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Review on Performance Analysis of SCIG and PMSG-Based Wind Energy Conversion System Systems

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Abstract
The huge power generation from wind energy is achieved by the number of various present available generators, i.e., PMSG, SCIG, and DFIG, as our primary objective is to supply ac power to the distribution system. This paper illustrates the model of wind power is driven by two separate generators working as a distributed generation (SCIG) and (PMSG). The aims of this research paper are to analyze the characteristics also performances of Squirrel cadge induction generator (SCIG) and Permanent magnet synchronous generator (PMSG) to analyze the performance of generator response under short circuit fault, generation capability at the antithetical current of airspeeds, generator's current waveform distortions at various operating speeds, the performance of stand-alone (PMSG) and (SCIG) and performance investigating of GRID-Connected WECS. The wind generator model is simulated and modeled by using MATLAB/Simulink. Results obtained from simulations explain the performance of two different generators in different scenarios, i.e., the effect of wind speed variations, activity during normal and during a fault condition. The simulated results after the successful modeling of the proposed system will prove the superiority of wind generator type under both operating conditions, i.e., Normal and faulty conditions in the distribution system.

Keywords — *Wind turbine generators, Squirrel Cage Induction Generator (SCIG), Permanent Magnet Synchronous Generator (PMSG), MATLAB/Simulink.*

I. INTRODUCTION

Energy conservation, environment protection, and the sustainable development of the environment are the three major encounters in the world [1, 2]. Wind energy Power generation is the world's fastest-growing renewable energy source. The average annual growth rate of the WECS turbine installment is around 30% during the last ten years [2, 3].

Fig. 1 shows the global additive current of wind power capacity worldwide. In this figure, the scenario 'reference' is based on the projection in 2004. The World Energy Outlook report was obtained from the International Energy Agency (IEA). The scenario 'Moderate' considered total policy measured to support renewable energy sources either planned worldwide or underway. The scenario of 'Advanced' assumes that total policy options are in favor of wind powers.

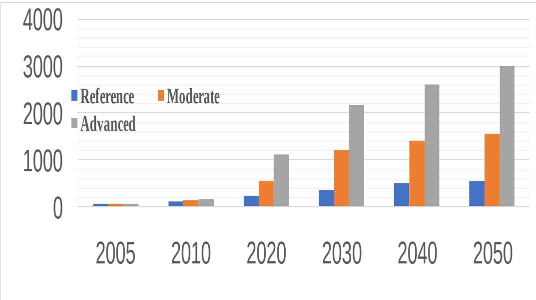


Fig-1. Global Cumulative Wind Power Capacity

Apart from these, the major current issue to consider is how we can meet the ever-growing energy demand without depleting the resources for natural energy and affecting the environment. In electrical power, the implementation of the Distributed Generation (DG) has emerged to be an efficient and more reliable generation system. The DG units usually comprise of generating units of small-scale which are less than (10 MW), that are interfaced with distribution systems. Clean energy sources like solar PV, wind, fuel cells and micro-turbines power sources enable DG units as One of the affordable and popular generation sources [2, 4].

It is very important to focus on a generation system that is clean, smokeless. For this reason, it has been realized that the consumption of renewable energies is the best solution considering environmental issues and the decrease of supply from fossil fuels. Moreover, in renewable energies, the increment of wind energy generation has been noticed over the years, the power generation from wind energy has been significant and considered as the fastest rate of generation compared to other resources [5].

At the end of 2013, the nameplate capacity of wind energy-powered generators worldwide was 318 GW. The increasing generation of power from wind energy in the market is expected to be increased by

8% in 2018 [6]. Furthermore, in the past 3 years, this increase of generation from wind energy has also been noticed by more than double. Various countries have been focusing on electrical power generation via wind and have successfully achieved a high capacity of generation. The contribution of the United States in wind power is 19.2% [7], whereas China contributes 28.7% [8]. On the other hand, counties such as Germany and Spain and India contributed 10.8%, 7.2%, and 6.3% respectively of the total wind energy power generation capacity worldwide.

As the wind energy source is one of the feasible technologies and its application as a DG unit is popular these days due to economically viable as compared to other clean energy sources. Wind energy power generation could be found from a small number of kilowatts to much more MW in largescale grid-connected or off-grid small scale stand-alone systems wind farms. This type of DG causes a problem in an electrical system due to a lack of control on reactive and active power; this type of DG usually causes problems in the electrical power connected system. So, accurate modeling control and, most importantly, selection of generator is required for WECS. Furthermore, it is so important to research various ways to improve technical control and as well as the performance of the plant as there is an increase of wind energy power integrated which is being integrated with the large-scale power system.

As the demand for electricity is increasing daily globally, and the depleting resources and increasing cost for the conventional power generation, the power distribution companies are shifting to renewable energy power generation. Furthermore, the capital and running cost of existing long-distance transmission networks and to locate the occurrence of the faults in these systems is quite complex.

Another issue regarding conventional generation is the greenhouse gases (GHG) emission in the environment, causing so many problems for humans and all living objectives. To tackle this issue, distributed generation-based distribution system proposed is in this paper. Moreover, to cope with the increasing environmental impact, increased power generation cost, and depleting reservoirs of conventional power generation, the WECS is intended to be consumed as a power generation source. Moreover, to best select, the generator type for WECS, which is based on the performance, maintenance, and quality of supplied power, has been simulated and studied in this research paper.

II. CONCEPTS FOR WIND TURBINE GENERATOR TYPES

Referring to the rotation speed, wind turbine concepts can be classified into fixed speed, limited variable speed, and variable speed. For variable speed wind turbines, based on the power converter rating related to the generator capacity, they can be further classified into wind generator systems with a partial-scale and a full-scale power electronic converter. Besides, considering the drive train components, the wind turbine concepts can be classified into geared-drive and direct-drive wind turbines. In geared-drive wind turbines, one conventional configuration is a multiple-stage gear with a high-speed generator; the other one is the multigrid concept, which has a single-stage gear and a low-speed generator [9]. In this section, according to contemporary wind turbine concepts, the basic configurations and characteristics of different wind generator systems are described [10].

A. Fixed speed concept

The fixed speed wind generator systems have been used with a multiple-stage gearbox and a SCIG directly connected to the grid through a transformer, as illustrated in Fig. 2. Because the SCIG operates only in a narrow range around the synchronous speed, the wind turbine equipped with this type of generator is often called the fixed-speed wind generator system. This is the conventional concept applied by many Danish wind turbine manufacturers during the 1980s and 1990s, and upwind, stall-regulated, three-bladed wind turbine concept using a SCIG [11], so that it is also referred to as 'Danish concept'. Since the SCIG always draws reactive power from the grid, during the 1980s, this concept was extended with a capacitor bank for reactive power compensation. A smoother grid connection was also achieved by incorporating a soft starter. Furthermore, a pole changeable SCIG has been used, which leads to two rotation speeds. Some manufacturers, such as Micon (currently merged into Vestas), Bonus (currently Siemens), Made, and Nordex, have products based on this concept.

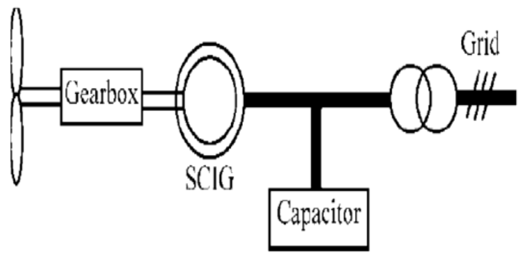


Fig-2. Scheme of a fixed speed concept with SCIG system

The well-known advantages of SCIG are it is robust, easy, and relatively cheap for mass production. Besides, it enables stall-regulated machines to operate at a constant speed when connected to a large grid, which provides a stable control frequency. Although the stall control method is usually used in combination with the fixed speed SCIG for power control, the active stall control or pitch control has also been applied [12].

B. Variable speed Concept

This configuration may correspond to a variable speed wind turbine with a direct-drive generator connected to the grid through a full-scale power converter. The most important difference between geared drive wind turbines and direct-drive types is the generator rotor speed. The direct-drive generator rotates at a low speed because the generator rotor is directly connected to the hub of the turbine rotor. To deliver certain power, the lower speed makes it necessary to produce higher torque. Higher torque means a larger size of the generator. Therefore, for direct-drive generators, the low speed and high torque operation require multi-poles, which demand a larger diameter for implementation of a large number of poles with a reasonable pitch.

Moreover, for a larger direct-drive generator, considering the current loading and gap. Flux density limitations, a higher torque also requires a larger machine's volume, so that the torque density could not be further significantly increased. To increase the efficiency, to reduce the weight of the active parts, and keep the end winding losses small, direct-drive generators are usually designed with a large diameter and small pole pitch [13]. Besides, the advantages of direct-drive wind turbines are the simplified drive train, the high overall efficiency, the high reliability, and availability by omitting the gearbox [14]. Types of direct-drive generators used in the market can be classified into the electrically excited synchronous generator (EESG) and the PMSG. The features of different topologies of PMSG are presented in Section 2.3.

C. PM synchronous generator

The scheme of a grid-connected PMSG for direct-drive wind turbines is shown in Fig.3.The advantages of PM machines over electrically excited machines can be summarized as follows according to works of literature [3, 14].

Higher efficiency and energy yield, no additional power supply for the magnet field excitation, improvement in the thermal characteristics of the PM machine due to the absence of the field losses, higher reliability due to the absence of mechanical components such as slip rings, lighter and therefore higher power to weight ratio. However, PM machines have some disadvantages, which can be summarized as follows:

The high cost of PM material, difficulties to handle in the manufacture, demagnetization of PM at high temperature [5]. In recent years, the use of PMs is more attractive than before because the performance of PMs is improving, and the cost of PM is decreasing. The trends make PM machines a full-scale power converter more attractive for direct-drive wind turbines [15].

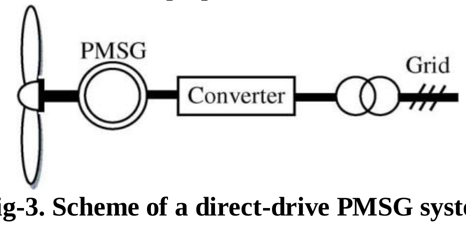


Fig-3. Scheme of a direct-drive PMSG system

III. MODELLING AND SIMULATION

The modeling and simulation of WECS generators are discussed in consecutive subsections.

A. Modelling and Simulation of SCIG

The system depicted in Figure 4 is modeled in the MATLAB Sim Power Systems toolbox. In [15], The stator of 4 pole SCIG is connected to an 11kV, 50Hz grid through two back to back connected PWM converters and a transformer. The induction machine is rated for three-phase, 690V, 50 Hz. The stator winding resistance (Rs) and self-inductance (Ls) are 0.007 pu and 0.18 pu, respectively, while cage resistance (Rc) and rotor self-inductance (Lr) are 0.0072 pu and 0.16 pu, respectively. The mutual inductance (Lm) between the rotor and stator is 3.2pu. The output of the SCIG stator is converted into DC by machine side converter, which charges a capacitor. The capacitor voltage (DC link voltage) is maintained at 1200V. This system is also operated at wind speed varying from 5-13 m/s. This machine is operated in two modes, namely subsynchronous and synchronous modes only. The optimal power control ensures that the rotor rotates at the reference value as per the wind speed. A PI controller with the input of the reference and actual speeds of generator yields the reference torque or indirectly Isq_ref for the machine side converter. A wind speed of 10 m/s causes the speed of the generator to reach its synchronous speed. At wind speeds greater than 10 m/s, a speed constraint is activated, limiting the generator speed to its rated value (1 pu). Here, the wind turbine enters the power limiting mode, and the pitch control is activated [7]. The pitch control mechanism reduces the power captured by the wind turbine to its rated value, following another constraint applied to limit the power at rated (i.e., 1 pu). The Grid side converter is controlled to keep the DC voltage on the capacitor constant at 1200V; hence the grid side control meets the real power demands of the machine side. The difference of actual DC link voltage and its reference is used as input to a PI controller, which provides a d-axis reference current (Id ref) for grid side controller [16]. The q-axis reference current (Iq ref) is achieved based on the difference between the reactive power reference and the actual reactive power required by the WECS. The q-axis reference current is controlled such that unity power factor operation is achieved, i.e., the power is taken through the grid only takes care of the reactive power requirements of the generator [7].

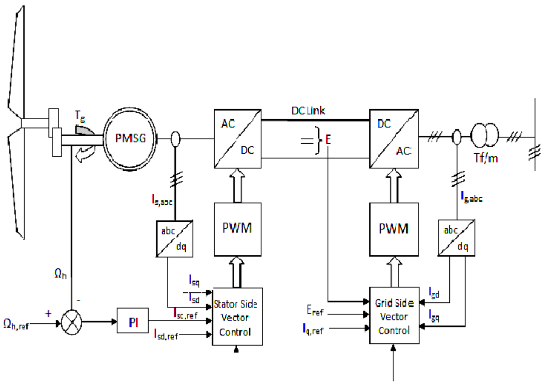


Fig-4. Block diagram of WECS using SCIG

B. Modelling and Simulation of PMSG

Modeling of PMSG WECS is discussed extensively in the literature. In [17], a comparative study of two different generator systems, including PMSG, for WECS is given. The complete modeling and simulation of a grid interfaced WECS based on PMSG is presented in [18-21]. For PMSG, the system depicted in Figure.5 is modeled in Simulink/MATLAB. The control strategy is adopted very similar to that of SCIG. However, the converters in PMSG are of full capacity, whereas in SCIG, they were at slip capacity. The system is operated in the same way, as was the case with SCIG. The system consists of a wind turbine coupled to a PMSG through a gearbox (Figure 5). The stator terminals of the PMSG are connected to the constant voltage and frequency grid by a bi-directional back-to-back connected voltage source converter cascade linked through a DC capacitor. The two back to back converters are controlled independently through the decoupled d-q vector control approach. The two converters are named stator side converter (SSC) and grid side converter (GSC). The GSC is responsible for maintaining the DC link voltage at the reference value and the converter operation at the desired power factor. By aligning the d-axis along with the grid voltage position, the d-axis current controls the active component and the q-axis current the reactive component [17]. A PI controller processes the error in generator speed to yield the torque reference (Tref), which references Isq. The reference speed can be obtained from the wind speed – power characteristics of the wind turbine, which is just the optimal power control operation. The d-axis stator current controls the reactive power exchange with the grid [22].

The PMSG is of 6 poles, 1.5 MW, 0.690 kV, 50 Hz rating. The stator winding resistance is Rs=0.05Ÿ, and the stator d-axis and q-axis inductances are Ld=Lq=0.484mH. The wind speed is varied from 6.5 m/s to 10.5 m/s. The SSC regulates the optimal generator rotor speed [23]. The d-axis component of the stator current is used to regulate the generator power factor. The q-axis stator current regulates the generator speed by adjusting the torque appropriately. The actual generator speed is compared with the reference speed, and the different error is passed through a PI controller to determine the q-axis current reference, Isq, ref. The reference currents Isd, ref, and Isq, ref is compared to the actual currents Isd and Isq, respectively. The error is then processed through a PI controller to yield the reference dq voltages, and finally, three-phase voltages desired at the SSC output are produced using PWM. The GSC is controlled in a similar way as described for SCIG. The q-axis component controls the reactive power exchange between the generator and the grid. The value of Id, the ref, is obtained by comparing the actual and reference DC link voltages. The overall control configuration is exactly the same as that for SCIG, which was already described earlier in section 3.1.

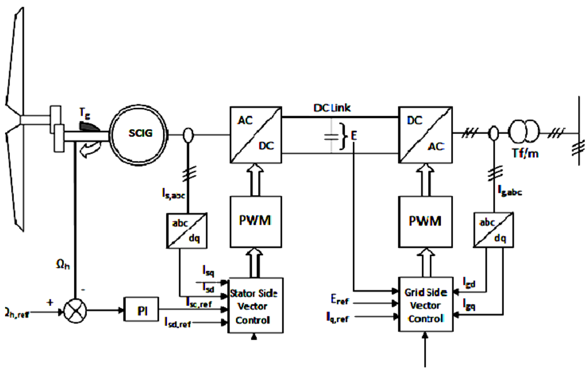


Fig-5. Block diagram of WECS using PMSG

IV. RESULTS AND DISCUSSIONS

The simulation of WECS based on SCIG and PMSG has been performed for similar generators' ratings. Both WECS are operated for different wind velocities to check if the system can successfully function in both sub-synchronous and super-synchronous speeds [17].

C. Characteristics of SCIG under short circuit fault

Since the purpose of this test is to evaluate the performance of the generator under faults, the generator is directly connected to the load bus without any power converters at this stage. At rated wind speed (12m/s) and after the generator reaches its steady-state at 1 pu rotor speed, corresponding to 1.017 pu of synchronous speed, a phase to phase fault is applied between stator terminals at t = 1 sec. Fig. 6 shows the responses of SCIG to the fault. Stator phase voltage completely collapses at 1.4 sec. Because the flux in the machine collapses. A sudden rise and fall in stator currents and electromagnetic torque starts at t = 1 sec. Furthermore, ends up at zero in around 0.2 sec. This demonstrates the desirable feature of SCIG in providing natural protection against short circuit. However, a speed control, such as a mechanical break or pitch angle control should be activated to limit the rotor speed under the fault [3].

D. Characteristics of PMSG under short circuit faults

PMSG is examined under the same conditions of part A. The response of the machine to the fault is shown in Fig. 7. Once the fault is applied, a transient condition occurs. Fault current increases but does not reach very high values due to the generator series inductance. Generator stator current reaches 4 pu in a second and keeps increasing. If such an overcurrent can persist, it may lead to the machine's thermal damage. Irreversible demagnetization of magnet material may also be caused [3]. The rotor speed suddenly falls and then keeps oscillating between 0.2 and 3 p.u, which is a heavy burden for the mechanical system. Electromagnetic torque suddenly ramps up to 2 pu and then keeps oscillating, adding high stress on the shaft. Therefore, Unlike SCIG, PMSG has an undesirable response to the fault, and hence a protection scheme becomes a must.

E. Power generation at various wind speeds

Both WECS configurations are run for different wind speeds. The MPPT controller, shown in Fig. 8, adjusts the rotor speed to the reference speed where maximum power, available at each wind speed, is captured [24]. Based on Figs. 9 and 10, the MPPT controller works well by tracking the reference speed. However, the actual speed cannot change instantaneously because of system inertia. Table I displays the active power generated (Pg) by SCIG and PMSG at various wind speeds. For comparison purposes, the same mechanical power is applied to both generators. Unlike SCIG, PMSG operates at almost unity power factor (UPF) and high efficiency. Therefore, PMSG performs better, especially at rated speed. However, as shown in Fig. 9, the PMSG rotor speed under UPF control does not reach 1 p.u, even at a wind speed higher than the rated wind speed. This is due to the UPF constraints specified by stator inductances, limiting the stator current magnitude and angle [25]. This limits the turbine's mechanical power available at rated and high wind speeds (i.e., 12m/s and 13m/s). Based on the simulation results obtained on MATLAB/SIMULINK, it can be noted that SCIG is less efficient than PMSG at low and high wind speeds[3]. Whereas the power delivered by PMSG is more at higher wind speeds [17]. However, SCIG is a competitor to PMSG at medium wind speeds. It has been shown that at constant load and excitation, the efficiency of SCIG is inversely proportional to the ratio of actual rotor speed to rated synchronous speed (i.e., wractual/wsrated) [26]. As this ratio decreases with a decrease in wind speed, the efficiency increases. However, the efficiency of SCIG is also proportional to the actual generated frequency, which is reduced as the wind speed becomes lower, resulting in a lower generator's efficiency. If the machine's magnetic saturation is to be considered, the variations of mutual inductance in SCIG and q-axis inductance in PMSG with magnetizing current, and q-axis stator current, respectively, should be considered [3, 27]. As a result,
the generated torque in both machines is no longer a linear function of the stator current. For accurate torque, power, and power factor results, the saturation effect has to be considered in machine modeling, especially in small machines, where the air gap is narrow, and effect of saturation is significant.

F. Generator current waveform quality at various wind speeds

The nonlinear characteristic of the three-phase diode bridge rectifier causes harmonic currents to flow in the generator. Moreover, the excitation capacitors amplify current harmonics in the SCIG turbine case, especially at high frequency, where the capacitance reactance is low [3, 28]. Fig. 11 shows the generator side current waveforms at rated operational speed for both WECSs. The total harmonic distortion (THD) in the case of SCIG is 17.4%, while it is twice as high in PMSG (i.e., 35%). However, THD varies with generated frequency. Thus, THDs of both generators' currents at different wind speeds are given in Table II. The table shows high THDs in both generators, especially at a low wind speed corresponding to low-frequency operation. However, the distortion in PMSG is more significant. Such high harmonics increase the generator's core and winding losses [3]. Therefore, a passive or active harmonic filter is often used in the generator side converters to limit the current distortion.

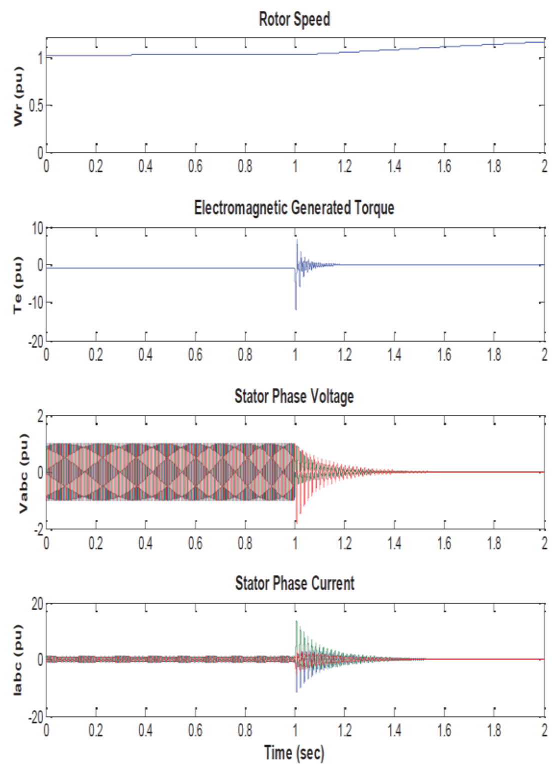


Fig-6. Response of self-excited SCIG to short circuit fault

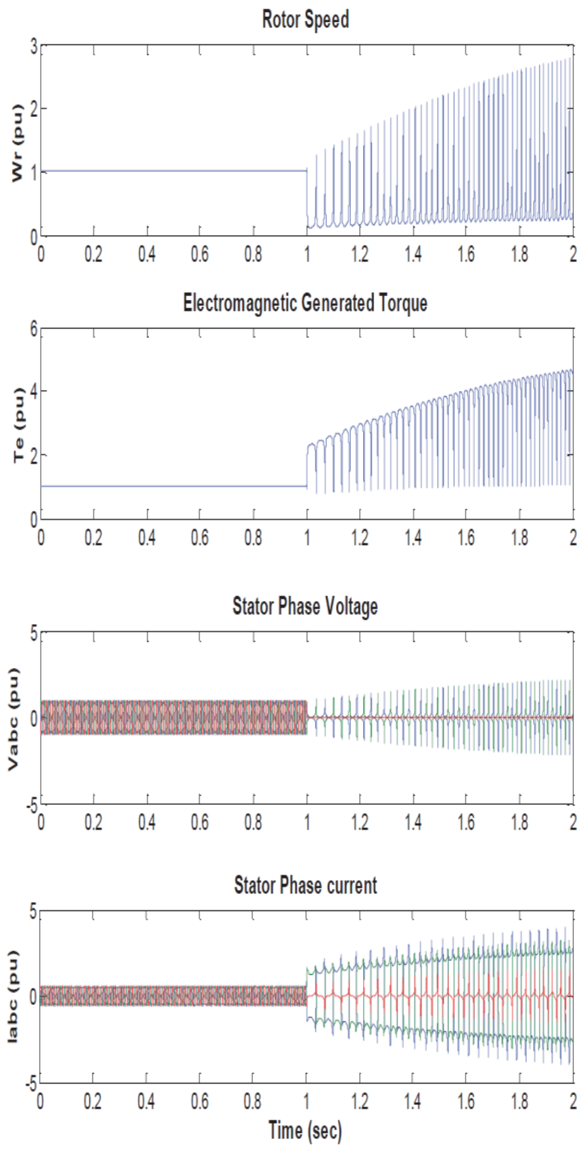


Fig-7. The response of PMSG to a short circuit fault

TABLE-1 comparison of active power generated at various wind speeds

Wind Speed (m/s)	SCIG			PMSG		
	Pg (kW)	Efficiency(%)	Power Factor	Pg (kW)	Efficiency(%)	Power Factor
3	0.310	67	0.72	0.44	94.7	0.98
4	0.91	82.8	0.76	1.04	94.7	0.98
6	3.59	95.6	0.84	3.56	94.7	0.98
10	16.3	93.4	0.82	16.5	94.8	0.98
12	27.4	86	0.8	27.6	94	0.96
13	32.3	86	0.8	33.2	94	0.96

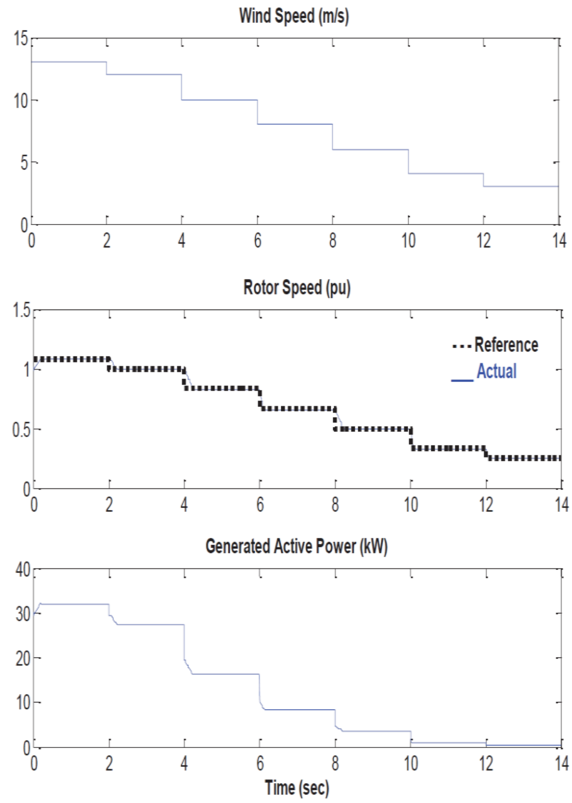


Fig.-8. MPPT response and generated power in PMSG

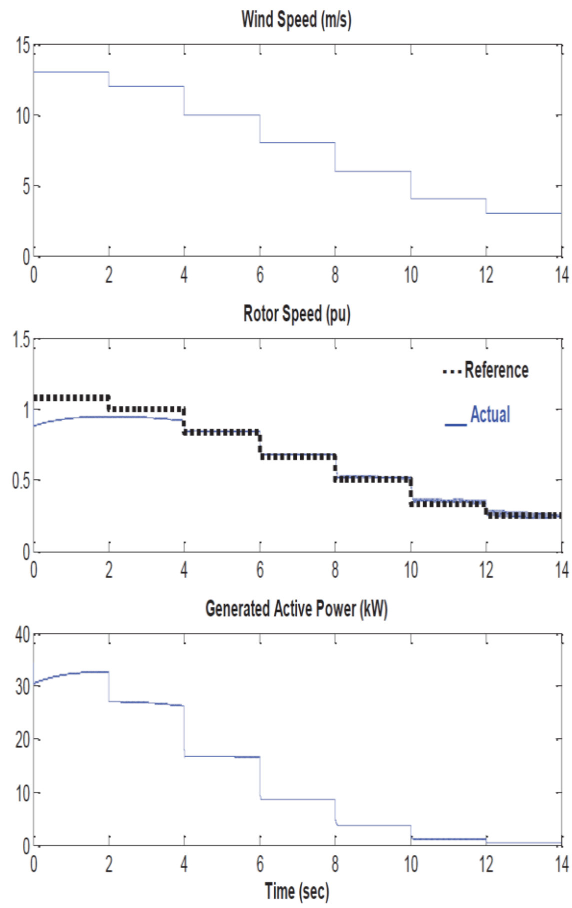


Fig-9. MPPT response and generated power in SCIG

TABLE-2. Comparison of THD for generator currents without filtering

Wind Speed (m/s)	THD (%)	
	SCIG	PMSG
6	54	61
8	50.8	52.2
10	30.3	37.5
12	17.4	35

G. Structure of stand-alone SCIG and PMSG WECSs

As shown in Figs. 12 and 13, stand-alone SCIG and PMSG based WECSs, with full-scale power converters, consist of [29, 30]:

1. Rotor blades
2. Generator
3. Three-phase diode bridge rectifiers
4. DC/DC boost converter, which is used to achieve maximum power point tracking (MPPT)
5. DC-Link capacitor
6. IGBT PWM- three-phase voltage source inverter
7. LC Filter which attenuates the harmonics produced by the PWM inverter
8. Point of common coupling (PCC) or Load Bus
9. Storage Battery which is connected to the DC link through a bidirectional buck-boost DC/DC converter.
10. Dump load is connected in parallel with the DC-link through an IGBT switch (Sd).

SCIG-WECS requires two more components: gearbox and capacitor bank, which supplies the reactive power required to excite the generator. On the other hand, multi-pole PMSG is directly coupled with the turbine's blades and excited internally by permanent magnets. Thus, neither gearbox nor capacitor bank is compulsory for PMSG WECS.

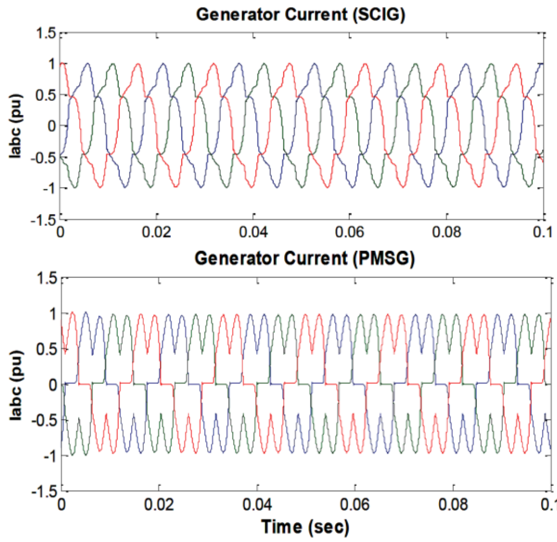


Fig-10. Generator stator currents at rated wind speed

H. Performance Analysis of Grid-Connected Wind Turbines

As a result of the high increase in the environmental worry, the installed capacity of grid-connected renewable energy sources is concerned up to date that minimized the impact of conventional electricity generation on the environment. For example, the average annual growth rate of wind turbine installation is around 30% during the last decade [31]. This leads to large rapid changes in non-programmable sources that can cause a significant reduction in reliability, power quality, and economy. In ref.[31], planning the connection or disconnection of renewable energy based on forecasting is presented in order to increase in reliability of renewable energy. The question that needs to be raised is how new renewable source systems will affect the whole grid. A part of the answer must be obtained from the impact that they have on the power quality. The main impact of the wind turbines on the grid concerning power quality that is affected by the sources of disturbances [31] is related to voltage dips and fluctuations, harmonic content. Currently, two main types of generator systems for large wind turbines exist, as shown in Figure 14,15. Computer simulations of their responsibilities related to power quality and efficiency during steady-state are researched. A simulation method numerically is applied to validate wind turbine generators. Finally, they are compared and analysed from technical point of view [31].

a). SCIG

The first concept consists of a rotor coupled to a SCIG through a gearbox. The gearbox is required as the optimal rotor, and generator speed ranges are different. The generator is directly coupled to the grid. Therefore, rotor speed variations are very small as the only speed variations that can occur change in the rotor slip. Due to speed variations are very small, the turbine is normally considered to operate at a constant speed. A SCIG consumes reactive power and behaves similarly to induction motors during a system contingency [17, 32]. Therefore, the capacitors are added to generate the induction generator magnetizing current, thus improving the power factor of the system. The power extracted from the wind needs to be limited because otherwise, the generator could be overloaded, or the pull-out torque could be exceeded, leading to rotor speed instability. In this notion, this is often done by using pitch angle. The system is described in Figure 13.

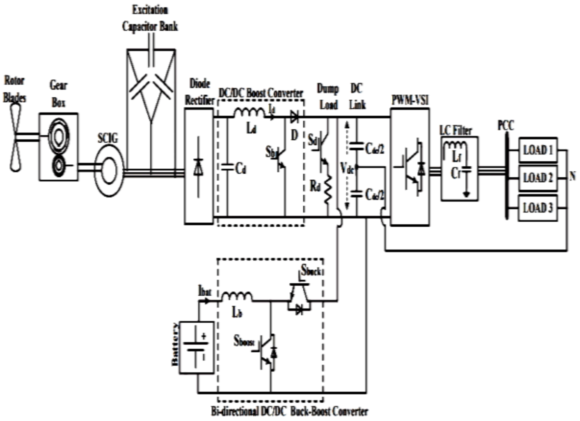


Fig-11. Stand-alone SCIG-based WECS

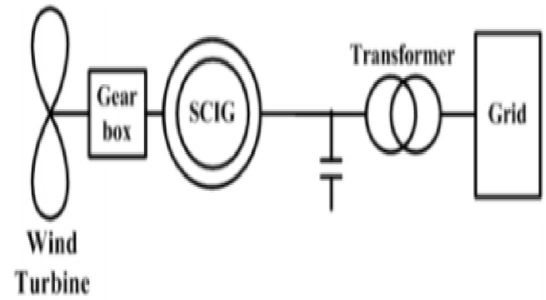


Fig-13. SCIG Grid-Connected

b). PMSG

This configuration may respond to a variable speed wind turbine with a permanent-magnet synchronous generator connected to the grid through a full-scale power converter (Figure 14). The converter system consists of two IGBT-based back-to-back voltage source converters, including a stator-side converter (SSC) and grid-side converter (GSC) connected via a DC link. Due to the converter system decouples the generator from the grid, the electrical frequency of the generator may vary as the wind speed changes, while the grid frequency remains unchanged. The rating of the converter system in this type corresponds to the rated power of the generator plus losses. The stator-side converter controls the operation of the generator to extract maximum power from the prevailing wind velocity. The grid-side converter is controlled to maintain the DC-link voltage at the reference value by exporting active power to the grid and also controls reactive power flow to the network [33].

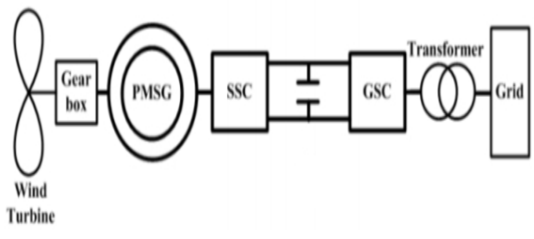
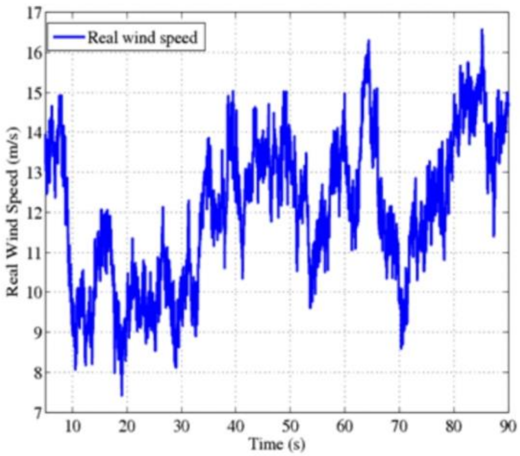


Fig-14. General structures of PMSG WECS connected to the grid

I. The Simulation Results

The performance of each type of wind turbines was evaluated with MATLAB/Simulink simulation for a wind turbine containing 3 MW ones. From Ref.[34], research related to the real wind speed in Figure 15. From ref. [35], the characteristic data of the simulated asynchronous and synchronous wind generators are reported in the table. 2. The integration of the SCIG wind turbine decreases the terminal voltage due to the reactive power absorbed from the grid, and PMSG operated in voltage control mode causes voltage rise (more than 1.0 p.u) in terminal voltage. It is seen that voltage at a terminal is well maintained with the voltage control mode of PMSG. The voltage profile is within the permissible limits (~ 6%). When the wind speed varies, the variation of the SCIG terminal voltage became larger, and voltage fluctuations resulting in flicker can occur, while PMSG connecting the grid keeps a nearly smooth terminal voltage profile. When more SCIG is connected to a power system, the problem due to the wind speed change will become more serious because this wind turbine could be affected the power system stability. Changes in wind speed often result in wind turbine active and reactive power fluctuations. Where the output active and reactive power changes with the wind speed [36]. The wind turbines with PMSG could be run at variable speed and control reactive power. As a result, they have much more efficient and can improve power quality during wind speed variation. The wind turbine with PMSG can keep reactive power at terminal nearly zero during steady-state operation, while the fixed-speed wind turbine absorbed a large amount of reactive power from the grid. During steady-state, the different behavior PMSG can also be explained by analyzing the active power exchanged between the generators and the network. In the case of PMSG, it can be noted that the active power injected by a generator is lower and smoother than SCIG due to higher losses and rating of the converter. This fact reduces power quality from SCIG compared to PMSG. The dynamic responses of rotor speed among all types. Compared to SCIG, which is constant rotor speed, indirect grid-connected wind turbines (PMSG) is much more efficient because they could run at variable speed. This advantage is especially useful for a wide wind speed, and a weak electrical grid, a very common occurrence as wind turbines are typically located remotely. From simulation results, the PMSG type of wind turbine has the widest rotor speed variation due to converter rated to 100% of the wind turbine power, but there is a higher delay because the generator is bigger than other types of wind turbines. As compared with the SCIG wind turbine, the maximum power captured Pmax by the PMSG is higher. The output power fluctuation of PMSG is smallest, then is SCIG is the last with this concept. From ref. [37], Small wind turbines only use the SCIG because they lack reactive power controlling, the market share the one has decreased slightly, whereas the variable speed of wind turbines increases. However, the PMSG is the preferred solution that the robustness, efficiency, and reliability-related power quality are of paramount importance.



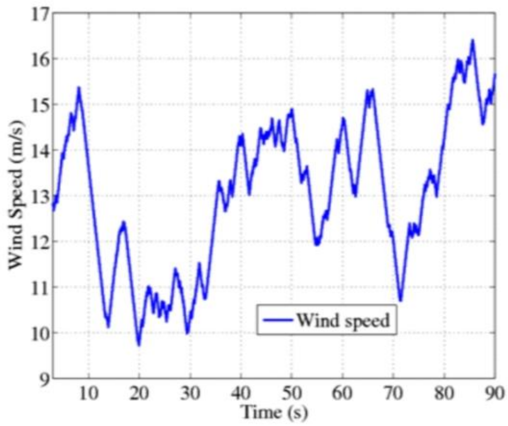


Fig-15. Real and filtered wind speed variations

Table-3. Simulated Parameters of SCIG and PMSG

Parameters	SCIG	PMSG	Unit
Rated Power	3	3	MW
Rated Speed	12	12	m/s
Cut in wind speed	5	5	m/s
Cut out wind speed	20	20	m/s
Rated Voltage/Frequency	690/50	690/50	V/Hz
Rs/Rr	0.004/0.005	0.02/0.02	p.u.
Qpf	200	-	kVAR
Vdc	-	1000	V

V. CONCLUSIONS

The performances of Wind Energy Conversion System configurations based on Squirrel cage Induction generator (SCIG) and Permanent Magnet Synchronous Generator (PMSG) both were compared in this research paper. The comparison of two different wind turbine generators was conducted pertaining to setup generator's fault aspects, Electrical power generated from two different generators at different wind speeds, the current harmonic distortions of SCIG and PMSG generators, and outcome of unbalanced load on two different generators. Both systems consist of full-scale power converters. The models of two different generators were developed by using the MATLAB/Simulink Power System toolbox. Both generators' models were controlled using the same MPPT scheme, load-side controller, and DC-link controller. The primary asset of the self-excited SCIG is that it is presuming the natural protection antagonistic towards short circuit damage has been illustrated. In the matter of generated power, SCIG is less productive than PMSG at lesser and greater wind speeds. In distinction, PMSG has an unpleasant retaliation to the fault. Though, SCIG is a contender to PMSG at moderate level wind speeds. Because of the nonlinear features of the diode rectifier, the harmonic currents flow in two different generators. Especially in less-frequency working, the distortion in Permanent Magnet Synchronous Generator (PMSG) is extra crucial. To conclude, the reaction of unstable load on one and the other generator's torque is alike in both, and it can be crucially reduced by controlling the DC-link voltage.

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