A Review on Wind Turbines by PMSG Generator For Power Generation

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Abstract

This paper mainly describes about the survey of power production in wind turbines by using permanent magnet synchronous generator . For this a different schemes of wind turbines are considered .

Keywords

PMSG (permanent magnet synchronous generator) , Boost converter , neutral-point-clamped (NPC) converter , low voltage ride-through (LVRT) , Direct drive wind turbine , Direct torque control (DTC) .

I. INTRODUCTION

In recent years, the electrical energy production from renewable energy resources, such as wind , are to a greater degree of appeal interest because of environmental problem and shortage of non-renewable energy resources in the near future [1] . The wind energy mainly depends on environmental and climatic conditions which changes periodically from time-to-time. Therefore it is essential to build a system that can produce maximum energy for all sustaining conditions.

Recently, Permanent Magnet Synchronous Generator (PMSG) is used for wind energy producing system due to its advantages together with better reliability, lower renovation and more green and so forth. The PMS generator is definitely devoted to a perpendicular axis of wind generators. By using a diode rectifier, it simplifies the shape and thus reduces the system cost (no role sensors and low-cost power inverter without control). An most useful active conduct is acquired if the active field of the Synchronous Generator may be fine-tuned [2] .

II. ENERGY MAXIMISATION

This study presents, that the wind generators converts the energy in the breeze to mechanical energy of the rotor shaft ; the mechanical energy in the shaft is then transformed to power in using a Permanent Magnet Synchronous Generator (PMSG) . The potential produced by the Permanent Magnet gadget is sorted out by using a 3-segment passive rectifier , which converts the AC voltage generated by the Permanent Magnet Synchronous Generator to a DC voltage . The schematic diagram of control system of a permanent magnet generator directly driven by wind generator is shown in Fig.1 . The primary circuits including composition of generators and enhance chopper , etc . was replaced in the equivalent circuit so one can theoretically examine this wind generating system . features such as generated electricity and DC output voltage were expressed in functions of duty ratio of the boost chopper and the generator rotational speed .

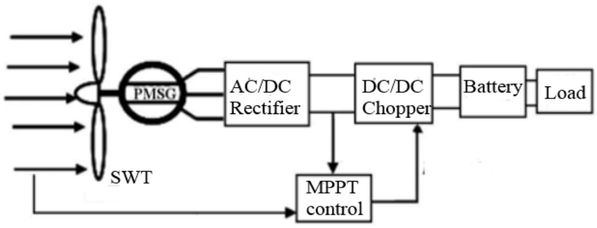

Fig 1. Schematic diagram of control system of a permanent magnet generator directly driven by wind turbine

A. Permanent Magnet Synchronous Generator Model

Since the energy for excitation source is not required for the Permanent Magnet Synchronous Generator, excessive regulation is anticipated. since the electromotive force in proportion to rotational speed is generated , it is possible to take out the produced output in the easiness [3]

B. Phase Diode Bridge Rectifier

The 3 phase diode rectifier is the easiest to handle low cost, and rugged rough analysis used in functions of power electronics. The downside of this 3 phase diode bridge rectifier is its incapacity to work in bi-directional strength waft . The generator is connected with rectifier circuits like the below Fig.2 .

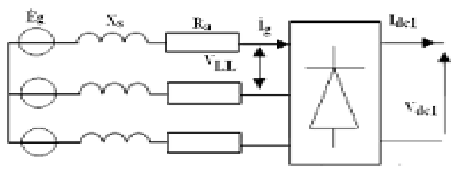

Fig 2. Connection diode rectifier circuits to the generator

C . Dc-to-Dc Converters

The DC-to-DC converters are regularly worn controlled switch-mode DC power supplies and in DC midriffs programs. Regularly, the input to this converter is an uncontrolled DC voltage which may be acquired by rectifying an AC voltage source. This uncontrolled potential will range due to modifications in the line. In order to manipulate this uncontrolled DC voltage into a controlled DC output it is required to apply a DC-to-DC converters. In this model, the boost converter has been controlled to yield constant output DC voltage level [4].

D. Maximum Power Point Tracking Condition

Two types of tracking algorithms (MPPT) exist, namely: methods found on the expertise of the (Cp) e.g. (λ) characteristics and strategies that allow seeking the optimal operation without knowing the turbine characteristics. Some control strategies are based on the power coefficient curve (Cp), e.g. λ control method , which changes angular velocity of wind rotor for maintaining an optimum λ value and consequently a maximum power coefficient (Cp) for all wind speeds . The wind turbine, when operating at maximum Cp, produces maximum mechanical power on shaft [5]. To the small wind turbine used as reference on this work the angular speed (Ω) for maximum mechanical power points do not coincide with angular speed for maximum electrical power points , so this strategy is not recommended .

III. FAULT RIDE-THROUGH CAPABILITY

Recently, many researchers have addressed the FRT methods for the wind farm connected through the voltage source-converter (VSC)-based high voltage dc transmission (HVDC). However, in the proposed CSC-based offshore wind farm, the long distances between generator- and grid-side converters cause a grid voltage dip that cannot be identified at the same instant by generator-side controller. In addition, the dc-link inductance in the CSC-based system is normally smaller (0.7 to 1.0 pF) compared to the dc-link capacitance (3 to 5 pF) of the VSC-based counterpart. This exerts significant challenges for the FRT capability of a CSC-based system, and therefore, recently proposed FRT methods for a VSC-based counterpart in cannot be adapted or made suitable for the proposed system [6]. In order to overcome this problem, a novel FRT method using inherent *short-circuit operating capability of the CSC is developed.*

IV. CHALLENGES IN EXISTING FRT METHODS FOR THE PROPOSED WIND FARM

The Proposed system configuration of cascaded CSC-based offshore wind farm and their block diagram is shown in Fig. 3 & Fig. 4.

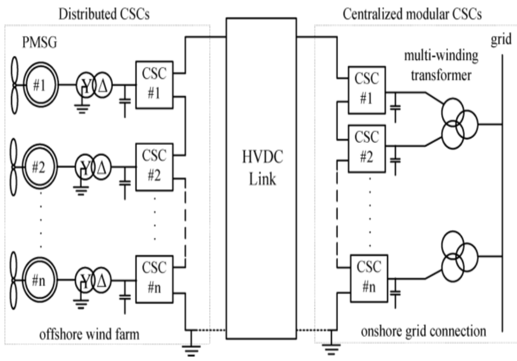

Fig 3. Proposed system configuration ofcascaded CSC-based offshore wind farm

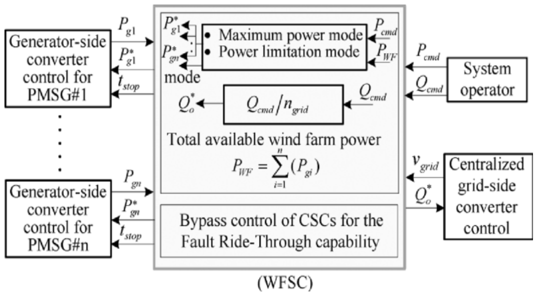

Fig 4. Block diagram of proposed wind farm.

Besides the grid fault, the other technical challenge for the cascaded CSC-based wind farm is to ensure continuous operation of the wind farm when one or more turbines fail to operate. This issue is not critical for the VSC-HVDC-based wind farm, where wind generators are parallel connected. Various recent studies have adopted a wind farm with series interconnection of wind turbines but this issue has not been researched. In this paper, a flexible operation is proposed which enables the isolation of the faulty turbine-generator unit from the surge system without affecting the process of other series interrelated wind turbines. The control module consists of the wind farm supervisory controller (WFSC), turbine-generator control units, and centralized grid-side converter control. As per the system operator's demand , *the WFSC* operates the wind farm in two active power control modes , namely maximum power mode and power limitation mode (e.g., for network frequency regulation In maximum power mode , all the wind turbines operate with their own maximum possible power [7] . In contrast, WFSC generates the active power references for each turbine-generator controller in power control mode.

The speed controller receives the reference speed from the MPPT algorithm and regulates the PMSG speed accordingly. The output of the generator speed controller gives the reference to the torque producing current (q -axis component of generator current). The zero–axis current control is applied to the generator. After capacitor current compensation, the converter reference current is used to obtain the modulation index and firing angle for the generator-side CSC #n. The gating signals are then generated using space vector modulation (SVM).

A. FRT Operation Mode

Owing to the low dc-link inductance, the CSC-based system needs a fast FRT capability.

VI. THREE-LEVEL BOOST AND NPC CONVERTER BASED PMSG WIND TURBINE

An analytical control in charge of scheme is proposed for the low power ride-through development of direct driven permanent magnet synchronous generator base Megawatt-level wind turbines. The proposed technique uses the turbine-producer rotor indolence to store the surplus energy during the grid voltage dips [8]. The power transfer system is realized using three-phase diode-bridge rectifier, three-level boost converter and neutral-point-clamp (NPC) inverter.

The wind turbine requirements, such as greatest power point tracking, net dc bus power control, parallel of the dc capacitor voltages, and imprudent power generation, are modeled as the reference control variables.

The generator and grid side free functions are described to compact with these control objectives. During each sampling interval, the control goals are achieved based on minimization of free functions. The synchronization of boost and NPC converters and the switch of orientation control variables during normal and low voltage ride-through operation are formulated such that the power converters operate in a safe mode while meeting the grid code requirements.

The power conversion system for the nonstop-driven PMSG based WECS is shown in Fig.6. It consists of three stages: ac-dc, dc-dc and dc-ac, and they are implemented using diode rectifier, three-level boost converter and NPC inverter, respectively [9]. The active switch devices in the TLB-NPC converters are realized using MV-IGBT/IGCT, and they work at few hundred Hertz to decrease the switching losses. The diode rectifier features series connected diodes due to the MV generator. The output of the diode rectifier, v in remains unregulated but is limited by the rated speed of the turbine, which defines the voltage rating of the capacitor.

The TLB converter enables MV operation for the dc-dc stage. The output of the TLB fits directly without delay the two dc-link capacitors of the grid-tied NPC inverter. This second dc-link provides decoupling for the generator- and grid-side converters and thus it provides better capability for the LVRT enhancement. The NPC multilevel and MV operation at grid-side improves the power quality and efficiency of the system. The Configuration of three-level boost converter and NPC inverter based MW-MV PMSG-WECS is shown in Fig.5.

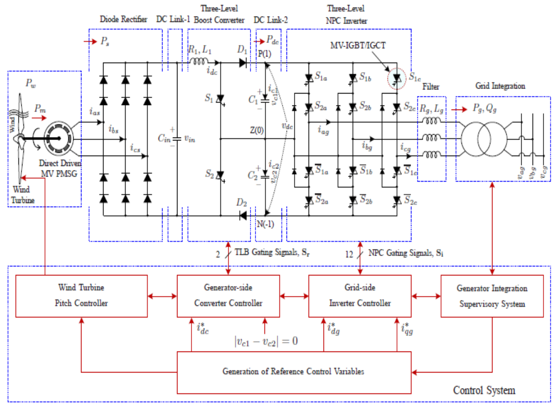

Fig 5. Configuration of three level boost converter and NPC inverter based MW-MV PMSG-WECS.

The pitch control system regulates the output power of the turbine when the wind speed is above its rated value. The magnitude, segment and regularity of the grid voltages are monitored by the grid assimilation administrative system [10]. It sends proper control signals to the references generation system in the event of grid faults.

During the normal and LVRT operation, with the help of the references generation system, the directed inductor current is generated for the TLB converter, while the reference d-q axis currents are developed for the NPC inverter.

The control objectives for the power converters include:

TLB Converter:

- Regulation of inductor current , I dc
- To achieve maximum power point tracking (MPPT) during normal operation

- To store the surplus active power in the turbine generator rotor inertia during LVRT operation
- Balancing of dc capacitor voltages during all operating conditions to maintain semiconductor device
- Voltage stress within safe limits NPC Inverter :
- Regulation of d-axis grid current
- To maintain net dc-bus voltage, V dc at its reference value during normal operation
- To limit the active power output, Pg during LVRT operation
- Regulation of q-axis grid current to generate reactive power to the grid.

VI. SPACE-VECTOR AMENDED SENSORLESS DIRECT-TORQUE CONTROL FOR DIRECT-DRIVE PMSG WIND TURBINES

This method plan a space vector modulation (SVM) based direct torque control (DTC) scheme for a PMSG used in an unpredictable speed direct-drive wind power generation system. A quasi-sliding-mode observer that uses a relatively low sampling frequency, e.g. 5 kHz or 10 kHz, is planned to estimate the rotor position and stator flux linkage based on the current model of the PMSG over a wide operating range. The optimal torque dominion is obtained directly from `the estimated rotor speed for the DTC by which the maximum power point tracking control of the wind turbine generator is achieved without the need of wind speed or rotor position sensors [11].

Compared to the conventional DTC, the proposed DTC-SVM achieves a fixed switching frequency, greatly reduces the flux and torque ripples, while retaining the fast dynamic response of the system. The effectiveness of the proposed DTC-SVM scheme is verified by simulation studies on a 1.5 MW PMSG wind turbine and is further verified by experimental results on a 2.4 kW PMSG with a 10 kHz sampling frequency .

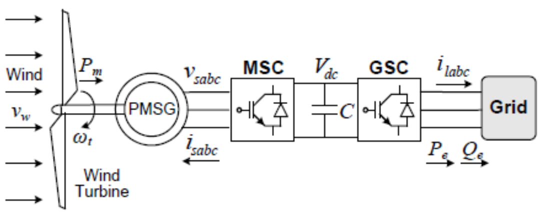

Fig 6. Configuration of a direct-drive PMSG wind turbine.

The configuration of a direct-drive PMSG wind turbine is shown in Fig.6, the wind turbine is connected to the PMSG directly. The electrical power generated by the PMSG is transmitted to a power grid and supplied to a load via a variable-frequency converter, which consists of a machine side converter (MSC) and a grid-side converter (GSC) connected back-to-back via a DC link.

This paper proposes an improved SVM based DTC system for direct-drive PMSG wind turbines, where the MPPT control is realized without the dimensions of wind speed or generator rotor position, leading to a position or speed sensor less control for the WTG systems. The optimal torque command generated by the MPPT algorithm can be applied directly to the DTC system, which eliminates the commonly adopted outer speed control loop in the vector control systems.

To minimize the CPU loading in the practical system implementation, a quasi-sliding mode stator-flux observer is proposed, which uses a lower sampling frequency, normally lower than 10 kHz, to achieve high-accuracy stator flux observation over a wide speed range of the PMSG. By adopting the proposed DTC scheme, the flux and torque ripples are reduced while using a fixed and lower switching frequency and retaining the fast dynamic response of the system, when compared with the conventional DTC scheme. The proposed DTC system is validated by simulation for a 1.5 MW direct-drive PMSG wind turbine and experimental results for a 2.4 kW direct-drive PMSG wind turbine.

VII. PROPOSED SVM-BASED DTC

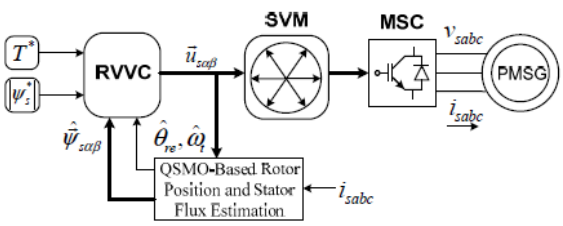

Fig 7. Proposed system

The plan of the proposed SVM-DTC for a non-salient pole PMSG WTG is shown in Fig. 7, where T* and ψ-s are the allusion torque and stator flux magnitude, respectively.

$$\hat{\vec{\psi}}_{s\alpha\beta} = [\hat{\psi}_{s\alpha}, \hat{\psi}_{s\beta}]^T \quad \text{and} \quad \vec{u}_{s\alpha\beta} = [u_{s\alpha}, u_{s\beta}]^T$$

Are the estimated stator flux linkage vector and the resultant stator energy space vector in the immobile α-β reference frame, respectively? From Fig. 8 it can be seen that the proposed DTC-SVM scheme retains the advantages of the conventional DTC, such as no coordinate transformation, no current control, etc. However, instead of adopting a switching table and hysteresis comparators, a reference voltage vector calculator (RVVC) is designed to determine the desired voltage vector →us α-β. The Experimental Setup is shown in Fig. 9

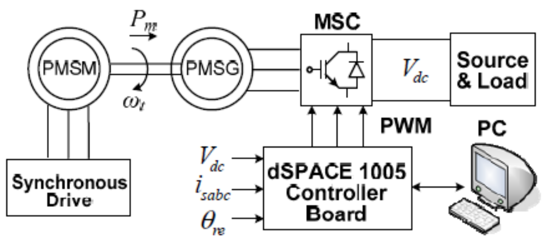

Fig 8. Experimental setup

A. Control Issues in PMSG Based Small Wind Turbine Systems

In the field of wind energy generation particular interest has been focused in recent years on distributed generation through small wind turbines (power unit 200 kW) because of their limited size and lesser environmental impact. The field of small generation was dominated by the use of asynchronous generators directly connected to the grid, while recently permanent magnet synchronous generators (PMSG) with power converter, either partially or fully controlled, became popular [11]. This paper reviews the control issues related to these small wind turbine systems: generator torque control, speed/position estimation, pitch control, braking chopper control, dc/dc converter control, and grid converter control. Specific issues for small wind turbines arise in the wind energy extraction optimization and limitation and in the innovative concept of "universal" wind turbine operation, that leads these system to operate grid-connected, standalone or in load supporting mode.

Fig. 9 shows the small wind turbine market segmentation: the maximum number of manufacturers in Europe corresponds to stand alone wind applications with a max wind-turbine size of 20 kW, but the average wind penetration rate is maximum in the pumping field.

It is possible to observe that the maximum wind turbine size increases in the case of wind diesel system with battery , and the maximum wind-turbine size increases in case of grid connection . The field of small generation was dominated by the use of asynchronous generators directly connected to the grid/load and more recently by Permanent Magnet Synchronous Generators (PMSG) with a diode rectifier, boosts converter and inverter.

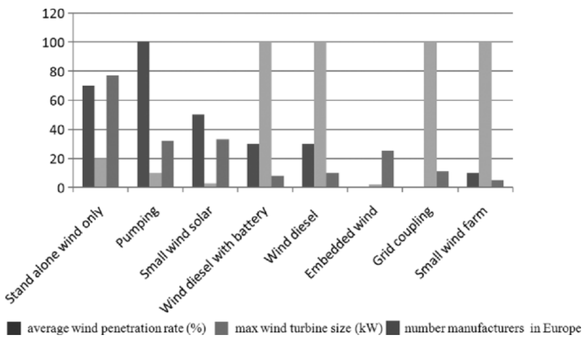

Fig 9. Small wind market segmentation

The use of a high number of pole pairsallow the PMSG to operate at low speed without decreasing the efficiency, thus allowing avoiding the gearbox. The use of a diode bridge reduces cost and control algorithm complexity. Moreover the well-known six-pulse DC voltage waveform allows implementing a simple estimator of the rotor speed. The generator low frequency harmonics (5th and 7th) can be reduced thanks to the dc inductor that unfortunately has a negative effect on the power factor. Moreover, the extracted power decreases as the wind speed increases due to the major effect of diode commutation and at low speed

Due to possible discontinuous operation of the dc/dc converter [11]. Hence, for power levels in the order of tens of kW, these generators will use a back-to-back converter leading to a 5%–15% more power. Besides the choice of the power converter configuration, the control issues in PMSG based small wind turbine systems are many.

VIII. WIND TURBINE SYSTEMS TOPOLOGIES

Numerous types of generators can be adopted in wind power turbines: dc and ac types, parallel and compound dc generators, permanent magnets or electrical field excited, asynchronous or synchronous generators. The right choice depends on the primary source, the type of load and the speed of the turbine. Besides, systems differ with respect to their applications, whether they are standalone or connected to the grid [11].

From Fig.10 & Fig. 11 the most adopted wind turbine generator for medium power systems is the doubly fed induction generator (DFIG) that could be used even in standalone operation. However, typically in small WTS for standalone applications, the choice is between variable speed asynchronous and synchronous generator. Variable speed asynchronous generators can easily operate in parallel with large power systems, since the utility grid controls voltage and frequency, while static and reactive compensating capacitors can be used for correction of the power factor and harmonic reduction.

Abrupt speed changes due to load or primary source changes are easily absorbed by the solid rotor of the asynchronous generator, and current surges can be effectively damped without demagnetization issues.

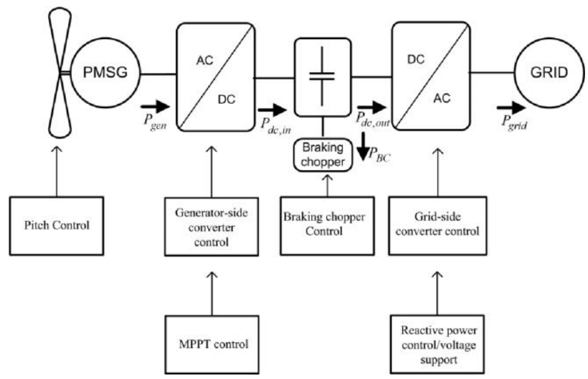

Fig 10. Control issues in PMSG-based smallwind-turbine systems.

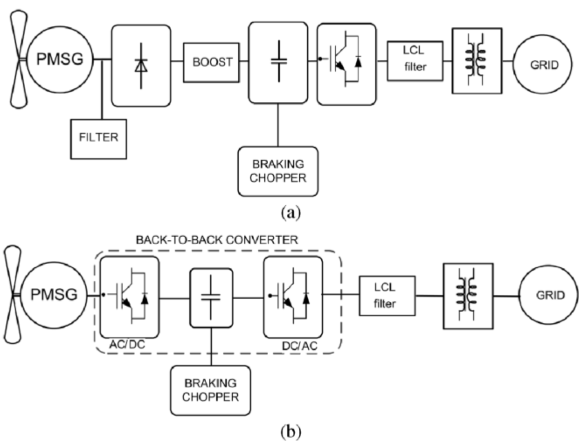

Fig. 11. Wind-turbine system. (a) Diode-bridge rectifier and boost converter . (b) Back-to-back converter .

IX. CONCLUSION AND FUTURE WORK

Thus the survey about the power generation of wind by permanent magnet synchronous generator is studied with different techniques. Out of these the most convenient technique is by using maximum power point tracking method. In this method, the losses are reduced and the efficiency is increased.

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