Wind energy conversion technologies based on grid-connected permanent magnet synchronous generators

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ABSTRACT: ***Researchers are being motivated to work in this area by the developing trends in wind energy technology, with the goal of optimizing energy extraction from the wind and injecting high-quality power into the grid. In recent years, permanent magnet synchronous wind turbines have gained popularity for current wind energy conversion, machines Permanent Magnet Synchronous Motors (PMSMs) are becoming the most preferred option the system wind energy conversion system (WECSs). It examines the latest developments in converter topologies, control approaches, and methods for extracting maximum energy from permanent magnetic synchronous generator (PMSG)-based WECSs. Several research papers, especially in reputable research journals and transactions, have been published in diverse research literatures in the last few years It also provides an overview of output-related grid connectivity difficulties. In addition to fault-ride-through (FRT) and grid support, power smoothing and reactive power regulation are available. WECSs based on PMSG have a variety of functionalities. The researchers working in the field of will benefit from this review paper in the examination of trends, advancements, and problems in the grid-integrated PMSG based WECSs previous research projects and in discovering.***

KEYWORDS: Converter topology, Fault-ride-through (FRT), Maximum power point tracking (MPPT), Permanent magnet synchronous generator (PMSG), Wind turbine (WT).

1. INTRODUCTION

Clean energy sources such as solar, tidal, and wind have recently gained popularity due to their reduced environmental impact Influences of the environment Wind energy is a type of renewable energy renewable energy solutions that are only starting to gain traction. In the past The capacity of wind turbine (WT) units has increased dramatically during the last few decades risen in power capacity from a few tens of kW to today's Multi-MW level In light of the continual increase in power, WTs' current level and greater penetration into the electrical system generators, power converter systems, and control systems that are more advanced To make the WT units more efficient, solutions must be found suited for interconnection with the electricity grid Any WT generator can run at a constant or variable speed For example, squirrel cage induction generators (SCIGs) can be used in both fixed-speed and variable-speed wind turbines (VSWTs), although DFIGs and synchronous generators (SGs) are typically used in VSWTs provides an overview of possible wind generator systems as well as comparisons. Even while a fixed-speed SCIG-based WECS is simple, stable, and less expensive, it suffers with significant mechanical stress, reactive power burden on the power grid, severe power fluctuations. In this approach, the variable-speed operation of the WT produces more power than the fixed-speed operation, resulting in the WT's aerodynamic efficiency being maximized. A mechanical gearbox, which are commonly used in VSWT in order to Matching the WT's low-speed operation with the generator's comparatively high-speed operation not only raises manufacturing costs and maintenance requirements, but also diminishes the WT's aerodynamic efficiency. The effectiveness of VSWT should be improved If the mechanical gearbox could be removed, the increase would be even greater .As a result, a number of WT manufacturers have embraced the direct-drive system.[1]

The variable-speed operation of the WT provides more power than the fixed-speed operation in this manner, maximising the WT's aerodynamic efficiency. A mechanical gearbox, which are frequently employed in VSWT. Matching the WT's low-speed operation to the generator's relatively high-speed operation increases manufacturing costs and maintenance requirements while also lowering the WT's aerodynamic efficiency. VSWT's effectiveness should be enhanced the increase would be substantially greater if the mechanical gearbox could be removed. As a result, the direct-drive method has been adopted by a number of WT manufacturers. Power semiconductor devices are the backbone of many power converter topologies used to interface renewable resources, and they allow greater flexibility in their operation and control during both steady-state and transient system operating situations .Soft-starters were employed to link the SCIGs to the power grid in the 1980s.

Wound-rotor induction generators (WRIGs) employed diode bridges with chopper circuits for rotor resistance management in the 1990s. Advanced ac–dc–ac converters have been used since 2000, first in partial-scale power capacity to regulate the generated power from DFIG-based WECSs, and then in full-scale power capacity. Figure 1 A shows that the graph between lambda and delta curve.

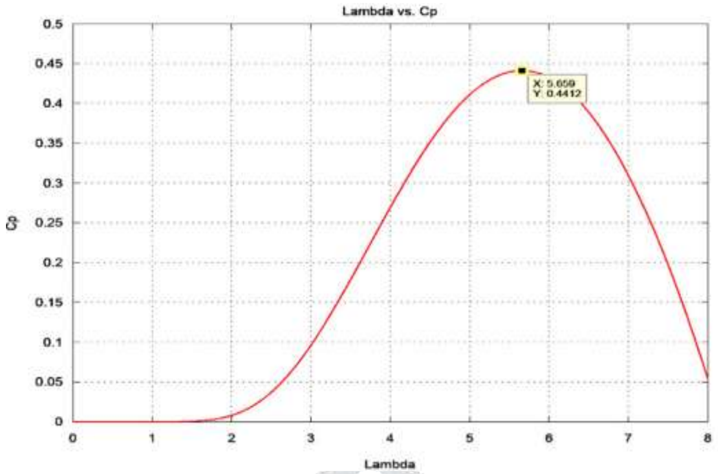

Figure 1: Illustrating the Cp Vs. Λ Curve

Due to its inherent advantages, the CSC-based ac–dc–ac converter architecture looks to be a potential choice among many high power and medium voltage power converter topologies such as a simple topology, a small number of devices, a small dimension, and a large number of devices Low dv=dt, simple control method, dependable short circuit current protection, flexible power flow management, and inherent power capacity Ability to operate in four quadrants On the other hand, if you're looking for a unique way to express yourself WECSs with variable speed PMSGs, unidirectional converters with diode rectifiers, and two-level VSCs with back-to-back IGBT samong others, are the most prevalent topologies and are becoming increasingly popular[2].

2. LITERATURE REVIEW:

Ayman S et al. in their case study suggested that the performance of modular permanent magnet machines is determined by the correct selection of pole and slot numbers, which results in minimal phase coupling. Low order harmonics in the stator MMF are eliminated by using preferred slot and pole number combinations, which reduce vibration and stray loss. In this study, three similar machines with various slots per phase per pole (SPP) ratios are built. The machine's mathematical model is described, which is based on a modified winding function. The flux linkage vector owing to the permanent magnet is determined using FEA. When comparing the performance of the three machine designs, a simulation study is carried out[3].

Ramji Tiwar et al .in their case study suggested that a comparison of several control strategies for extracting maximum power from a Permanent Magnet Synchronous Generator (PMSG) based Wind Energy Conversion System (WECS) under various wind speed conditions is described in this study. A wind turbine, a PMSG, and a DC/DC converter coupled to a DC load make up the WECS. Proportional Integral (PI) control, Perturb and Observe (P&O) approach, and Fuzzy Logic Controller are the Maximum Power Point Tracking (MPPT) control techniques compared here (FLC). The output DC voltage and power across the load are the metrics used to evaluate the MPPT controller's efficiency[4]

M.Chinchilla et al. in their case study suggested that variable speed generators that operate on a constant grid frequency are commonly used in wind energy. A modern wind energy system of this type comprises of a permanent-magnet generator placed on the ground with a frequency converter that allows variable speed operation. The grid inverter limits the maximum power capability of the wind energy system. The active and reactive power restrictions are theoretically formulated. This formula is used to set the inverter's power reference limits. Depending on the amount of tolerated AC current harmonic distortion, two distinct areas are identified.[5]

Mohammed H. Qais et al. in their case study suggested that wind farms' substantial power penetration into power grids necessitates new transmission system operator requirements to keep them linked to the grid for as long as possible. Grid disturbances, such as voltage dips, necessitate wind farms to be islanded in order to safeguard their equipment from being damaged by the high current flowing. Because of the islanding of large-scale wind farms, grid stability will deteriorate. To help restore grid stability, wind farms should maintain connecting to the grid during low voltages for a set period of time [low voltage ride through (LVRT) capabilities]. LVRT capabilities of a permanent magnet synchronous generator (PMSGVSWT) that is directly driven by a variable speed wind turbine.[6]

3. DISCUSSION:

3.1. Diode rectifier-based topology:

A small-scale WECS design typically comprises of a PMSG, a diode bridge rectifier-based architecture employing six diodes, a dc chopper (often a boost converter), and a grid-side inverter. To save money, MSC is made up of an unregulated diode rectifier cascaded with a boost converter. A diode rectifier circuit converts the variable–magnitude–variable–frequency ac power from the WT generator to dc power, which is then converted back to ac power at the desired frequency and voltage level by a grid-side controlled inverter. The boost converter used on the dc side has two advantages: first, it makes maximum power point tracking (MPPT) easier, and second, it gives GSC control more flexibility. Proposes using a diode rectifier cascaded by a dc chopper to drive a variable- speed PMSG. [7]

3.2. Applications:

Despite its low cost and ease of installation, this system lacks control over the generator power factor, resulting in a drop in generator efficiency. Figure 2 discloses two stage converters

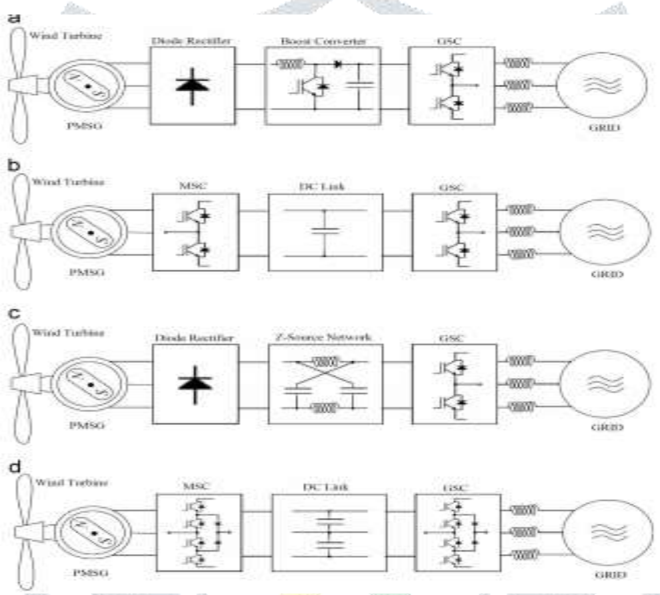

Figure 2: Two-Stage (Ac-Dc-Ac) Converter Topologies for PMSG Based WECS - (A) Diode Rectifier Based Topology (B) Two-Level Back-To-Back VSC Based Topology (C) Z-Source Inverter Based Topology (D) Multi-Level Converter Based Topology.

Considerable stator harmonic current efficiency, shorten life, and cause significant electromagnetic torque ripple. The PWM converter (used to control current at the machine) minimises input current harmonics and produces a ripple-free electromagnetic torque. The MSC can fully regulate the generator in terms of speed, power factor, and electromagnetic torque, while the GSC can fully regulate the power flow to the grid in order to maintain the dc-link voltage and improve output power quality by lowering total harmonic distortion (THD).

3.3. Advantage:

At the machine level, two of the most common vector control systems, field-oriented control (FOC) and direct torque control (DTC), are used and have nearly identical dynamic responses. The FOC is a well-known generator speed control strategy that uses a dual loop control structure with an outer speed control loop and an inner current control loop that is usually based on hysteresis control in a natural reference frame or PI control in a synchronous reference frame. The electromagnetic torque in FOC is regulated by the q-axis component of the stator current, whereas the d-axis stator current is driven to zero to achieve the highest electromagnetic torque[9].

3.4. Working:

In an ST-DTC, uneven torque, flux, and current ripples cause overstress on the turbine shaft, shorten turbine life span, and generate a lot of acoustic noise. Integrating space–vector modulation (SVM) into the DTC is an efficient way to alleviate the issues associated with ST-DTC. The GSC, on the other hand, often manages the dc-link voltage to balance the input and output powers, allowing the grid to always absorb / supply a balanced set of fundamental current at unity-power-factor by supplying reactive power to non-linear loads linked at PCC. A voltage-oriented control (VOC) technique for the GSC uses dual-loop control in a similar way to the FOC. Considers two PMSG control strategies, namely unity-power-factor control and rotor-flux-orientation control, to build an optimised control strategy for the machine-side three-switch buck-type rectifier. The DTC technique presented in reduces flux and torque ripple by adopting a fixed and low switching frequency. A feedback linearization technique is also published in for dc-link voltage control of a PMSG based WECS. The study given in was expanded upon in , which also includes experimental data. References present comparative assessments of a PMSG-based WECS that uses FOC and DTC control techniques for the MSC, as well as VOC and DTC control strategies for the VOC and DTC[10].

4. CONCLUSION:

The efficient use of wind energy has been a major concern. As a result, WT manufacturers are becoming more interested in VSWT systems with power electronics interfaces. It is feasible to improve the WTs' controllability by using power electronics, which is a big source of concern for the integration with the electrical grid Among the most well-known ideas The PMSG is the one who delivers a solution in the present VSWTs is a serious chance to attain gearless operation, and as a possible candidate for innovative designs in high-power WT applications, Cost reductions and breakthroughs in permanent magnet materials have recently made them even more appealing. The back-to-back converter topology, which is currently the most advanced among the power converter topologies used in WECSs, can be used as a benchmark for the implementation of other converter topologies, taking into account the requirements of active switches and auxiliary components, as well as their ratings, harmonic performance, and converter efficiency. With the increasing power capacity of WTs, a trend toward the utilization of multiple converter topologies in WECSs may be seen. The latest developments in MSC and GSC control techniques for PMSG-based WECSs were also examined. When comparing the MSC and GSC control strategies, it is clear that the FO is superior. The back-to-back converter architecture, which is currently the most advanced among power converter topologies utilized in WECSs, can be used as a benchmark. Other converter topologies are being implemented with this in mind. active switches and accessory components are required in addition to their scores, the harmonic performance, and the efficiency of the converter WTs are becoming more powerful as their capacity grows. a trend in which multilayer converter topologies are being used in WECSs are also seen. Control trends in MSC and GSC The tactics employed in WECSs based on PMSGs were also examined. While It can be concluded by comparing the MSC and GSC control techniques. Looking at a glance towards the technology trends and status of research, it was visualized that the two-level back-to-back converter and the diode rectifier-based topologies; FOC and VOC methodologies; ORB and HCS based MPPT algorithms being the most researched concepts for PMSG based VSWTs. It was also recognized that the FRT capability of PMSG based WECSs being the most investigated grid-interconnection issue. With a goal toward more optimized WECSs, the future research studies expect more technological improvements in current WT design concepts. Moreover, the existing control strategies can further be improved. Figure 3 discloses the wind turbine power characteristics information.

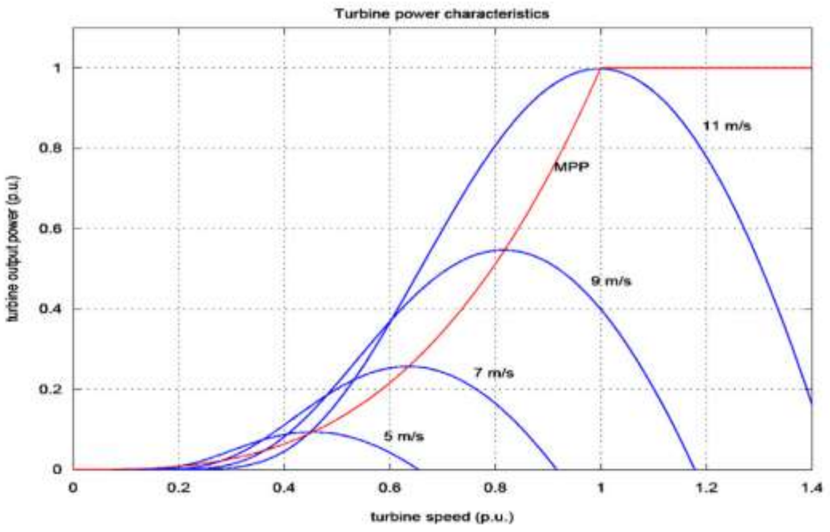

Figure 3: Illustrating the Wind Turbine Power Characteristics.

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