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Modelling and Analysis of Wind Turbine using Permanent Magnet synchronous generator for Maximum Power Tracking Control

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Abstract:

This research uses Matlab/Simulink simulation tools to analyse and simulate the performance of a wind power system powered by a low-speed Permanent Magnet Synchronous Generator (PMSG). A wind turbine (WT), PMSG, maximum power point tracking (MPPT), a three-phase diode bridge rectifier, a dc bus connected to a capacitor, and a PWM voltage source inverter regulated by a current source are all part of the system. With an MPPT control, the optimum coefficient of performance parameter was attained in the WT model as a function of wind velocity. The use of low-speed PMSG, which results in improved efficiency, eliminates the need for a gearbox. The ac output power obtained from PMSG is supplied to a three-phase rectifier bridge, which allows for maximum power extraction by using the boost converter's optimal voltage and current settings. The total system is connected to the electrical utility using a current source PWM inverter for dc/ac conversion.

1. INTRODUCTION

Wind energy has gained popularity in recent years due to a number of advantages, including the fact that it is clean, endless, exhaustible, and secure. The wind energy conversion system takes the available power (sometimes the maximum) from the wind turbine and converts it to electrical energy through a series of procedures.

Variable rotation speed wind turbines, also known as VSWTs, are primarily used in electrical power systems and, in some cases, in WECSs. The doubly fed induction generators (DFIGs) or permanent magnet synchronous generators (PMSGs) are commonly used in VSWT-driven systems [1–3]. The PMSG-based WTs have been widely utilised and gained relevance due to substantial advantages such as a simplified structure, low maintenance costs, the ability to track maximum power, and simplicity of operation at higher power factors [4–8]. Furthermore, WTs with several megawatts are being created, which is fueled by the PMSG [4]. Machine side converter (MSC) and grid side converter (GSC) are the terms used in this article. These are mostly introduced for converters that convert ac/dc and dc/ac in a WECS (wind energy conversion system) with a PMSG and are fed into the utility grid [9]. MSC is a machine-side converter that consists of a voltage source converter (VSC) that uses pulse width modulation or can be created using a bridge rectifier with diodes and a boost circuit, whereas GSC is a normal VSC converter.

The synchronous generator fitted WT with an ac/dc converter and boost converter circuit is used in this paper. Figure 1 shows a block schematic of the WECS coupled to a PMSG with a diode bridge rectifier, boost converter, and GSC. The boost converter maximises the output dc voltage of the rectifier to a regulated dc voltage that matches the value necessary for the successful operation of the GSC, and then the diode bridge converts this variable output ac voltage from the PMSG to the dc voltage. The dc/dc boost circuit guarantees that the generator speed is at its greatest value in order to capture the maximum power available from wind power. GSC allows for the controlled maintenance of dc-link voltage while concurrently transferring MSC-related real power to the mains. In the meantime, it aids in the regulation of reactive power that the turbine exchanges with the load [10].

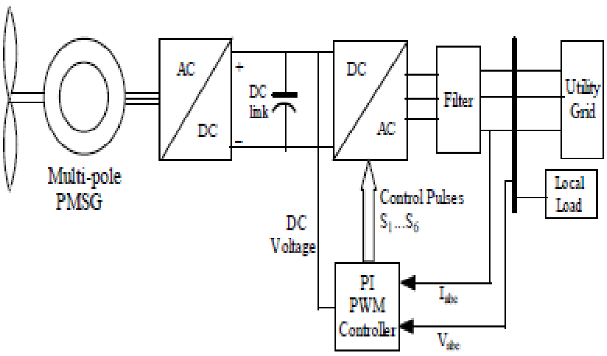

Fig. 1 PMSG based WT and connected to a diode rectifier and boost converter.

Some research articles that have been reviewed, such as [11–20], which deals with the different types of wind turbine configurations that are employed, are listed as well as detailed below. Paper [11] investigates PMSG-based WT coupled to a grid for the many

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oscillation modes observed, as well as the strategies for solving each type of oscillation mode, such as sub-synchronous control interaction (SSCI), sub-synchronous oscillation (SSO), and low-frequency oscillations. The references [12–14] deal with low-power WTs that have been configured with PMSG for sensor-less maximum power tracking using a dc/dc converter circuit. [12] develops the optimum voltages and currents on the dc side and establishes a relationship between them so that the system may be managed in the MPPT mode from the DC side. In[15], for feeding the DC load through a tiny PMSG wind conversion system, a maximum power point tracking design based on incremental conductance algorithm is created is displayed. The strategy for sliding-mode controller design for WTs including the diode rectifier and boost converter with grid connection is presented in [16]. For the control of WT, [17,18] proposes a logical control scheme with LVRT capabilities, in which the complete model layout of the system consists of a three-phase dc/dc converter, a three-step-boost circuit, and an inverter with neutral-point clamping configuration. [19] describes the creation of a three-phase modular boost converter that is stabilised by a linear quadratic regulator and supplied from a PMSG for battery charging.

The modelling of the wind turbine and synchronous generator, which is fed to a utility with the help of a dc/dc rectifier and boost model, is the focus of this work. This is used to create a detailed model that includes a wind turbine, PMSG, three-phase bridge rectifier, and a boost circuit with MPPT. Furthermore, a relationship between the electromagnetic torque of the PMSG and the current obtained through the boost converter can be established using the overall designed model, which then provides information on the development of control-loops for system behavior. Other phenomena relating the output power provided by the PMSG to the output voltage derived by the DC converter are known to be found as relative functions in terms of the boost converter's duty ratio and the synchronous machine's accomplished rotating speed.

The maximum power point tracking control technique is designed utilising the boost converter circuit, with an ideal duty ratio provided by numerous equations involved in reaching the power output by the boost converter's duty ratio.

2. SIMULATION RESULTS

In figure 2 the complete model of the WECS is simulated so as to consider and derive the parameters using the developed control strategy. Fig. 4 and 5 represents the electromagnetic torque & rotor speed of the permanent magnet synchronous generator, respectively as coupled into a shaft of a turbine The simulation model is set to move at a configurable speed of 5-12 m/s. Figure 6 depicts the voltage of an uncontrolled bridge rectifier circuit, which is boosted by control pulses delivered to the boost converter using the MPPT approach, as illustrated in figure 7. The voltage for the inverter circuit is shown in fig.8, which illustrates that during the conversion from ac to dc, the voltage remains constant according to the parameters taken into account. A load voltage waveform is shown in fig. 9 to show that this system can handle any type of load up to its design capacity.

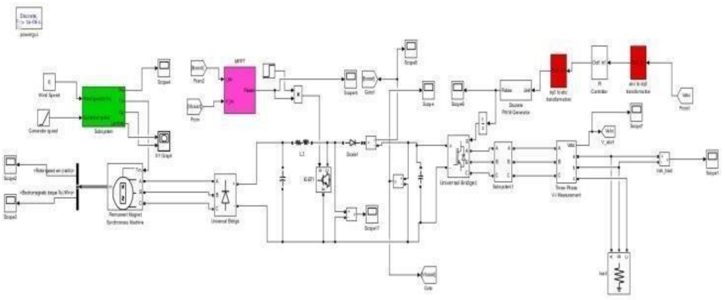

Fig. 2 The complete system diagram modelled in MATLAB Simulink

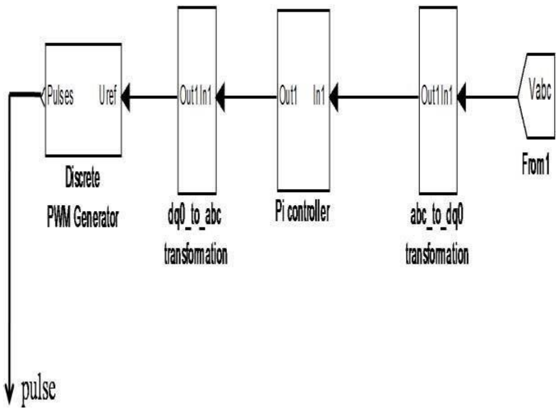

Fig. 3 The Controller for the inverter circuit

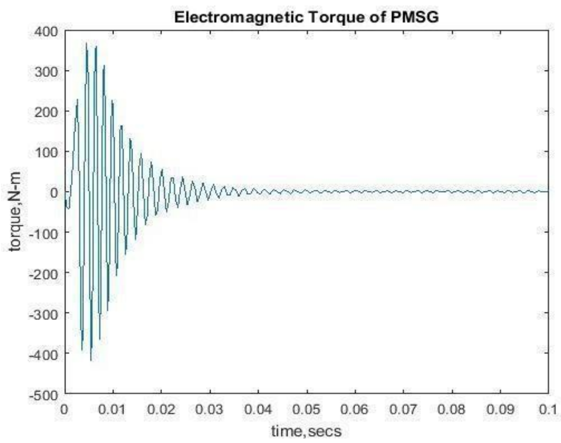

Fig. 4 Torque of PMSG

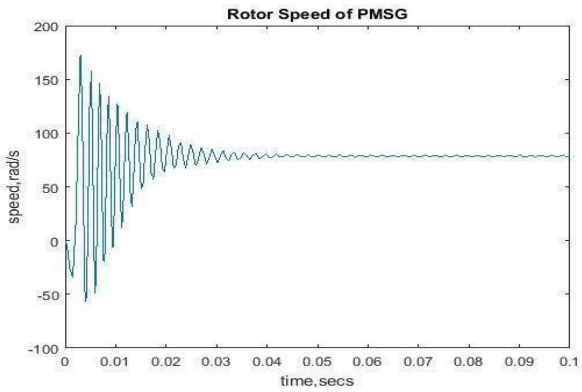

Fig. 5 Rotor speed of PMSG

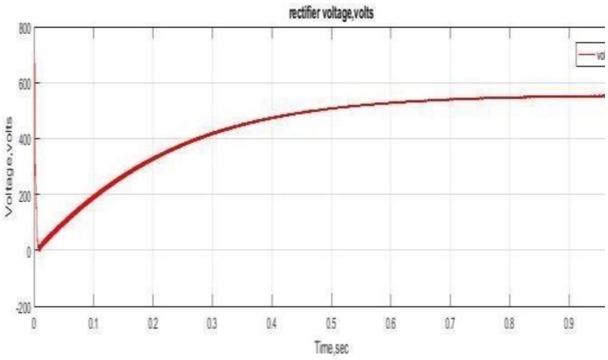

Fig. 6 ac to dc converter voltage

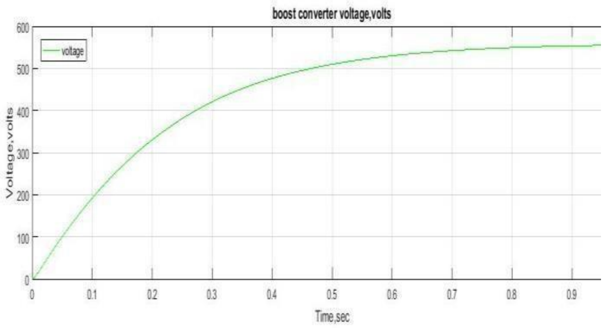

Fig. 7 dc to dc boost converter voltage

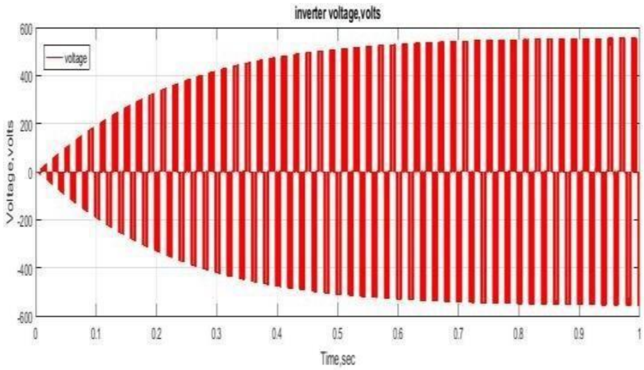

Fig. 8 Inverter voltage

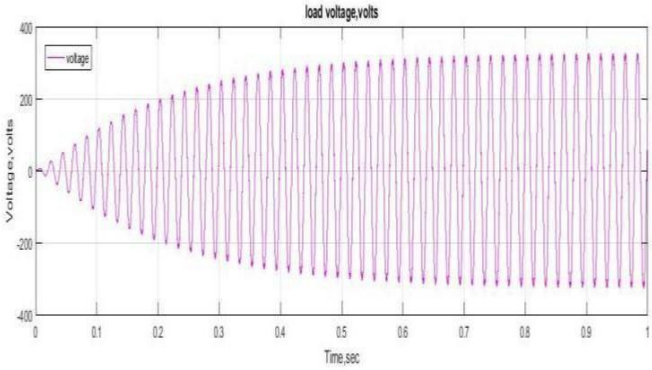

Fig. 9 load voltage

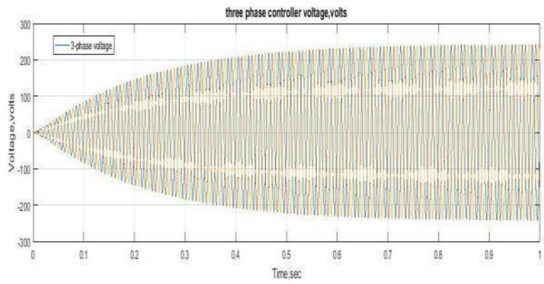

Fig. 10 Controlled three-phase voltage of the inverter Controller

3. CONCLUSION

This study covers the whole system design and modelling of a PMSG-based WT coupled to an ac load, as well as a diode bridge rectifier and boost converter simulation model for wind energy system performance analysis. First, the full system's average linear Simulink model design is shown. Then, utilising the electromagnetic torque of the PMSG and current from the boost converter circuit, an MPPT model is constructed in this work, which is then used to design control loops for the complete system. The PMSG's entire modelling process is based on the utilisation of a large number of equations. The PI controller-based model is used to construct a control design model for the load side converter. The work presented in this study concentrates on a single MPPT algorithm, but it can be expanded in the future to include a variety of additional techniques for extracting maximum power from the wind.

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