TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol. 12, No. 8, August 2014, pp. 5751 ~ 5757
DOI: 10.11591/telkomnika.v12i8.6273

Growing Neural Gas Based MPPT for Wind Generator using DFIG

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Abstract

This paper presents Growing Neural Gas (GNG) based a maximum power point tracking (MPPT) technique for a high performance wind generator using DFIG. It is used in variable speed wind energy conversion system. Here, two back to back converters is used and connected to the stator, correspondingly FOC and VOC is done on machine and supply side converter. Constant voltage over the grid is obtained through dc link voltage. For Variable speed wind energy conversion system the maximum power point tracking (MPPT) is a very important requirement in order to maximize the efficiency. Here Neural Network has been trained to learn the turbine characteristic i.e torque versus wind speed and machine speed. It has been implemented to obtain maximum power point tracking for varying wind speed. And finally comparison has been made with and without growing neural gas.

Keywords: *MPPT, DFIG, FOC, VOC, GNG*

1. Introduction

Due to energy crisis, use of renewable energy for electricity generation has increased. Renewable energies have low environmental impact and thus it is the best solution for growing demand. And the Wind energy meets the increased demand that could not be offered by conventional methods electricity generation [1, 2]. Recent technology in wind energy conversion system has led to cost reduction compared to that of non renewable energy sources.

In case of grid connected systems, interface is required to ensure good power quality. The interface may consist of a power electronic converter, transformer, filter, etc [1]. They play a very important role in modern wind energy conversion system (WECS).

WTs are classified into two main categories [3]:

a) Fixed speed WTs;
b) Variable speed WTs.

Fixed speed WTs are equipped with induction generator (squirrel cage induction generator SCIG or wound rotor induction generator WRIG) directly connected to the grid and a capacitor bank for reactive power compensation. In Induction Generator, synchronous speed is fixed; this implies that WTs can obtain maximum efficiency at one wind speed only. As power electronics are not used in this configuration, it is not possible to control neither reactive power consumption nor power quality.

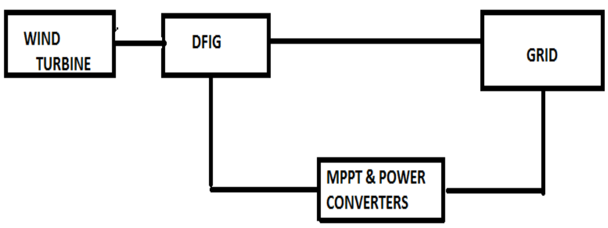

Figure 1. Block Diagram of WECS using DFIG

Received March 3, 2014; Revised May 7, 2014; Accepted May 25, 2014

Variable speed WTs are equipped with an induction or synchronous generator connected to the grid through a power converter. The variable speed operation, made possible by means of power electronics, allows WTs to work at the maximum conversion efficiency over a wide range of wind speeds. Nowadays doubly fed induction generators are used in case of variable speed wind energy conversion system. Figure 1 shows the basic block diagram of WECS using DFIG.

Here the wind turbine is directly connected to doubly fed induction generator. Initially it works as a motor, drawing power from the grid i.e 30% power is drawn from the grid [4]. When it reaches the synchronous speed it works as the generator, supplying power to the grid i.e 100% power is given to grid (30% is drawn and 70% is generated). The stator of this generator is directly connected to the grid. Two back to back converters are used. Power converters are used to convert either ac to dc or dc to ac. And along with this mppt technique is also used [5]. MPPT are used to extract the maximum available wind power. Doubly fed induction generator has various advantages. They are [6]:

a) Reduced cost of the inverter filters and EMI filters.
b) Can operate in both super synchronous and super synchronous mode.
c) Back to back converter used.
d) At lower cost, Power-factor control can be implemented.
e) Dynamic performance and controllability are good.
f) Filters are used to reduce harmonics due to converters.
g) System efficiency is improved. And by using IGBT inverters, approximately 2-3% efficiency improvement can be obtained.

2. Proposed Method

Figure 2 shows the block diagram of the proposed method. Here DFIG uses two back to back converters connected to the rotor which is then connected to the grid. And the stator is directly connected to the grid. Field oriented control and maximum power tracking is done on generator side converter. Growing Neural Gas based Maximum PowerPoint Tracking is used to track the maximum available power from the wind. Voltage oriented control is done on grid side converter.

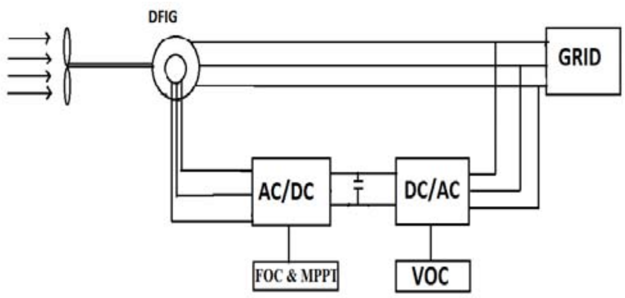

Figure 2. Block Diagram of Proposed Method

3. DFIG Modeling

The general model for wound rotor induction machine is given as follows [7]:

3.1. Voltage Equations

Stator Voltage Equations:

$$V_{qs} = p\lambda_{qs} + \lambda_{ds}\omega + r_s i_{qs} \quad (1)$$

$$V_{ds} = p\lambda_{ds} - \lambda_{qs}\omega + r_s i_{ds} \quad (2)$$

Rotor Voltage Equations:

$$V_{qr} = p\lambda_{qr} + (\omega - \omega)\, \lambda_{dr} + r_r i_{qr} \quad (3)$$

$$V_{dr} = p\lambda_{dr} - (\omega - \omega)\, \lambda_{qr} + r_r i_{dr} \quad (4)$$

3.2. Power Equations

$$P_s = 3/2(V_{ds}i_{ds} + V_{qs}i_{qs}) \quad (5)$$

$$Q_s = 3/2(V_{qs}i_{ds} - V_{ds}i_{qs}) \quad (6)$$

3.3. Torque Equation

$$T_e = -\,(3/2)(p/2)(\lambda_{ds}i_{qs} - \lambda_{qs}i_{ds}) \quad (7)$$

3.4. Stator Flux Linkage Equations

$$\lambda_{qs} = (L_{ls} + L_m)\, i_{qs} + L_m i_{qr} \quad (8)$$

$$\lambda_{ds} = (L_{ls} + L_m)\, i_{ds} + L_m i_{dr} \quad (9)$$

3.5. Rotor Flux Linkage Equations

$$\lambda_{qr} = (L_{lr} + L_m)i_{qr} + L_m i_{qs} \quad (10)$$

$$\lambda_{dr} = (L_{ls} + L_m)i_{dr} + L_m i_{ds} \quad (11)$$

4. Control Methods

4.1. FOC on Generator Side Converter

Field Oriented Control technique is adopted control technique because of its high performance and also controls the active and reactive power flows. Figure 3 shows the foc control on generator side converter. Here stator phase currents are measured and is converted to (d,q) system. Flux linkage control is obtained through d-axis component and similarly speed control is obtained through q axis control. Here, DFIG works in the dq reference frame.

Aligning the d–axis of reference frame to be along the stator flux linkage.

$$\lambda_{qs} = 0 \quad (12)$$

And hence from (8):

$$i_{qs} = -[L_m/(L_{ls} + L_m)]\, i_{qr} \quad (13)$$

For λ_{ds} to remain unchanged at zero, $p\lambda_{ds}$ must be zero. Substituting for $p\lambda_{ds}$ using (1) and (2) will result in:

$$V_{ds} = r_s i_{ds} \quad (14)$$

Neglecting stator resistance will lead to Vds = 0 and substituting in (5) and (6) will be simplified as follows:

$$P_s = 3/2(V_{qs}i_{qs}) \quad (15)$$

$$Q_s = 3/2(V_{qs}i_{ds}) \quad (16)$$

The above equations show that active and reactive powers of the stator are controlled independently. PI controllers along with NN are used to control these currents. The power corresponds to the reference speed of the machine is obtained through the GNG based MPPT.

Actual and reference currents are compared and produces the error signals and it is again given to PI controller. It produces the dq voltage which is again converted into αβ and fed in to space vector Pulse Width Modulation (PWM). Output from this is given as pulses to machine side converter [8].

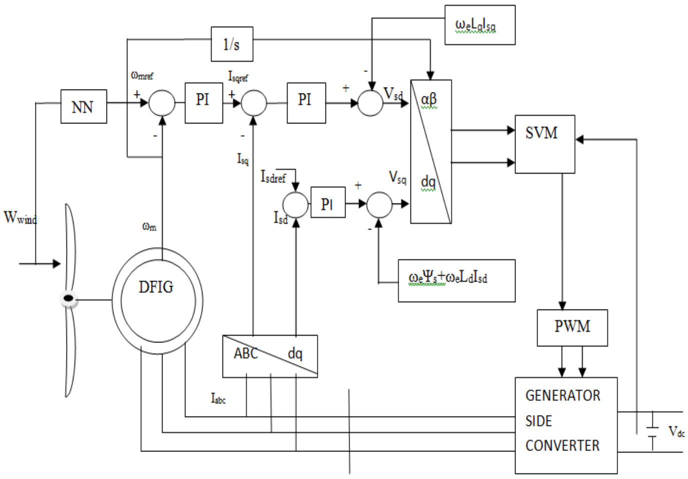

Figure 3. FOC Technique on Generator Side Converter

4.2. VOC on Grid Side Converter

Voltage oriented control is done on grid side converter. The constant voltage is used to inject power to the grid from the machine. If voltage is reduced in the grid, the dc link voltage is given to the grid to maintain the constant voltage [9]. Here the three phase currents are measured and are converted in to dq co-ordinate system. The reference dc link voltage are set, the actual voltage is measured and compared. The voltage equations in synchronously rotating dq-axis reference frame are [7]:

$$V_{ds} = V_{d1} - RI_{ds} - L(d/dt)I_{ds} + L\omega_e I_{sq} \quad (17)$$

$$V_{qs} = V_{q1} - RI_{qs} - L(d/dt)I_{qs} - L\omega_e I_{ds} \quad (18)$$

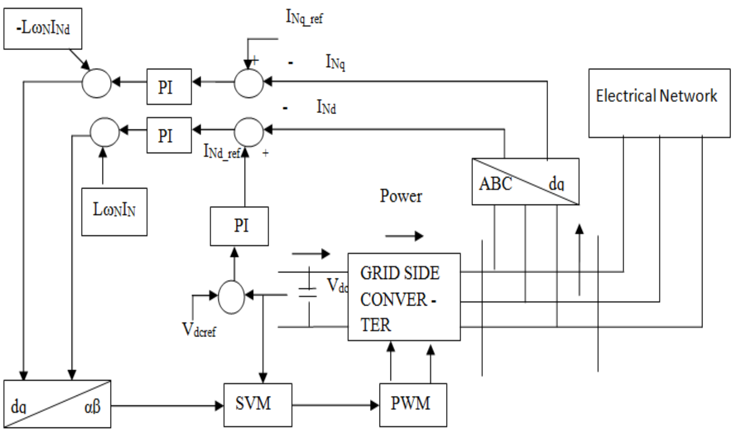

Figure 4. VOC Technique on Grid Side Converter

The d-axis of the reference frame is aligned with the grid voltage angular position θe. Since the amplitude of the grid voltage is constant, V_{qs} is zero and V_{ds} is constant.

$$V = V_{ds} + 0 \tag{19}$$

The active and reactive power will be proportional to i_{Nd} and i_{Nq} respectively. The grid-side transformer connection is star, the converter active and reactive power flow is:

$$P_s = 3/2V_{ds}I_{ds} \tag{20}$$

$$Q_s = 3/2V_{ds}I_{qs} \tag{21}$$

The control scheme has slightly been modified by adding another control loop for the dc-link voltage, which outputs the direct reference current In voltage oriented current control depends on the dc link voltage whereas in FOC current control depends on the generator reference speed. The compared signals are given to PI controllers and it is used to generate the appropriate signals. Again the dq currents are converted to αβ, it is given as the input to the PWM. Output from the PWM is given as the pulses to the grid side converter [10]. In voltage oriented current control depends on the dc link voltage whereas in FOC current control depends on the generator reference speed.

5. Growing Neural Gas Based MPPT

In order to increase the output it is necessary to operate the system at the optimal point. So we go for Growing Neural Gas based MPPT. There are two main controls in tracking the maximum power from the wind. First approach is based on torque and second approach is based on the speed of the machine. Here the speed control method is adopted and the neural network has to be specifically trained for a particular characteristic on which it will be used. Neural network have three layers: input, hidden, and output layers. The number of nodes in each layer varies and is user-dependent. The GNG network has been trained online and then used offline. During training phase the input to this neural network is wind speed and generator speed or torque as shown in Figure 5. And the output is the reference generator speed which makes the wind turbine to operate at, or close to, the MPP [11], depending upon algorithms used by the hidden layer and the training phase of the neural network, the operating point gets to the MPP. The neural network has to be periodically trained to get the exact MPPT as the characteristics of a wind turbine also change with time. And now the inversion of this turbine function has been implemented online by measuring the wind free speed based on the estimated torque and measured machine speed [12].

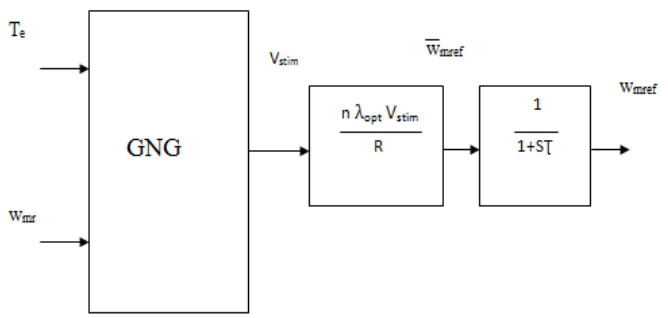

Figure 5. Block Diagram of the GNG-based MPPT Algorithm

6. Results and Analysis

The voltage is maintained constant over the grid say 400V. Figure 6 shows the voltage over the grid. The active P and reactive Q power flowing into the power grid are measured.

They show that the reactive power Q is nearing to zero and real power is about 25 KW. Figure 7 shows the comparison of reference generator with and without GNG. And the result shows speed increases in case of GNG network and the maximum power is obtained.

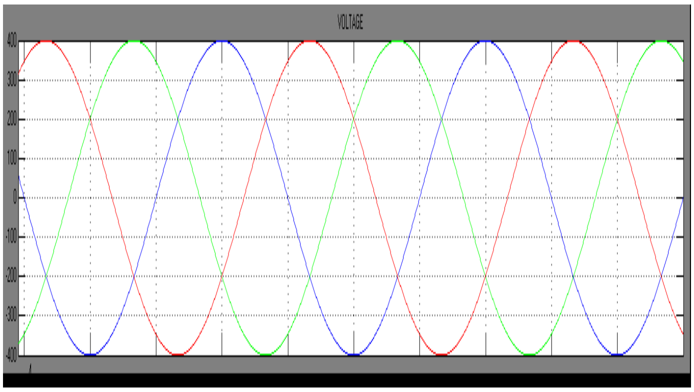

Figure 6. Voltage over the Grid

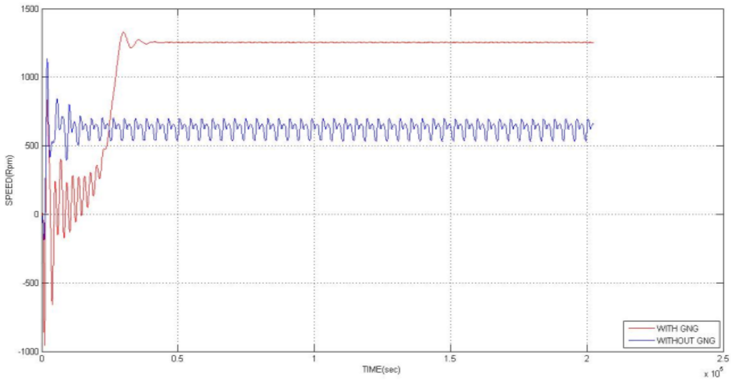

Figure 7. Shows the Comparison of Reference Generator with and without GNG

7. Conclusion

This paper presents the wind turbine having DFIG connected to the grid and the maximum power is extracted from the wind speed using neural network. Two voltage source converters are used. One on the generator side and another on the grid side. The grid-side converter is controlled by a voltage oriented control. The d-axis voltage component is fixed with grid voltage, and the q-axis voltage component is zero. The generator side converter is controlled by a field oriented control. The speed control of the machine is done instead of the torque control. The information of wind speed is necessary to track the maximum power over a wide speed range. Thus the GNG network which has been implemented tracks the maximum power.

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