ROBUST ANALYSIS OF PID CONTROLLED INVERTER SYSTEM FOR GRID INTERCONNECTED VARIABLE SPEED WIND GENERATOR

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ABSTRACT

This project deals with the analysis, modeling and control system for permanent magnet synchronous generator (PMSG) based wind turbine connected to the grid. An ac/dc/ac power converter is an important device used to extract power from variable speed permanent magnet wind generators and feed it into the grid. This paper describes how these converters incorporate maximum power point tracking based on its power feed to the grid at different wind speeds. Using the permanent magnet generator voltage, grid current, and grid voltage samples, the proposed system achieves an enhanced dynamic behavior. The thyristor controller also protects the inverter from high dc voltage input from the wind generator at high wind speed. Preliminary results are included using a laboratory 2-kW prototype converter. A 2 MW wind energy conversion system (WECS) is presented and has been simulated via the dynamic simulation . This WECS consists of a 2 MW permanent magnet synchronous generator connected to the transmission grid through a power conversion scheme.

The topology of this converter system consists of a passive AC/DC rectifier as well as a PWM DC/AC IGBT inverter, used to interface the DC link with the grid. The inverter has an integrated current control system for power factor correction to improve output power stability.

In this paper, an isolated wind energy conversion system is implemented using a variable speed permanent magnet synchronous generator (PMSG) with PWM rectifier and a battery for storing the excess amount of wind energy. To change the duty cycle of the converter, a controller of DC-DC buck converter with MOSFET as a switching component is designed using P, PI and PID controller to provide the efficient choice for the selection of the controller. The proposed scheme is implemented in MATLAB using Simulink & the simulation results show that the output voltage of the converter can be controlled according to the value of duty cycle and the excess power is stored in battery to provide balance between the generator and the load.

Keyword : - *Wind Energy Conversion System (WECS), Double feed induction generator (DFIG), Back to back converter, Maximum power point tracking (MPPT), Wind turbines(WT), Wind generators(WG).*

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1. Introduction

Wind energy is an important renewable source which is used for power generation for a stand-alone as well as grid connected applications. In many remote areas, loads are usually connected away from the grid. In such cases, isolated wind energy systems can be considered as an effective way to provide continuous power to electrical loads. stand-alone wind energy systems usually can provide communities with electricity at the lowest cost.

In this paper, an isolated wind energy conversion system is implemented using a variable speed permanent magnet synchronous generator (PMSG) with PWM rectifier and a battery for storing the excess amount of wind energy. To change the duty cycle of the converter, a controller of DC-DC buck converter with MOSFET as a switching component is designed using P, PI and PID controller to provide the efficient choice for the selection of the controller. Multiple types of generators are being used with wind turbines. The major types of AC generators that are possible candidates in wind turbine systems are as follows:

• Squirrel-Cage rotor Induction Generator (SCIG).

• Wound-Rotor Induction Generator (WRIG),

• Doubly-Fed Induction Generator (DFIG)

• Synchronous Generator (With external field excitation),

•Permanent Magnet Synchronous Generator (PMSG).

PMSG generator has the capability of direct connection (direct-drive) to wind turbines, with no gearbox [12]. This advantage is favorable with respect to lifetime and maintenance. Synchronous machines can use either electrically excited or permanent magnet (PM) rotor. The PM and electrically-excited synchronous generators differ from the induction generator in that the magnetization is provided by a Permanent Magnet pole system or a dc supply on the rotor, featuring providing self-excitation property. Self-excitation allows operation at high power factors and high efficiencies for the PMSG . A comparison between the variable speed wind turbine and the constant speed wind turbine shows that variable speed reduce mechanical stresses, gusts of wind can be absorbed, dynamically compensate for torque and power pulsations caused by back pressure of the tower. This backpressure causes noticeable torque pulsations at a rate equal to the turbine rotor speed times the number of rotor blades .

The main features of the permanent magnet synchronous machine are as follows:

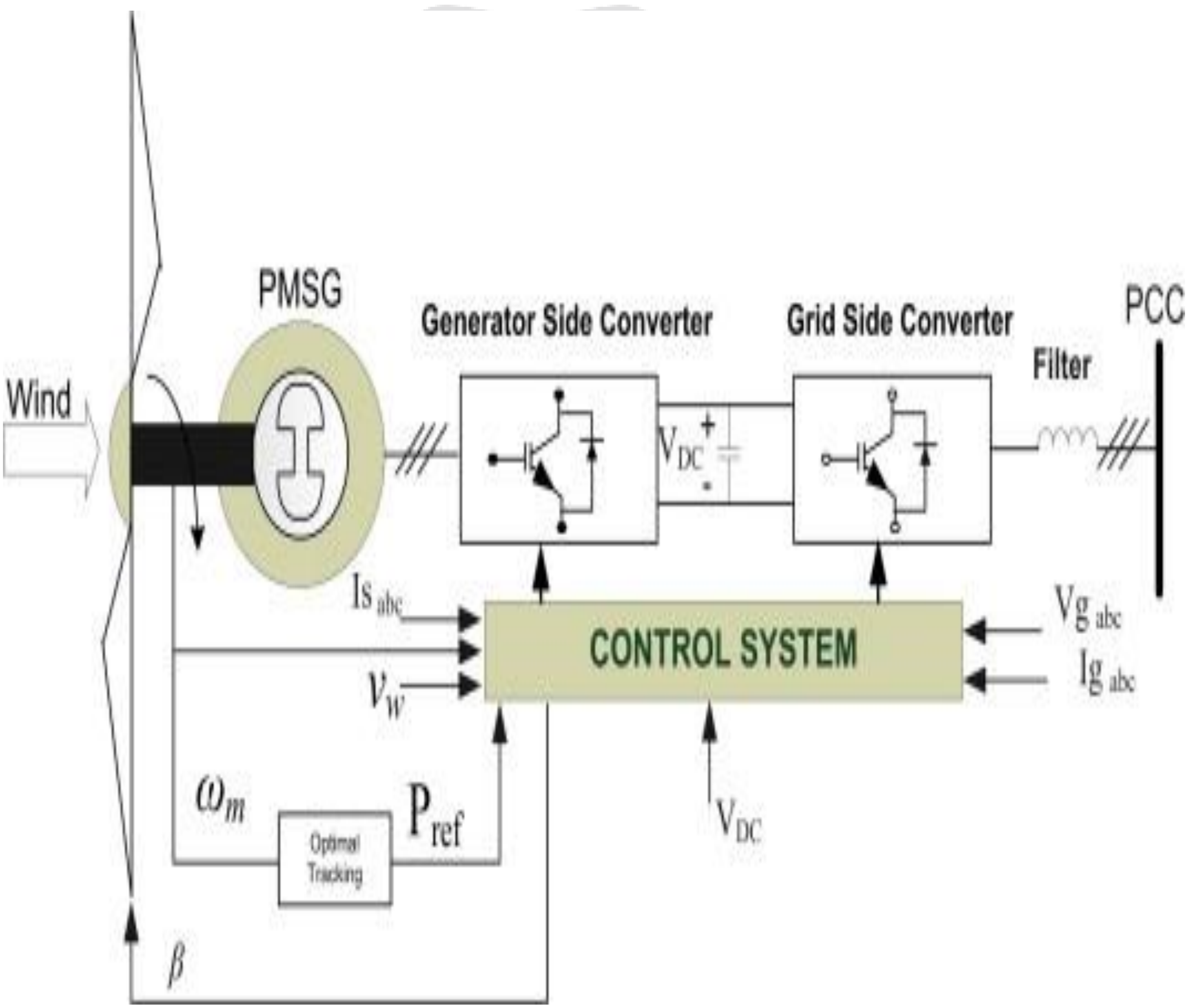
1. Robust, compact and less weight.

2. Copper loss due to the current flow which is the largest loss in case of induction machine is approximately half that of induction motor.

3. High efficiency in case of permanent magnet synchronous machine compared to induction machine.

By using P, PI, PID controller we can control rotor side voltage ,current, pitch angle and speed, but we go for PID controller because The PI-controller offsets or eliminates the steady state oscillations that are occurred using a proportional-controller and the system stability is improved .the output voltage using PID controller got changed by reducing the peak-overshoot & the time of response got decreased to a certain extent. Hence for economical savings; PID controller serves better purpose apart from the other controllers proposed in this design. So, PID controller serves the efficient choice for the selection of the controller. to obtained results it is clearly observed that the oscillations free output can be obtained by using a PID-controller and PID controller improves the stability of the system and hence is the best choice for the selection of the controller.

2. BLOCK DIGRAM



2.1 OPERATION AND WORKING PRINCIPLE

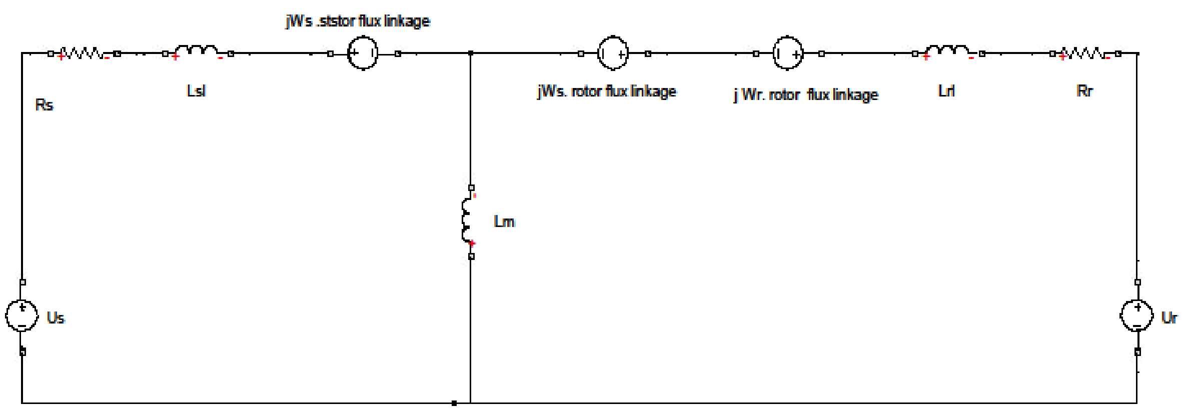
Additional converters that are used to interface energy storage devices power losses as well as increased system cost and complexity. The need for additional converters can be eliminated if the grid side inverter can itself be effectively used as the interface for energy storage. This paper therefore proposes a technique whereby the grid side inverter can also be used as an interface to connect a super capacitor energy storage for wind energy conversion systems. The proposed grid side inverter is formed by proposed system in suppressing short term wind power fluctuations cascading a 3-level inverter and a 2-level inverter through a coupling transformer. The three-level inverter is the main inverter and it is powered by the rectified output of the wind turbine coupled AC generator while the 2-level auxiliary inverter is connected to the super capacitor bank that is used to compensate short term power fluctuations.

Novel modulation and control techniques are proposed to address the problems associated with non-integer and dynamically-changing dc-link voltage ratio, which is caused by the random nature of wind. Simulation results are presented to verify the efficacy of the proposed system in suppressing short term wind power fluctuations. Wind turbines generate electrical power in the same way as all other generation technologies. The only difference is in the source of the mechanical power supplied to the electrical generator: wind, rather than a diesel engine or steam turbine, provides the energy. Blades capture energy in the wind and turn the turbines. Control mechanisms point the blades into the wind (yaw control) and, on large wind turbines, adjust the pitch of the blades (blade angle) as wind speeds change. Typically, a gearbox connects the shaft from the blades (rotor) to the electrical generator.

The electrical generators used on wind turbines may either be induction generators or synchronous generators. A transformer may be required to increase or decrease the voltage so it is compatible with the endues, distribution or transmission voltage, depending on the type of interconnection. Small wind turbines produce a variety of voltages and some produce DC power. Small wind turbines generally require an inverter to match the power output with the load and/or interconnection frequency and voltage.

This generator is connected through a back-to-back converter to the grid. This provides maximum flexibility, enabling full real and reactive power control and fault ride-through capability during voltage dips. The system configuration of a direct drive PMSG based grid interfaced WECS is shown in Fig 1. A horizontal axis wind turbine is used to drive the PMSG. A salient pole type PMSG is used. The kinetic energy present in the wind is converted into the mechanical torque using a wind turbine. Mechanical energy is converted into electrical energy using a PMSG. To facilitate variable speed operation for achieving MPPT, the PMSG cannot be interfaced with the grid directly. Therefore, two VSCs are used in back to back configuration with common DC link known as a MSC and a GSC. These VSC's are controlled independently. Pulse width modulation technique is used to control these VSC's. The midpoint of each leg of a GSC is connected to each phase of grid supply through an interface inductor. The MSC controls PMSG currents in a desired phase, frequency and magnitude to achieve MPPT. The GSC is synchronized with the grid unlike a MSC. Fig. 1: Configuration of PMSG based WECS using back to back VSCs The reactive power and an active power exchange with the grid are function of phase and amplitude of terminal voltage at AC terminals of a GSC. The objective of controlling a GSC is to keep constant DC link voltage under change in generated active power while keeping sinusoidal currents of PMSG. If Vdc is maintained constant at its reference value and keeping the modulation index of load side inverter at a fixed value, the amplitude of output ac voltage can be controlled and maintained at the rated voltage.

3.MATHEMATICAL ANALYSIS



3.1 Transfer function of PMSG

Us= stator voltage (grid voltage)

Ur= rotor voltage

Ψs= stator flux linkage

Ψr= rotor flux linkage

Is= stator current

Ir= rotor current

Ls= stator inductance

Lr= rotor inductance

ωs= grid frequency

Ꮚr= rotor frequency

All equation utilize nominal quantities unless per unit is specially stated

$$Us = RsIs + \frac{d\Psi s}{dt} + jWs\,\Psi s \qquad \text{……(1)}$$

$$Ur = RrIr + \frac{d\Psi r}{dt} + j(\omega s - \omega r)\,\Psi r \qquad \text{……(2)}$$

$$\Psi s = LsIs + LmIr \qquad \text{……(3)}$$

$$\Psi r = LmIr + LrIr \qquad \text{……(4)}$$

Substitute equation 3 & 4 into 1 & 2 in following two equation. When stator & rotor currents have been eliminated in order to simplify equation.

Stator & rotor flux only

$$Us = \left(\frac{Ps}{Ls} + JWs\right)\Psi s + \left(\frac{dWs}{dt} - \frac{KrPs\Psi r}{Ls}\right)$$

$$\Psi r = -Ks\left(\frac{Rr}{L'r}\right)\Psi s + J\,\frac{Rr}{L'r} + J(Ws - Wr)\Psi r + \frac{d\Psi r}{dt}$$

Where

$$Ks = \frac{Lm}{Ls}$$

$$Kr = \frac{Lm}{Lr}$$

L’s= σLs

L’r= σLr

σ= 1-KsKr

This allows equation to be stator and rotor flux linkages at state variable in state space form.

Relationship between electrodynamics torque, rotor speed, flux linkages must be

$$Te = \frac{3}{2}\sigma\left(\frac{Kr}{L'r}\right)(\Psi Rd\,\Psi Sq - \Psi Rq\,\Psi Sd)$$

P= respective number of machine poles.

Relationship between electromagnetic torque produced by machine, load torque from wind turbine Tl, rotor side speed differentiating equation,

$$\frac{J}{p}\left(\frac{dWr}{dt}\right) = Te - Tl - \frac{bWr}{p}$$

J=inertia of machine & turbine in KgM^2

b= speed dependent damping ratio

Te,Tl- changed by change in rotor speed.

Swing equation in state space from flux linkage & rotor speed equation is

$$\frac{J}{p}\left(\frac{dШr}{dt}\right)=\frac{3}{2}\sigma\left(\frac{Kr}{Ls}\right)(\Psi rd\,\Psi sq-\Psi rq\,\Psi sd)-Tl-b\,\frac{Шr}{p} \qquad ....(1)$$

Stator & rotor current by solve equation (1) we get ,

$$Is=\frac{\Psi s-Kr\Psi r}{L's}$$

$$Ir=\frac{\Psi r-Ks\Psi s}{L'r}$$

$$\mathrm{Ur}=\ \mathrm{Us}+\mathrm{L}\sigma\frac{\mathrm{dIr}}{\mathrm{dt}}+\mathrm{Rs}+\mathrm{Rr})\mathrm{Ir}+J(Шs-Шr)L\sigma Ir-\frac{Rs}{Lm}\Psi s-\frac{JШr}{\Psi s}$$

Rotor voltage equation by taking Laplace transform

$$\mathrm{Ur}=\ \mathrm{Us}+\mathrm{Ir}(\mathrm{Rs}+\mathrm{Rr}+\mathrm{SL}\sigma)+\mathrm{J}(Шs-Шr)\mathrm{L}\sigma\mathrm{Ir}-\frac{Rs}{Lm}\Psi s-JШr\Psi s$$

Transfer function of PMSG

$$\frac{Us}{Ur}=\frac{\left(RsIs+\frac{d\Psi s}{dt}+jШs\,\Psi s\right)}{\left(RrIr+\frac{d\Psi r}{dt}+\mathrm{j}(Шs-\ Шr)\Psi r\right)}$$

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4. OBJECTIVES OF PROJECT

the main objectives of project is to control the

1 pitch angle of wind turbine.

2 yaw control

3 speed of pmsg (grid side voltage v)

5. ADVANTAGES

GRID CONNECTION-

- Indirect grid connection is that it is possible to run the wind turbine at variable speed.

- The secondary advantage is that power electronics one may control reactive power (i.e. the phase shifting of current relative to voltage in AC grid), so as to improve power quality in the electrical grid.
- Particularly if the turbine is running on weak electrical grid, then Variable speed may also give the silent advantages of annual production.
- It can operate in generator /motor mode for both sub/super-synchronies speed mode with four possible operation conditions.
- A speed variation of 30% around synchronous speed can be obtained by the use of power converter of 30% of nominal generated power.

PID-

- No or very less oscillation and low overshoot.
- Simple & easy to use.
- Faster.
- Robust: insensitive to changes to plant parameter & disturbance.

PMSG-

- No additional power supply for the magnet field excitation
- No sliding contacts, so it requires less maintenance.
- Higher reliability due to the absence of mechanical components like slip rings.
- No field winding, no field copper

6. DISADVANTAGES

- the basic disadvantage of indirect grid connection is cost . because turbine will need a rectifier and two inverter ,one to controlled stator current, and another two generate output current .
- power electronic may introduce harmonic distoration of alternating current in electrical grid.
- The Demagnetization of PM at high temperature.
- More difficult to configure and tune.
- power factor of operation cannot be controlled due to the absence of the field winding.

7. APPLICATIONS

- Sensor less Control of PMSG in Wind Energy Conversion System Using PID Controller
- Grid Connected WECS with A Five Level DCMLI using PID Controller
- Power Quality Control and Design of Power Converter for Variable-Speed Wind Energy Conversion System with Permanent-Magnet Synchronous Generator
- Control of a standalone variable speed wind turbine with a permanent magnet synchronous generator.
- Wide application in petrochemical, pharmaceuticals, food, chemical, aerospace and semiconductor etc.
- Robust insensitive to change plant parameter and disturbance.

DFIG is used in wind mill for power generation from wind energy.

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