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Harmonic Current Reduction Using Hysteresis Current Controller for Renewable Energy Applications

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ABSTRACT

In this paper, the current harmonics reduction method using hysteresis current controller is explained for wind power applications. The wind energy conversion system is a non-linear system of energy conversion. The non-linear inputs introduce harmonics in the electrical output thereby affects the system effectiveness. In this proposed method, a hysteresis band is used for the current wave which is controlled to reduce the ripple in the current output. The hysteresis bandwidth is controlled by a controller to produce desired output. The hysteresis current controller is mathematically modeled for a 4kW wind turbine model. The wind turbine used is a self-excited induction generator. The 4kW proposed system is simulated using MATLAB and a similar prototype model is experimented and the results are discussed

Keywords: Hysteresis Current Controller, Stand Alone Wind Power, Self-Excited Induction Generator, Total Harmonic Distortions.

INTRODUCTION

The wind power energy conversion system is considered to be one of the most dynamic power generation systems in renewable energy conversions. Wind turbines are mainly used to generate the power of higher orders. The stand-alone wind powers generally apply to one application. In industries, the AC drives are very common and requires adequate power supply though out. The wind power turbines are designed to produce the voltage at constant frequency. However the turbine input like wind speed, directions, geographical locations etc., are deeply responsible for the power generation. The inputs are not constant and subjected to variations with respect to time. Various works on the terminal output of the wind turbine model is being executed. The direct voltage control (DVC) (Hua Geng, D Xu, Bin Wu,Wei Huang,2014) is used in the control of terminal voltage and frequency. This strategy is dynamic for the voltage control with low harmonics. The variation in wind directions is tracked by the pitch angle; however some wind turbines are modeled with fixed pitch angles. This is determined by studying the geographical constrains of the location and the pitch angle values are determined. Such turbine models are connected to variable source inverters (VSI) (L.A.C Lopes, R G Almeida,2006). The VSI consists of the DC link which is controlled to absorb and inject the active power to maintain better regulation thereby increasing the system efficiency. In applications of drives, the drive controlled system is depends on the current supplied to the drives. The harmonics contents in the current should be as less as possible to provide an efficient output. The proposed system is designed to have a very low current harmonics. The current harmonics reduction method by hysteresis current controller (HCC) is more effective in non-linear applications. The SEIG wind turbine model is controlled by HCC for non-linear load applications.

MODELING OF PROPOSED SYSTEM

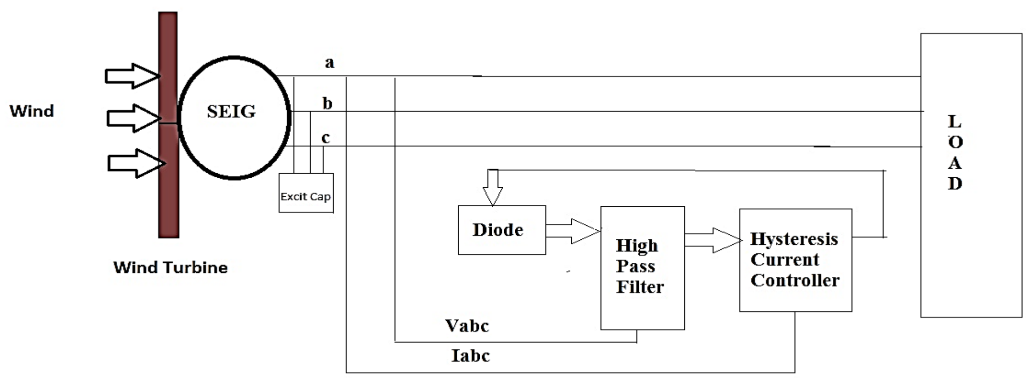

Figure.1.Proposed System model

The proposed system consists of a self-excited induction generator (SEIG) (Aloah A., Alkanhal M,2014), as a wind turbine model. The wind turbine output is controlled using a hysteresis current controller loop to reduce the current harmonics generated in the turbine output due to non-linear inputs. The proposed system design is shown in the figure 1.

The wind turbine is a generator driven by wind when the wind hits the turbine blades. The wind turbine blades are connected to the shaft of the generator rotor for the rotation. The generation of power is based on the energy transformation from mechanical energy (translational motion) to electrical energy. The output of the generator depends on the rotor speed. A simple model of the self-excited induction generator (SEIG) as a wind turbine model is similar to an induction machine driven by a prime mover. The voltage excitation is produced by connecting the capacitors in parallel. The capacitance used for the excitation is called as excitation capacitance. The modeling of the excitation capacitance (Ali M. Eltamaly, 2002), depends on the voltage and the current ratio that has to be maintained during the power generation. The excitation capacitance is determined by conducting a synchronous speed test. In the synchronous test, the no load saturation curve of the machine is obtained at normal rated frequency. When the motor is driven using a prime mover or coupled to a DC motor which is driven at a speed corresponding to the synchronous speed of the machine at its rated frequency, the voltage will be developed at the stator terminal. The difference in the rotor and stator current is assumed to be the magnetizing current where the slip value is practically zero. The no load curve obtained gives the critical capacitance range under linear region of the curve. The value of the excitation capacitance is selected such that it is within the limit determined by the curve. The minimum capacitance value obtained is limited to the rated voltage and the maximum capacitance value obtained is limited to the rated motor current. The selection of capacitance value below the minimum and above the maximum values will not be applicable for obtaining the rated voltage at reduced power loss. This analysis is modeled to obtain the values of the critical capacitance that is used in excitation of the SEIG system.

Modeling of hysteresis current controller (HCC): The current waveform obtained from the SEIG depends on the turbine input parameters. The variations in the input values like wind speed and wind directions produce a disturbed output current. This current has the ripple content when closely observed.

The input power is generated by the SEIG wind turbine. The output connected to a non-linear load whose harmonics is reduced by the hysteresis current controller loop. The output of the power generator is connected to a discharging capacitance through a three phase controlled rectifier circuit. The capacitance is charged and discharged by using the short-circuit switch. The capacitor voltage is compared with the reference voltage which is set equal to the load input voltage. The value is set so because the voltage supplied to the load requires a constant value. The comparative output error is then given to PID controller to obtain the desired output. The HCC loop is used to reduce the current harmonics so a comparative modeling of the input current and the current obtained from the current controller is done. This is done by using the reference frame theory by converting the dq0 to abc reference frames. The output current is compared with the input current of the generator. A hysteresis band is set along the current wave and by adjusting the band gap of the hysteresis band, the ripple in the current waveform is reduced. This error is used to produce the gate pulse of the controlled rectifier, which is connected to the input line of the load.

The reference sine wave is expressed as,

$I_{reference} = (V_{dc}/3V_{peak})\times I_{dc}$

This equation is adjusted for any variation in the load current. The AC side neutral current i_{n1} is expressed as,

$I_{q1}= \sqrt{2}I_{reference}\ [\sin\omega t + \sin(\omega t- \frac{2Л}{3}) +\sin(\omega t + \frac{2Л}{3})]$

Using the above expression, the injection current consists of the current through the three bidirectional switches and are given the equation,

$I_{q2} = i_{2} - i_{1} =\frac{2I_{dc}}{3}\sin(3\omega t),$

Where the current i_1 and i_2 are the currents. Using the above three equations, the current injection in order to minimize the harmonics

Simulation results and discussion: The proposed circuit is mathematically modeled in MATLAB. The wind driven SEIG is modeled using the machine variable using the reference frame theory. The SEIG wind turbine is modeled for 4kW output. The input parameters like wind speed, pitch angles are varied and the results are taken. The SEIG wind turbine generator is modeled as a real time model. The SEIG system is simulated under variable wind velocity. This is performed to validate the SEIG power output for the variable conditions. The wind velocity is varied from 9 m/s to 18 m/s and the output power is measured. It is observed that the rated power of the generator is obtained at a wind velocity of 15 m/s. The SEIG wind turbine is simulated with a constant wind velocity of 15m/s. and the pitch angle is varied to find the maximum power obtained. This is performed by keeping the wind velocity constant and the pitch angle is varied. It is observed that the maximum power is obtained from the wind turbine for the given wind velocity.The SEIG wind power turbine is modeled and simulated by synchronizing the variable turbine inputs like wind speed and the pitch angle. The pitch angle is varied under the assumption that the wind direction is also variable. By applying the variable inputs, the power output of 4kW is obtained. The harmonic analysis of the SEIG current without the HCC is found to be the THDi is 20.27%. The total current harmonic distortion of SEIG wind turbine without using Hysteresis current controller is given in table.1

Table.1.Total current harmonic distortion of SEIG wind turbine without the HCC

Harmonic order	0	0.5	1	1.5	5
% Mag (Fundamental)	64	42	66	15	2

The current harmonics generated due to the non-linear operation of the SEIG wind turbine is of high range. Therefore, it is necessary to reduce the current harmonics level. The hysteresis current controlled (HCC) is therefore designed to reduce the current harmonics of the proposed system. Using the HCC, the proposed system is simulated and the outputs are obtained. The SEIG RMS current obtained after introducing the HCC is found to have a very low harmonic level. The total current harmonics of the SEIG is found to be 2.97%. The total current harmonic distortion of SEIG wind turbine using Hysteresis current controller is tabulated in table.2. The power output is obtained for various pitch angles and it is tabulated in table.3.

Table.2.Total current harmonic distortion of SEIG wind turbine with HCC

Harmonic order	0	0.5	1	1.5	5
% Mag (Fundamental)	25	4	20	1	0.1

Table.3.Power output for various Pitch angles

Pitch Angle	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45
Power Output (Watt)	3000	3000	4000	3000	3000	1000	3000	3000

A similar model is experimented by using a SEIG driven by a DC motor as a prime mover. This system model is similar to a wind driven SEIG. A four pole, 415V, 7.5A squirrel cage induction generator is driven by a DC separately excited DC motor. The DC motor acts as a prime mover and drives the generator.

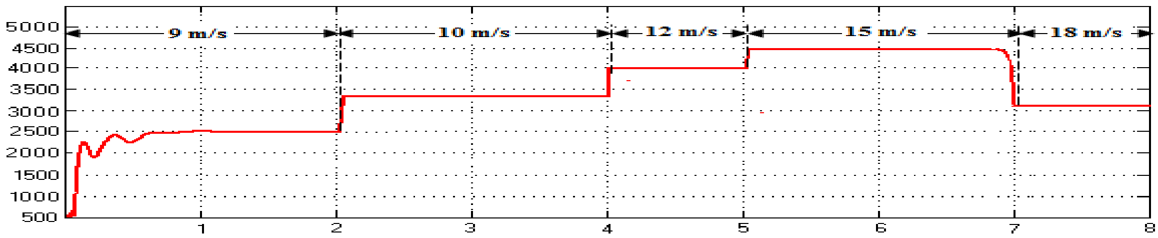

Figure.2.

The excitation capacitance used in the hardware setup is taken as 60μF. The speed of the DC motor is controlled by armature rheostat of 220V/5A. The SEIG driven by the prime mover is controlled using the hysteresis current controller (HCC). A Gate pulse applied to the controlled rectifier generated by the HCC. The SEIG output is controlled and the current obtained has less harmonic levels.The total current harmonic distortion THD_i which is found to be 3.25%.

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CONCLUSION

The wind driven SEIG for a non-linear system produces current harmonics of greater levels. The wind turbine output from a variable input can be made constant by using gear box setup or a power electronic circuit. However, this is expensive and will end up in huge power loss due to energy transfer. In consideration to any application it is necessary to note that the current harmonics should be less below the standard values. The proposed system is designed with a hysteresis current controller for non-linear load operation of a wind driven SEIG. The simulation and the hardware results show that the current harmonics of the SEIG output using the HCC reduces nearly 20% of the harmonics obtained for the system without the HCC. Thus the system output efficiency and the power factor can be increased for non-linear loads.

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