Engineering, Vol. 2, No. 6, (June 2013).
[3] Aishwarya P. Mulmule, Rambabu A. Vatti and Pratik M. Porwal, "MPPT Technique to Improve Efficiency in Wind-Solar Hybrid System", International Journal of Electrical Engineering and Technology, Vol.4 Issue.1, pp. 74-82 (2013).
[4] Dinakaran.C, Balasundaram.G, "A Newly Constructed Rectifier for Hybrid Wind-Solar Energy System", Global Research Analysis, Vol.2, Issue. 8, (Aug 2013).
[5] J.S.Lather, S.S Dhillon, S.Marwaha, "Modern control aspects in Doubly Fed Induction Generator based power systems: A Review," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 2, No. 6, (June 2013).
[6] Nitesh Kumar, Suraj Kumar and Abhishek Kumar, Kunal kumar, Vinay Kumar, Vivek Sinha, "Hybrid Wind-Solar Energy", Undergraduate Academic Research Journal, Vol.1, Issue. 3,4, (2012).
[7] Lokanadham.M, Vijaya Bhaskar.K, "Incremental Conductance Based Maximum Power Point Tracking (MPPT) for Photovoltaic system", International Journal of Engineering Research, Vol.2 Issue.2, pp. 1420-1424, (Apr 2012).
[8] Aryuanto Soetedjo, Abraham Lomi and Widodo Puji Mulayanto, "Modelling of wind energy system with MPPT control," International Conference on Electrical Engineering and Informatics, (July 2011).
[9] Jogendra Singh Thongam and Mohand Ouhrouche, "MPPT control methods in wind energy conversion systems," Intech 978-953-307-508-2, (June 2011).
[10] Aravindan.P, Thangavel.S and Sanavullah.M.Y, "Maximum Energy Extraction in Wind Solar Hybrid Energy Conversion System", European Journal of Scientific Research, Vol.63 No.1, pp. 90-98, (2011).
[11] Joanne Hui, Alireza Bakhshai and Praveen K Jain, "A Hybrid Wind-Solar Energy System: A New Rectifier Stage Topology", Queen's center for Energy and Power Electronics Research, pp. 155–161 (2010).
[12] J. H. Laks, L. Y. Pao, and A. D. Wright, "Control of Wind Turbine: Past, Present, and Future," US National Science Foundation(NSF Grant CMMI-0700877), (2009).
[13] E. Koutroulis and K. Kalaitzakis, "Design of a maximum power tracking system for wind-energy-conversion applications," IEEE Transactions on Industrial Electronics, vol. 53, (April 2006).
[14] S. Suryanarayanan and A. Dixit, "On the Dynamics of the Pitch Control Loop in Horizontal Axis Large Wind Turbines," Proc. Amer. Ctrl. Conf., pp. 686–690, (June 2005).
[15] Quincy Wang and Liuchen, "An Intelligent Maximum Power Extraction Algorithm for Inverter-Based Variable Speed Wind Turbine Systems," IEEE Transactions on Power Electronics, VOL. 19, NO. 5, (September 2004).
[16] T. Tanaka and T. Toumiya, "Output control by Hill-Climbing method for a small wind power generating system," Renewable Energy, vol. 12, no.4, pp. 387–400, (1997).