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MPPT Control Algorithm for Variable Speed WECS

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***Abstract*—Wind energy is regarded the most prominent development of the world's energy challenges as it is clean, fuel free and a renewable source of power. Wind plants have graced from steady advances in technology. The amount of energy obtained from a Wind Energy Conversion System (WECS) not only depends on the characteristics of the wind regime at the site, but it also depends on the approach for the control used for the WECS. Wind energy supply fluctuates over day time, through the year and across region. The demand of electrical power varies over daytime and over the year but not correlated with the deviation of wind. To reach the upper limits of maximum power extraction from the wind one needs to be in command of the power electronic circuitry in order to run the system efficiently. Hence here is a inevitability to take up a project titled "MPPT Control Algorithm for Variable Speed WECS" using Perturb & Observe method. This thesis presents the modeling and simulation of a 1.5 kW variable speed wind energy conversion system. The controller part is developed for grid-side inverter as well as for the generator-side converter. The control of inverter is achieved using three sensors. Sinusoidal currents are supplied through PWM inverter by controlling the active and reactive current components in d–q rotating reference frame. While the quadrature-axis current is controlled to obtain maximum power of the wind turbine, the direct – axis current is adjusted to control the power factor. The simulated outcomes are represented incorporating P&O MPPT controller method using MATLAB 07. It indicates that the proposed format provides a viable solution for the variable-speed wind turbine using an efficient power conditioning system.**

I. INTRODUCTION

Resolving the demand for world's growing energy, curtailing associated impacts on the environment and bringing down the potential geopolitical tensions connected with increased competition for energy supplies represent some supreme technical and policy dispute of the next several decades. Fossil fuels supply 80 percent in excess of the world's primary energy but they are finite resources and major contributors to global climate change. The procedures for their ultimate replacement with clean, affordable and sustainable energy sources at the scale required to power the whole system are not yet fully obvious, readily available or, in many occurences, technically feasible. Turning off the carbon releases the first step and many of the elucidation are recognizable: windmills, solar panels, nuclear plants. Energy mix of all three industry science, although each has its issues, comprising noise from windmills and radioactive fritter away from nukes. Likewise, around the world the existing energy infrastructures are complicated and very large, represent massive capital investment and cover operational life spans of 50 years or more. In windmills (a much older

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technology), wind energy was used for purposes like grinding grain or spices, pumping water, sawing wood or hammering seeds (Figure. 1(a)). The progression of modernized turbines is remarkable success stories of scientific and engineering skill, united with a strong entrepreneurial fortitude. In recent years the progress of wind energy around the world has been consistently remarkable, with the main engineering challenge to design an efficient wind turbine and harness that energy and turn it into electricity. Figure 1(b) shows a current wind turbine structural design.

Figure.1 (a) Conventional windmill design, (b) Modern WECS integrate well in urban environments

In the last 25 years turbines have increased in power by a factor of 100, the cost of energy has reduced and the industry has moved from an idealistic fringe activity to the edge of conventional power generation. As of the end of 2015, the worldwide total cumulative installed electricity generation capacity from wind power amounted to 432,883 MW, an increase of 17% compared to the previous year. Global wind power installations increased by 63,330 MW, 51,447 MW and 35,467 MW in 2015, 2014 and 2013 respectively (GWEC), due to a broadening of the worldwide wind energy market to engage a spread of new countries across all continents. Stabilization of greenhouse-gas (GHG) emissions is essential, which requires that annual emissions be brought down to the level that balances the Earth's natural capacity to remove such gases from atmosphere. Most countries have formulated policies to support the wind industry, which is a powerful motivation that has seen wind turbine innovation across the globe. The updates in configurations of computer and related systems past 10 years provide numerous ways for improving the sector advancement. Incorporation of huge amount of wind power into electric power system takes place; several technical problems will be encountered that need innovative unfolding. The approach relies on computer modeling and simulations to develop effective control schemes to ensure reliability of the WECS and smooth assimilation of wind power into the grid.

II. MPPT- Maximum Power Point Tracking

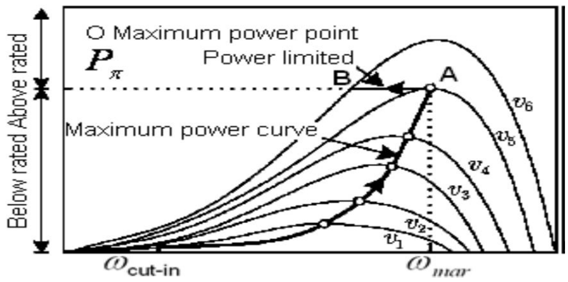


Figure.2: Best possible Power Point tracked. [8]

Figure2. shows the power characteristics curve of wind turbine where best possible power point is tracked. The controller requires both voltage and current inputs for operation of WECS at maximum power point. MPPT is a very vital necessity in a system of energy conversion from a non-conventional energy resource. The maximum extractable power from a renewable energy source not only depends on the strength of the source but also on the operating point of the energy conversion system. Thus MPPT is of the paramount importance in renewable energy conversion systems for not only to maximize the system's efficiency but also to minimize the return period of the installation cost. In WECS the interpretation of MPPT is to optimize the generator speed relative to the wind velocity such that the power is maximized in WECS.

A. Perturbation and Observation Technique

MPPT means that the WECS is always made-up to be operated at utmost output voltage/current rating. The proposed MPPT algorithm for control uses a “Perturbation and Observation” (P&O) method that proves to be efficient in tracking the MPP of the WECS for a wide range of wind speeds. By constantly perturbing the WECS MPPT algorithm operates so as to increase or decrease the output voltage of the WTG which is rectified and thus controlling speed of rotation the turbine rotor comparing the actual output power with the previous perturbation sample. If the power is increasing, in the following cycle so that the rotor speed will be increased, the perturbation will persist in the same direction, otherwise the perturbation path will be inverted.

B. Functional Block-Diagram

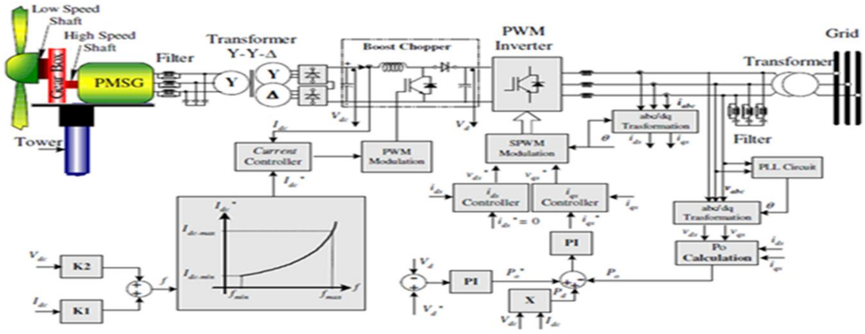


Figure.3: A seriestype12 pulse rectifier and PWM inverter for WP generation system [1]

Figure.3 displays the system of a full power converter for a variable-speed WP generation system. The proposed power-conditioning system, connected to an PMSG driven by a wind turbine, consists of a series-type12 pulse rectifier and an inverter. Table1 shows specifications for PMSG. The 12 pulse rectifier is energized by Y/Y/Δ transformer with a turns ratio of 2:1:$\sqrt{3}$, where in secondary line to line voltages have the matching value. By means of three-phase transformers the 3-phase voltage--fed PWM inverter is linked to the power grid. The power converter is a customary two-level 3-leg voltage controlled voltage source inverter. The grid-side inverter is controlled for achieving the control of MPPT by controlling its active current. The PWM inverter is employed to provide sinusoidal currents to the utility line by controlling the active current and reactive current components in the *q-d*rotating reference frame. While the *q*-axis active current of the PWM inverter is regulated to follow the optimized active current reference so as to track the upper limit of power from wind turbine, the *d*-axis reactive current can be fine-tuned so as tocontrol the power factor. Moreover, it is possible to have high generator efficiency with connecting a passive generator filter on the generator terminals. The passive filters are used to compensate harmonic currents produced by a seriestype12 pulse diode-rectifier as well as to smooth-out the ripple on the generated compensation voltages.

TABLE I. SPECIFICATIONS OF PMSG[1]

Number of pair poles Pn	3
Magnet flux-linkage $\sqrt{3/2}$ øa = φa	0.2878
q-axis inductance Lq	11.96mH
d-axis inductance Ld	8.90mH
Armature resistance r_s	0.774
Maximum current I_{am}	6.3A
Rated power	1.5kW
Rated speed	1750 rpm
Rated voltage	190 V

C. MPPT-Control for PWM Inverter

The MPPT-control at inverter side is achieved using three sensors, namely
Phase-Locked-Loop Circuit, PID controller ,abc/dqo transformation

1 Phase. Locked. Loop. Circuit - The Laplace. Transform. permits the representation of. time. Response. $f(t)$. of a system in. the complex. Domain F(s). This response. is two-fold in nature including. both transient and steady. state solutions. Thus, all. operating circumstances are contemplated.. and evaluated. The use of

Laplace transform. must be justified for the PLL. which includes. both linear and. nonlinear functions as it will. be valid only. for positive real. time linear parameters.

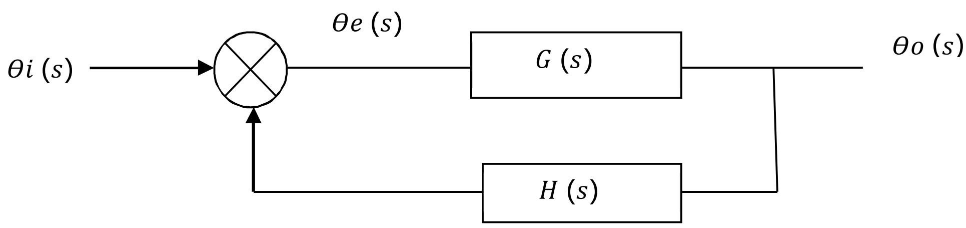


Figure.4: Feedback System

Using servo theory, the following relationships can be obtained.

$$\theta_e(s) = \frac{1}{1+G(s)H(s)} = \theta_0 \tag{1}$$

$$\theta_0(s) = \frac{G(s)}{1+G(s)H(s)} = \theta_i \tag{2}$$

These parameters relate. to the functions of a PLL as shown. in Figure 4.

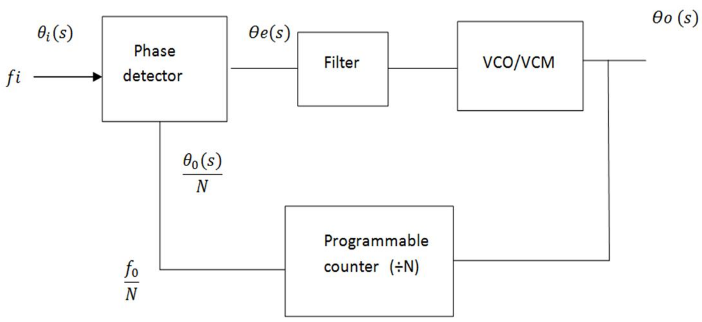


Figure.5: Phase. Locked. Loop.

Figure 5 depicts the PLL. circuit. Here the phase detector generates a voltage proportional to the phase difference. between the signals θ_0 and $\frac{\theta_0}{N}$. This voltage upon filtering is used as the control signal for the VCO/VCM (Voltage. Controlled Multi vibrator). Since the VCO/VCM produces a frequency proportional to its input voltage, any time. variant signal appearing on the control. signal will frequency. modulate the. VCO/VCM. The output frequency. during phase. Lock. is given. by,

$$f_0 = N f_i \tag{3}$$

The phase. detector, filter, and VCO/VCM compose. the feed forward. path with the. feedback. path containing. the programmable divider. Removal of the. programmable counter. produces unity gain. in the feedback path. (N = 1). As a result, the output. frequency is then. equal to that of. the input. Various types and. orders of loops. can be .constructed depending upon. the configuration of the. overall loop transfer. function.

PID Controller.

A proportional–integral–derivative. controller (PID controller) is a generic. control loop feedback. mechanism (controller) widely used. in industrial control systems – a PID is the. most commonly used feedback. controller. A PID. controller determines an "error" value. as the difference. between a measured process. variable and a desired. set point. The. controller attempts to minimize. the error by adjusting. the process control. inputs. A PID controller will be called a PI, PD, P or I controller in the absence of the respective control actions. PI controllers are fairly common, since derivative action is sensitive to measurement noise, whereas the absence of an integral term may prevent the system. from reaching its target value due to the control action.

The PID controller. calculation (algorithm) involves three. separate constant parameters, and is. accordingly sometimes called three-term control: the proportional, the integral and derivative. values, denoted P, I, and D. Heuristically, these values can be. interpreted in terms of. time: P depends on the present error, I on the accumulation. of past errors, and D is. a prediction of. future errors, based on current. rate of change. The weighted. sum of these three. actions is used to. adjust the process via. a control element. such as the position. of a control valve or the. power supply of a heating. element. In the absence. of knowledge of the. underlying process, a PID. controller is the best controller. By tuning the. three parameters in the PID. controller algorithm, the controller. can provide control action designed for. specific process. requirements. The response. of the controller can be. described in terms of the. responsiveness of the controller. to an error, the degree. to which the .controller overshoots the set. point and the degree .of system oscillation. This is achieved. by setting the other parameters. to zero.

Proportional. term

The proportional .term (sometimes called *gain*) makes a change. to the output that is proportional. to the current .error value. The proportional. response can be adjusted. by multiplying the error. by a constant Kp, called the. proportional gain.

The proportional term. is given by: $$Pout = Kp\, e(t) \qquad (4)$$

Where,Pout: Proportional term. of output Kp: Proportional gain, a tuning. parameter
SP: Set point, the desired. value PV: Process value. (or process variable), the measured value
e: Error = SP – PV t: Time or instantaneous. time (the present)

Integral. term- The contribution. from the integral. term (sometimes called *reset*) is proportional. to both the magnitude. of the error and the duration. of the error. Summing the instantaneous. error over time (integrating the error) gives. the accumulated offset. that should have been. corrected previously. The accumulated. error is then multiplied. by the integral gain and. added to the controller. output. The magnitude of the contribution. of the integral term to the overall. control action is determined. by the integral gain, Ki.

The integral term is given by: $$Iout = Ki \int_0^{\tau} e(\tau)\, d\tau \qquad (5)$$

Where, I_{out}: Integral term. of output Ki: Integral gain, a tuning. parameter
SP: Set point, the desired. value PV: Process value (or process variable), the measured. value
e: Error = SP – PV t: Time or instantaneous. time (the present)
τ: a dummy integration. variable.

2.4.3 abc/dqo transformation

The abc to dq0 transformation computes. the direct axis, quadrature axis. and zero sequence quantities. in a two-axis rotating reference. frame for a three-phase. sinusoidal signal. The following. transformation is used for three-phase. voltage:

$$V_d = \frac{2}{3}\left(V_a \sin\omega t + V_b \sin(\omega t - \frac{2\pi}{3}) + V_c \sin\left(\omega t + \frac{2\pi}{3}\right)\right) \qquad (6)$$

$$V_q = \frac{2}{3}\left(V_a cos\omega t + V_b\, cos\left(\omega t - \frac{2\pi}{3}\right) + V_c \cos(\omega t + \frac{2\pi}{3})\right) \qquad (7)$$

$$V_o = \frac{1}{3}\left(V_a + V_b + V_c\right) \qquad (8)$$

Where ω= rotation speed (rad/s) of the rotating. frame.

The transformation in the case. of a three-phase current used is:

$$I_d = \frac{2}{3}\left(I_a \sin\omega t + I_b \sin(\omega t - \frac{2\pi}{3}) + I_c \sin\left(\omega t + \frac{2\pi}{3}\right)\right) \qquad (9)$$

$$I_q = \frac{2}{3}\left(I_a cos\omega t + I_b cos\left(\omega t - \frac{2\pi}{3}\right) + I_c \cos(\omega t + \frac{2\pi}{3})\right) \qquad (10)$$

$$I_o = \frac{1}{3}\left(I_a + I_b + I_c\right) \qquad (11)$$

This transformation is .commonly used in three-phase. electric machine. models, where it is known as a Park. transformation. It allows eliminating time-varying. inductances by referring the stator. and rotor quantities to a fixed or rotating reference frame. In the. case of a synchronous machine, the stator quantities. are referred to the rotor. I_d and I_q represent the two DC. currents flowing in the two equivalent rotor windings (d winding. directly on the same. axis as the field winding, and q winding. on the quadratic axis), producing .the same flux as the stator I_a, I_b and I_c currents.

III. Modeling. Of WECS

A. Signal Builder. Block

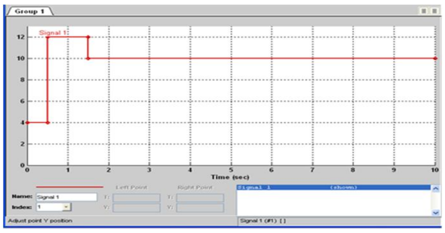


Figure.7: Signal Builder. Block

The figure. 7 shows signal. builder block. It is used to give wind speed. as an input to the. wind turbine. Wind. speed is in the range. of 4 – 12 m/s. The signal is given. along the y – axis with. a sample time. of 0.5 sec.

B. Wind Turbine

Figure08 implements. a model of a variable. speed wind turbine.

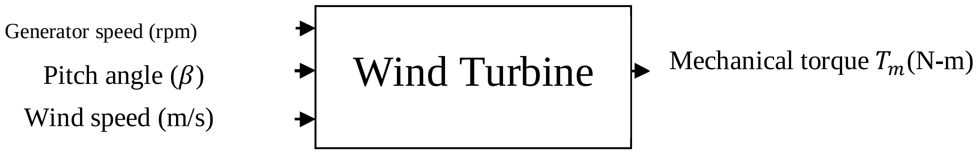


Figure.8: Wind Turbine Model

The model is based on the steady.-state power characteristics. of the turbine. The stiffness of the. drive train is infinite. and the friction factor .and the inertia of the turbine must be. combined with those of the generator. coupled to the turbine. The output. power of the turbine. is given by the following. equation.

$$Pm = \frac{1}{2}\,\rho\, Cp\, A\, V^3 \tag{12}$$

Where

Pm - Mechanical output power. of the turbine (W), Cp - Performance coefficient. of the turbine

ρ - Air density (kg/m^3) A - Turbine swept area (m^2) V - Wind speed (m/s)

Inputs:

- Generator speed (rpm) - The generator speed (1750 rpm) is given as input. to the wind turbine.
- Pitch angle (deg) - It is denoted. by the symbol β. The pitch angle $\beta = 0$ degree is given for. maximum power transfer.
- Wind speed (m/s) - The wind speed. is given in the range of 4 - 12 m/s for a variable speed. wind turbine.

Output:

- Mechanical torque Tm – The output of. wind turbine Tm (N-m) is given as an input. to the generator. The nominal torque of the. generator is based on the nominal. generator power and speed ($T_m \propto \frac{P}{N}$).

C. Permanent Magnet. Synchronous Machine

Model the dynamics of a three-phase. permanent magnet synchronous. machine with sinusoidal flux. distribution, or trapezoidal flux distribution.

Figure 9 shows the Permanent Magnet .Synchronous Machine block which operates in either generator. or motor mode. The mode of operation is dictated by the sign of the mechanical torque (positive for motor mode, negative for generator mode). The electrical and mechanical parts of the machine are each represented

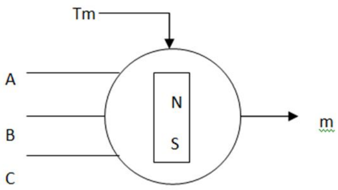


Figure. 9: Basic block of Permanent Magnet Synchronous Machine

by a second-order state-space model. The sinusoidal model assumes that the flux established by the permanent magnets in the stator is sinusoidal, which implies that the electromotive forces are sinusoidal. For the trapezoidal machine, the model assumes that the flux established by the permanent magnets is purely trapezoidal, which implies a trapezoidal electromotive forces waveform.
The block implements the following equations for a sinusoidal model electrical system. These equations are expressed in the rotor reference frame (q-d frame).

$$\frac{d}{dt}\, i_d = \frac{1}{L_d}\, V_d - \frac{R}{L_d}\, i_d + \frac{L_q}{L_d}\, p\omega_r i_q \tag{13}$$

$$\frac{d}{dt}\, i_q = \frac{1}{Lq}\, V_q - \frac{R}{Lq}\, i_q - \frac{L_d}{L_q}\, p\, \omega_r\, i_d - \frac{\lambda\, p\omega_r}{Lq} \tag{14}$$

$$T_e = 1.5\; p\,[\,\lambda\, i_q + (L_d - L_q)\, i_d\, i_q\,] \tag{15}$$

Where (all quantities in the rotor reference frame are referred to the stator)

L_q, L_d - q and d axis inductances
R - Resistance of the stator windings
i_q, i_d - q and d axis currents
V_q, V_d - q and d axis voltages
ω_r - Angular velocity of the rotor
p - Number of pole pairs
Te - Electromagnetic torque

Input:

- Tm - The Tm is the mechanical torque at the generator shaft. This input should normally be positive because the Permanent Magnet. Synchronous Machine block is usually used as a motor. Nevertheless, by applying a negative torque input it can be used in generator mode.

Output:

- m – 'm' indicates output of PMSG. It is a vector containing 13 signals such. as three phase stator currents, voltage and current of d-q axis, Hall. effect signals, rotor speed, rotor angle and electromagnetic torque for the sinusoidal model. These signals. can be demultiplexed by using the Bus Selector. block provided in the Simulink library.

D. Universal. Bridge

The Universal Bridge block implements a universal. three-phase power converter that consists of up to six power switches connected in a bridge configuration. The type of power switch. and converter configuration is selectable from the dialog box.
The Universal Bridge block allows simulation. of converters using both naturally commutated. (or line - commutated) power electronic devices. (diodes or thyristors) and forced-commutated. devices (IGBT, MOSFET). The Universal. Bridge block is the basic block for. building two-level voltage-sourced converters. (VSC) as shown in figure 10 and 11.
The device numbering is different if the power. electronic devices are naturally commutated or forced-commutated.

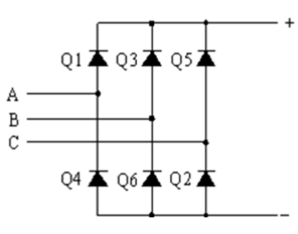


Figure.10: Three-phase. rectifier Diode Bridge. [4]

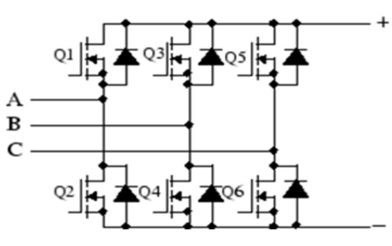


Figure.11: Three-phase. inverter (IGBT) bridge. [4]

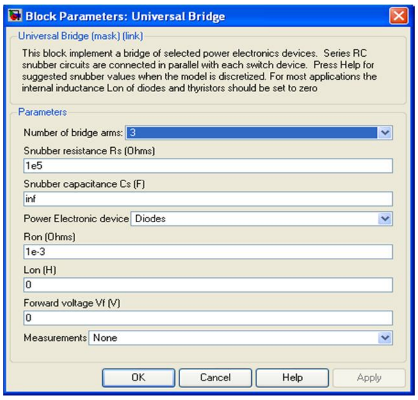


Figure.12: Dialog Box and .Parameters of Universal. Bridge Block

Figure.12 shows the dialogue box of Universal. Bridge block. The parameters. of this block are as follows:

- **Number of bridge arms -** The number of bridge arms. is set to 3 to get a three-phase converter connected in Graetz bridge configuration (six switchig devices).
- **Snubber resistance Rs -** The snubber resistance is measured in ohms (Ω). It is set to inf to eliminate the snubbers from the model.
- **Snubber capacitance Cs -** The snubber capacitance is measured in farads (F). This parameter. is set to 0 to eliminate the snubbers, or to inf to get a resistive snubber. In order to avoid numerical oscillations when system is discretized, Rs and Cs snubber values for diode and thyristor bridges must be specified.

If firing pulses to forced-commutated. devices are blocked, only anti-parallel diodes operate, and the. bridge operates as a diode rectifier. In this condition. appropriate values of Rs and Cs must also be used.

When the system is discretized, the following formulas. are used to compute approximate values of Rs and Cs:

$$R_s > 2\frac{T_s}{C_s} \tag{16}$$

$$C_s < \frac{P_n}{1000\,(2\pi f)V_n^2} \tag{17}$$

Where P_n = nominal power of single. or three phase converter (VA) T_s = sample time (s)
V_n = nominal line-to-line AC voltage (V_{rms}) f = fundamental frequency (Hz)

Power electronic device -When switching-function based VSC is selected, a switching-function voltage source converter type equivalent model is used, where switches. are replaced by two voltage sources on the AC side and a current source on the DC side. This model uses the same firing pulses. as for other power electronic devices and it correctly represents harmonics normally generated by the bridge.When average-model based VSC is selected, an average-model type of voltage source converter is used to represent the power-electronic switches. Unlike the other power electronic devices, this model uses the reference signals (uref) representing. the average voltages generated at the ABC terminals of the bridge. This model does not represent harmonics. It can be used. with larger sample times while preserving the average voltage dynamics.

- **Ron –** It represents the internal resistance. of the selected device measured in ohms (Ω).
- **Lon -** It represents internal inductance which is measured in Henries (H), for the diode or the thyristor device. When the bridge is discretized, the Lon parameter must be set to zero.

E. PWM Generator. Block

The PWM. Generator block generates pulses for carrier-based pulse width modulation (PWM) converters using two-level topology. The block can be used to fire the forced-commutated devices (FETs, GTOs, or IGBTs) of single-phase, two-phase, three-phase, two-level bridges or a combination of two three-phase bridges.

The number of pulses generated by the PWM. Generator block is determined by the number of bridge arms to control:

- Two pulses are generated for a one-arm bridge as shown in figure 13. Pulse 1 fires the upper device and pulse2

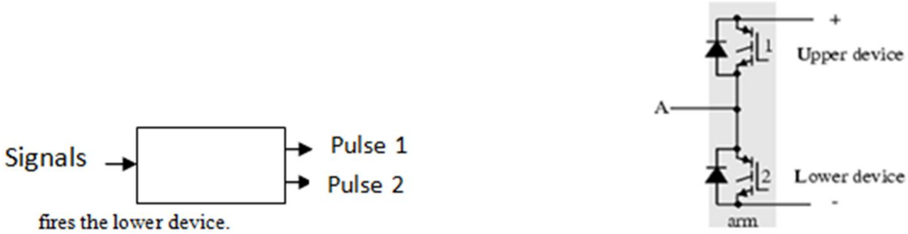
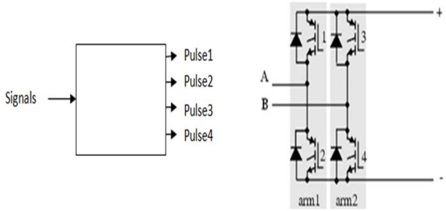


Figure.13: Single arm Inverter Bridge [8]

- Four pulses are generated for a Double-arm bridge as shown in figure14. Pulses 1 and 3 fire the upper devices of the first and second arm. Pulses 2 and 4 fire the lower devices.



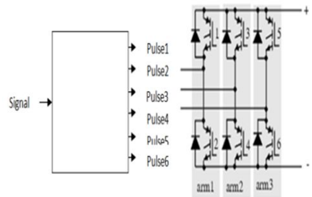
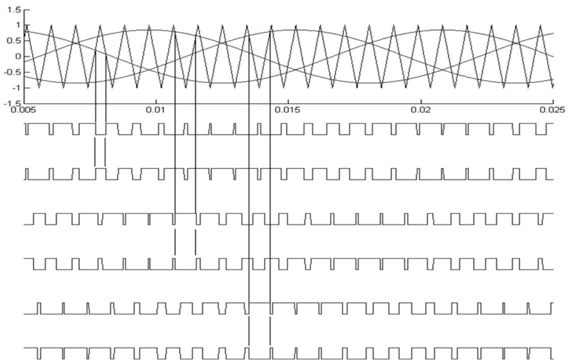


Figure.14: Double-arm Inverter Bridge [8]

Figure.15: Three-arm Inverter Bridge. [8]

- Six pulses are generated for a three-arm bridge as shown in figure 15. Pulses 1, 3, and 5 fire the upper devices of the first, second, and third arms. Pulses 2, 4, and 6 fire the lower devices.

The pulses are generated by comparing a triangular carrier waveform to a reference sinusoidal signal. The reference signal can be generated by the PWM. generator itself, or it can be generated from a signal connected at the input of the block. In the second option, the PWM. generator needs one reference signal to generate the pulses for a single- or a double-arm bridge, or it needs a three-phase reference signal to generate the pulses for a three-phase bridge (single or double bridge). The amplitude (modulation), phase and frequency of the reference signals are set to control the output voltage (on the AC terminals) of the bridge connected to the PWM. Generator block. The figure 16 displays the six pulses generated by the PWM. Generator block when programmed to control a three-arm bridge. Pulse 2 is the complement of pulse1, pulse 4 is the complement of pulse 3 and pulse 6 is the complement of pulse 5. Unlike the pulses generated by the Synchronized 6-Pulse Generator block, the pulses generated by the PWM. Generator block are of variable width.



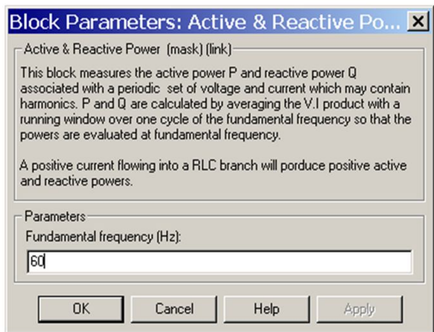


Figure.16: Pulses generated by the PWM Generator Block

Figure.17: Dialogue box and parameters of Active & Reactive Power Measurement Block

F. Active and Reactive Power. Measurement Block

This block measures the active and reactive power of a voltage-current pair. The Active. and Reactive Power block measures the active power P and reactive power Q associated with a periodic voltage-current pair that can contain harmonics. P and Q are calculated by averaging the V, I product with a running window over one cycle of the fundamental. frequency, so that the powers are evaluated at fundamental frequency.

$$P = \frac{1}{T}\int_t^{t+T}\left(V\ (\omega t) \times I\ (\omega t)\right)dt \qquad (18)$$

$$Q = \frac{1}{T}\int_t^{t+T}\left(V(\omega t) \times I\ \left(\omega t - \frac{\pi}{2}\right)\right)\ dt \qquad (19)$$

Where T = 1/ (fundamental frequency).

- **Fundamental frequency (Hz) -** The fundamental frequency, in hertz, of the instantaneous voltage and current.

Inputs and Outputs - The first input is the instantaneous voltage. The second input is the instantaneous current. The output is a vector [P Q] of the active and reactive power.

IV. Results and Discussion

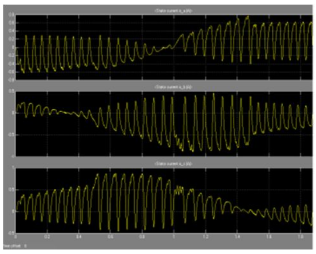


Figure.18

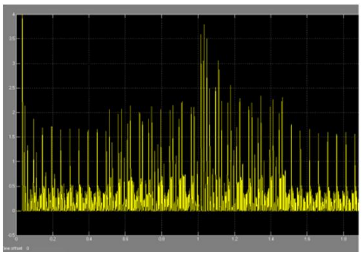


Figure.19

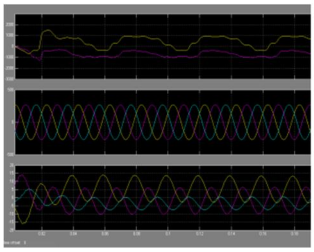


Figure.20

Figure 18 shows the three-phase uncontrolled stator. currents of the PMSG. The simulated result. for a dc link current which is controlled by the rectifier side. controller is shown in figure 19. It is observed that. the dc link current does not exceed the maximum. value of current I_{am} as specified by the generator. Figure 20 shows the output waveforms for the active and reactive power, voltage and the current supplied to. the grid. It can be observed that by. employing the MPPT scheme the rated. output (1.5kW) can be obtained for a variable speed operation range .from 4 – 12 m/s. The PWM. inverter is utilized. to supply the sinusoidal current. i.e q-axis active current I_{qs} to the utility. line. The d-axis. current reference is set. to zero for unity power factor operation, while. the q-axis current and the active power. are transferred to the grid based. on the MPPT. control algorithm.

V. Conclusion

The MPPT control is achieved at the grid side inverter to supply the maximum power to the grid. Modeling and simulation of a 1.5kW variable speed wind energy conversion system employing a MPPT control algorithm is presented in the thesis.. Here the performance of proposed MPPT method was tested by simulating the model for various frequencies. P & O technique employs three sensors namely abc/dqo transformation, three phase PLL and PI controller which provides efficient operation. Also the inverter is controlled using these sensors to provide sinusoidal current waveform to the utility line. This method was able to maintain the operating point of the system at the maximum power point, thereby improving the amount of energy successfully extracted from the wind turbine.

Reference

[1] Tarek Ahmed, Katsumi Nishida, Mutsuo Nakao, “MPPT Control algorithm for Grid Integration of Variable Speed Wind Energy Conversion System”: IEEE Trans 2009.

[2] J. Ribrant and L. M. Bertling, “Survey of Failures in Wind Power Systems With Focus on Swedish Wind Power Plants During 1997- 2005,” IEEE Trans. on Energy Conversion, Vol. 22, No. 1, pp.167-173, March 2007.

[3] K. Tan and S. Islam, “Optimum Control Strategies in Energy Conversion of PMSG Wind Turbine System without Mechanical Sensors,” IEEE Trans. on Energy Conversion, Vol.19, No.2, pp.392- 399, 2004.

[4] M. G. Molina, P.E. Mercado, “A New Control Strategy of Variable Speed Wind Turbine Generator for Three-Phase Grid connected Applications” IEEE Trans 2008.

[5] Shigeo Morimoto, Hideaki Nakayama, Masayuki Sanada, and Yoji Takeda, "Sensorless Output Maximization Control for Variable-Speed Wind Energy System using IPMSG", IEEE Transactions on Industry Applications, Vol. 41, no.1, January/February 2005.

[6] S. Morimoto, M. Sanada, and Y. Takeda, " Wide Speed Operation of Interior Permanent Magnet Synchronous motors with high performance current regulator", IEEE Trans. Ind. Appl., vol. 30, no.4, pp. 920-926, Jul./Aug. 1994.

[7] S. Morimoto, M. Sanada, and Y. Takeda, " Effects and compensation of magnetic saturation in flux-weakening controlled permanent magnet synchronous motor drives," IEEE Trans. Ind. Appl., vol. 30, no.6, pp.1632-1637, Nov./Dec.1994.

[8] R. Bharanikumar, A. C. Yazhini, A. Nirmal Kumar, "Modeling and Simulation of Wind Turbine Driven Permanent Magnet Generator with New MPPT Algorithm" Asian Power Electronics Journal, Vol.4 No.2, August 2010.