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Integration of SCIG Wind Energy Conversion Systems to the Grid

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ABSTRACT: *Energy is an important factor for a country economic development. Concern towards the environment and nature is forcing mankind to reduce energy production from fossil fuels and it is also the driving force for energy production from alternate and renewable energy resources. Of the available renewable energy resources usage of wind power is drastically increasing because of its good power quality, high power conversion efficiency, less footprint, bulk and continuous energy production capability etc. The wind power is generated by the generators coupled to the wind turbines. In this review paper different wind energy technologies like wind turbines, gear boxes, generators and transformers are presented. This paper also explains in detail about the different classes/types of wing energy generators and different converter configuration used in integrating wind power to the grid.*

KEYWORDS–*Wind power, Wind turbine, Generators, Grid integrating converters.*

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I. INTRODUCTION

Due to abrupt changes in the environmental conditions there has been more focus on renewable energy technologies like wind solar biomass and fuel cell. Due to advanced technologies, decrease in cost and less effect on the nature, wind power is playing a vital role in the energy scenario in the world as shown in fig1.The major problems which may occur in future on the transmission and distribution network are listed below

1) Supplying the increased growth of demand and reliability with very few lines;
2) Power system stability when renewable energy sources like wind, sun, biomass and fuel cell.
3) Customer satisfaction by providing reliability and power with good power quality

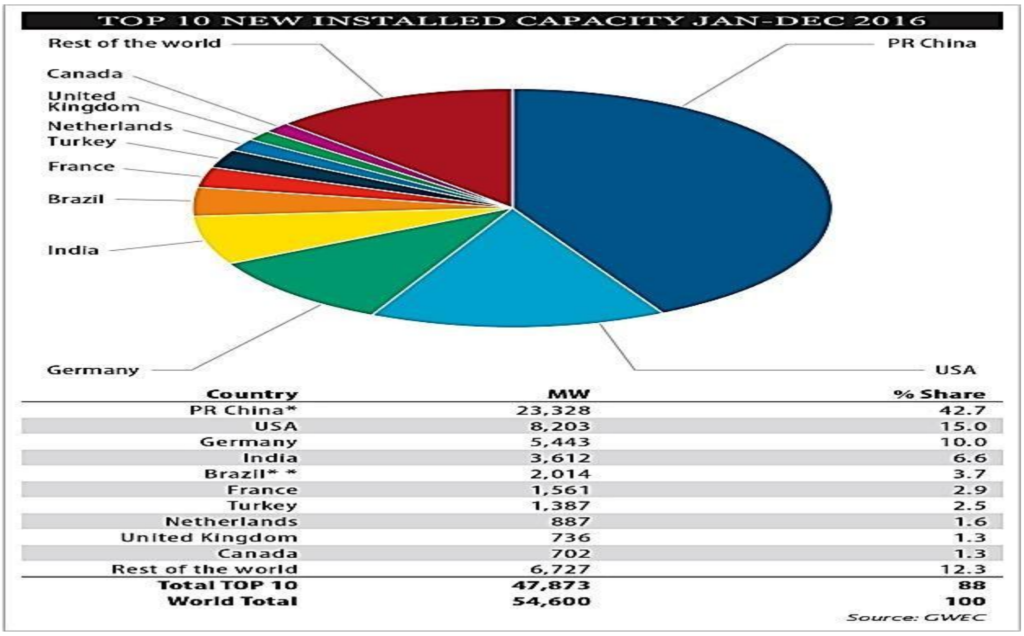
Distributed energy resource (DER), recently has become a solution for the above mentioned problems

DER has small local generation units and storage units (Batteries) whose location will be very close to users. Decentralized generations help the utilities by decreasing the load on the grid, reducing the necessity of new generation, transmission and distribution lines. It also help in reduction of transmission losses and also provides the voltage, frequency control and provides the users with power of high quality.

As the infiltration of renewable energy resources increases, the irregular way of renewable vitality requires the central production to give a backup supply. This increments both the strengths and weakness (losses) of the system. Decentralized power production and storage capacity can give the required energy with very less loss and strength affect. Renewable vitality era must be supplemented with dispatch able assets, for example, stockpiling and nearby era to adjust the produced vitality with request.

II. WIND ENERGY SCENARIO

The global wind energy outlook situations as exhibited by GWEC and Greenpeace look at the future capability of twist catalyst to 2030, beginning from a range of presumption which will impact the development of the wind industry.Before the end of 2010, there were more than 190,000MW of wind installed in the world[1]. China secured more than 75,000MW. US in the second 60,000MW and Germany third as 31,000MW.The global annual installed wind capacity is shown below in Fig.1



Country	MW	% Share
PR China*	23,328	42.7
USA	8,203	15.0
Germany	5,443	10.0
India	3,612	6.6
Brazil* *	2,014	3.7
France	1,561	2.9
Turkey	1,387	2.5
Netherlands	887	1.6
United Kingdom	736	1.3
Canada	702	1.3
Rest of the world	6,727	12.3
Total TOP 10	**47,873**	**88**
World Total	**54,600**	**100**

Fig.1. Installed wind capacity (2016) of world.

III. BASIC CONFIGURATION OF GRID CONNECTED WIND POWER PLANT

The general schematic of wind power generation system connected to the grid is shown below. A typical wind power plant converts the kinetic energy available in wind to electrical energy using several components.

Components of a wind power plant can be classified in three major categories as mechanical, electrical and control systems. The mechanical components include tower, rotor blades, rotor hub, gearbox, wind speed sensors and mechanical brakes. Electrical components are electric generators, power electronic converter along filter and step- up. The control related components are used with both the mechanical and electrical energy conversion system. The visible parts in wind power plants are tower and rotor blades, and rest of the components is placed inside the wind turbine. The below figure 2 represents the major components of wind power generating system[2].

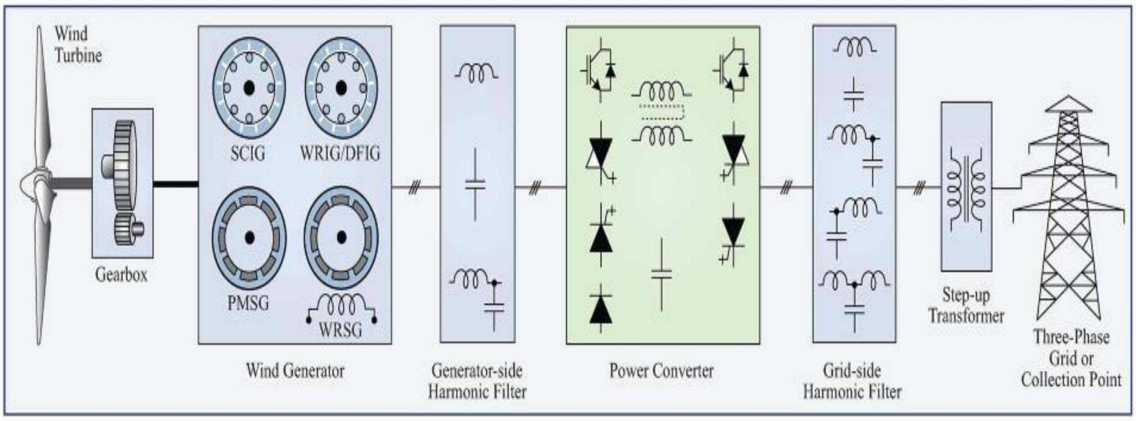


Fig. 2. Components of a grid connected wing power plant.

MAJOR ISSUES RELATED TO WIND TURBINES

Wind turbine are acted upon by wind so they are prone to failures. Few factor that affect the wind turbines which leads to the failure of wind turbine are briefed below. It presented the tutorial exercise arrangement on fatigue failure of component and harm models. That failure depends on materials basic deformity, damage incited during making the product and on conditions amid capacity and field use. Nair et al had introduced, wind control has ended up being a potential source for era of electricity with significant environmental effect. It overviewed a scope of problems related with the association of a propelled static var compensator to a wind turbine power generation. It is demonstrated that high pass filter impact a noteworthy harmonic reduction for all frequencies. It explained about the down wind turbine noise and its impact on the power generation[3]. It tells about his experience of wind cultivation in the US based on various cases such as problem in the design, poor machine installed, and bad maintenance. So, these types of problems occur in wind turbine components expressed by some workers, engineers working for wind vitality. Noise, maintenance, structural effect, manufacture defect etc. are the major issues that comes under wind turbine.

INNOVATIONS IN WIND TURBINE TECHNOLOGY

The various types of innovations in wind turbine technology that increases the reliability, performance of wind power plants and reducing the cost of wind energy are explained below. It inspected the development of innovation of wind turbines and its effect on cost of wind vitality. Reviewed about the cost and features of smaller machine with few MW to 2MW ratings.The new innovations in wind turbine technology that come in the market in recent years reviewed b Eize de viress. The innovation depends on some challenges that developers have to face that are basically design, loads connected on wind turbine, blade used in wind turbine, gearbox , generator, transformer , integration to grid and control of system.

TRANSFORMERS

Transformer used for increasing the voltage level of power generated from the wind turbine coupled with generator to the utility grid.Steps involved in sizing the transformer, design of transformer, testing of the transformer are presented

GEARBOX

The failure of gearbox create a huge impact on harvesting the energy from the wind. To increase the gearbox life cycle some cost effective improvements was proposed many authors a few are listed below. Here concentrated on parameters for weariness damage of auxiliary components under stacking and drastic changes in environmental conditions [4].

GENERATOR CONFIGURATIONS

Other than the blades and gearbox, generator plays a very important role in wind power plants. The use of power converter is very significant in integrating wind power plants to the grid. Considering the converter and generator in a wind system, the different wind energy systems are classified as

1. Type 1-Fixed Speed with SCIG.
2. Type 2-Semi-variable speed with WRIG
3. Type 3-Semi-variable speed with DFIG

Type 1 has typical speed variation of 1%, Type 2 of 10%, Type 3 of 30%, Type 4 is fully variable, and Type 5 is also fully variable. These all configurations are in the market for the last thirty years and have been studied, analyzed fully[5].

1. Type-1WECS

Type 1 turbine is a constant speed squirrel cage induction generator based wind energy conversion system that does not contain power converter. The generating unit is interfaced via transformer and starting unit which is meant for smooth starting,this methodology was the first to come into commercial use. WECS whose power ratings are higher, generally 4 poles are used for 50 Hz operation and 6 poles are used for 60 Hz operation. The variation in the generator speed is around 1% as compared with the synchronous speed for changing wind velocities. This is the main reason for knowing this type of arrangement as fixed speed conversion system. For the constant velocity operation, a gearbox is used at the input of the generator. The smooth start unit is isolated once the starting speed is achieved. In this configuration it can be seen that energy conversion is possible without the use of any power converter unit. The generator type used in the configuration demands reactive for a capacitive compensation is used. The advantage of Type 1 arrangement includes less implementation cost and the working is quite independent of any flaw during the runtime. This configuration suffers from some drawbacks likewise the efficiency of conversion is quite less, the disturbance in the wind velocity is seen on the generator output and thus creates a problem in the power extraction, the faults occurring at the grid level creates a problem for the parts of the turbine. Type 1 configuration is supported by FACTS devices to follow up with the standards. With all these disadvantages, this configuration is in commercial market and is available in high power range [6]. The companies using this configuration include VESTAS, SIEMENS.

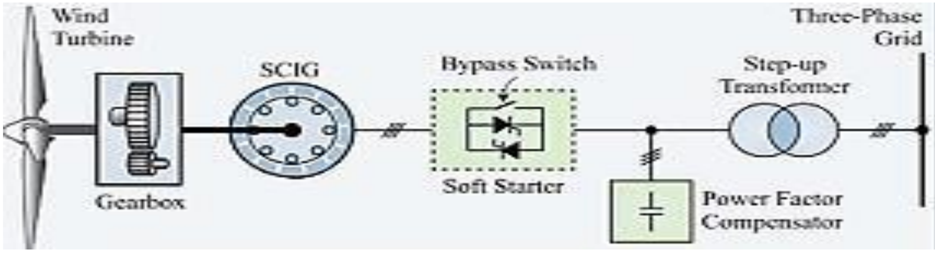


Fig. 3. Type-1 type WECS

The constant speed configuration was very much in the market in the last ten years but now with the many new configurations, this arrangement is losing its marketplace. The already established WECS of this type are still into working.

2. Type-2 WECS

Type 2 wind energy conversion system has the advantage of variable wind speed operation which improves the overall energy conversion, lowers the mechanical stress due to the changing wind velocity, less stress on gear system and thus improves the overall service period of the system. Type 2 conversion system uses wound rotor induction generator which also has power converter. The power converter is rated at 10 %. This configuration consists of resistance which can be varied via external control and thus the torque and speed of the machine can be changed accordingly. The control with the help of external rotor is also called as Opt slip Control [7].

The variable resistance is brought into picture with the help of converter. The converter consists of a rectifier and a chopper with the controlling element being a diode. As mentioned with this variable speed of nearly 10 % with respect to the rated speed, the system is able to perform better by absorbing more power from the source that is wind. The rotor resistance contributes to losses which is a disadvantage. Gear system, smooth starting unit, reactive power compensation are also included in this system. VESTAS and SUZLON are manufacturing theseType 2 conversion system with power ratings of few megawatts [8].

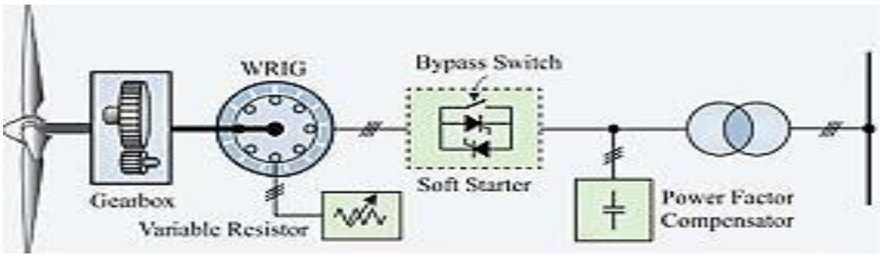


Fig. 4. Type-2 type WECS

The restricted variable speed range and less energy transfer capability are among the major reasons which has resulted into decreased market share of this type of conversion system.

3. Type-3 WECS

There is a third category of wind conversion system which make use of DFIG and is called as Type-3 configuration. The speed can be varied up to a greater extent as compared to other two conversion systems. The energy transfer is through rotor and stator[9]. This system consists of a power converter which is rated at 30 % with no smooth starting unit and no need of reactive energy compensator. The gear system is used for variable wind speed operation.

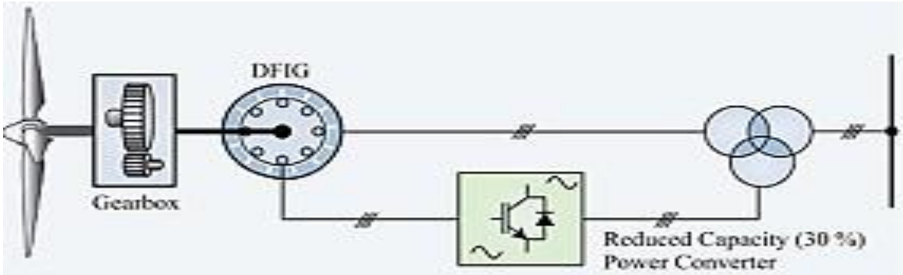


Fig. 5. Type-3 WECS

The power converter used makes the flow of power in both the directions possible. It also enhances the variability extent of the speed. MPPT is possible in this type of energy system to extract maximum power in the system. The speed range is improved to 30 %, there is increased tolerance to the disturbances happening in the power system. These advantages has made this Type-3 configuration as commercially available with half of the market share[10].

Fault ride through feature of this type is influenced by converter rating that is less. The cost of this configuration is higher due to gear system. The gear system is heavy and needs periodic service. The converter is connected across the rotor with the help of slip rings and brushes which have limited life cycle. Therefore this configuration requires huge service[11]. These drawbacks constrains the use of this type of system in off the shore plants. The major manufacturers of this type of system are REPOWER, BARD, and ACCONICA.

IV. CONVERTERS USED FOR GRID INTEGRATION

This section discusses in detail about the various power electronic converters used in wind energy conversion systems. The below figure 4 represents the various converter types used in wind energy conversion systems. The main objective of power converter is convert variable voltage/frequency power available from wind power generator to fixed voltage/frequency power so that it can be connected to the grid. The converter are classified into direct and indirect types[12]. Direct type power converters converts AC to AC directly. While the indirect type power converters converts AC to AC through various stages like AC to DC then DC to DC then finally DC to AC .

The major characters which a converter should possess are as follows. 1) Low initial cost, 2) highly reliable, 3) Modular in construction, 4) less maintenance cost, 5) highly efficient, 6) converter should provide good power quality, 7) Converters should compile with the grid code and finally 8) converters should have less foot space and weight[13].

Various power converters used in wind energy converters are represented in the below.

8.1 Back to back converters

These converters are very much similar on both the generator- and grid-side and linked through a dc-link. First they convert variable voltage/frequency output of the generator to DC, then DC to AC. Finally the obtained DC is converted to fixed voltage/ frequency for the grid connection [14]. The power flow in a back to back converter is bi- directional so it can be used with SCIG, DFIG, PMSG, and WRSG. The back to back converters are classified as represented below.

A. Low voltage converters

The low voltage converters operate at a voltage of 690 and 575 V. There are four types of low voltage converters they are explained below.

a) Full scale BTB 2L VSCs:

Back to back converter consist of a voltage source rectifier and voltage source inverter. They both are linked by a dc-link capacitor. The output from the inverter is connected to a LCL filter to remove the harmonics. Then the voltage is stepped up to grid voltage and connected to the grid by a transformer. The below figure represents the figure represents a full scale BTB 2L VSCs[15].

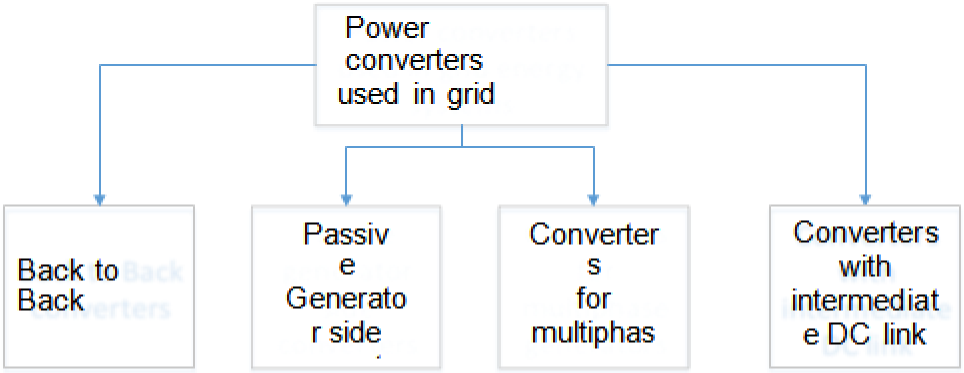


Fig. 6. Classification of power converters used in wind energy conversion system

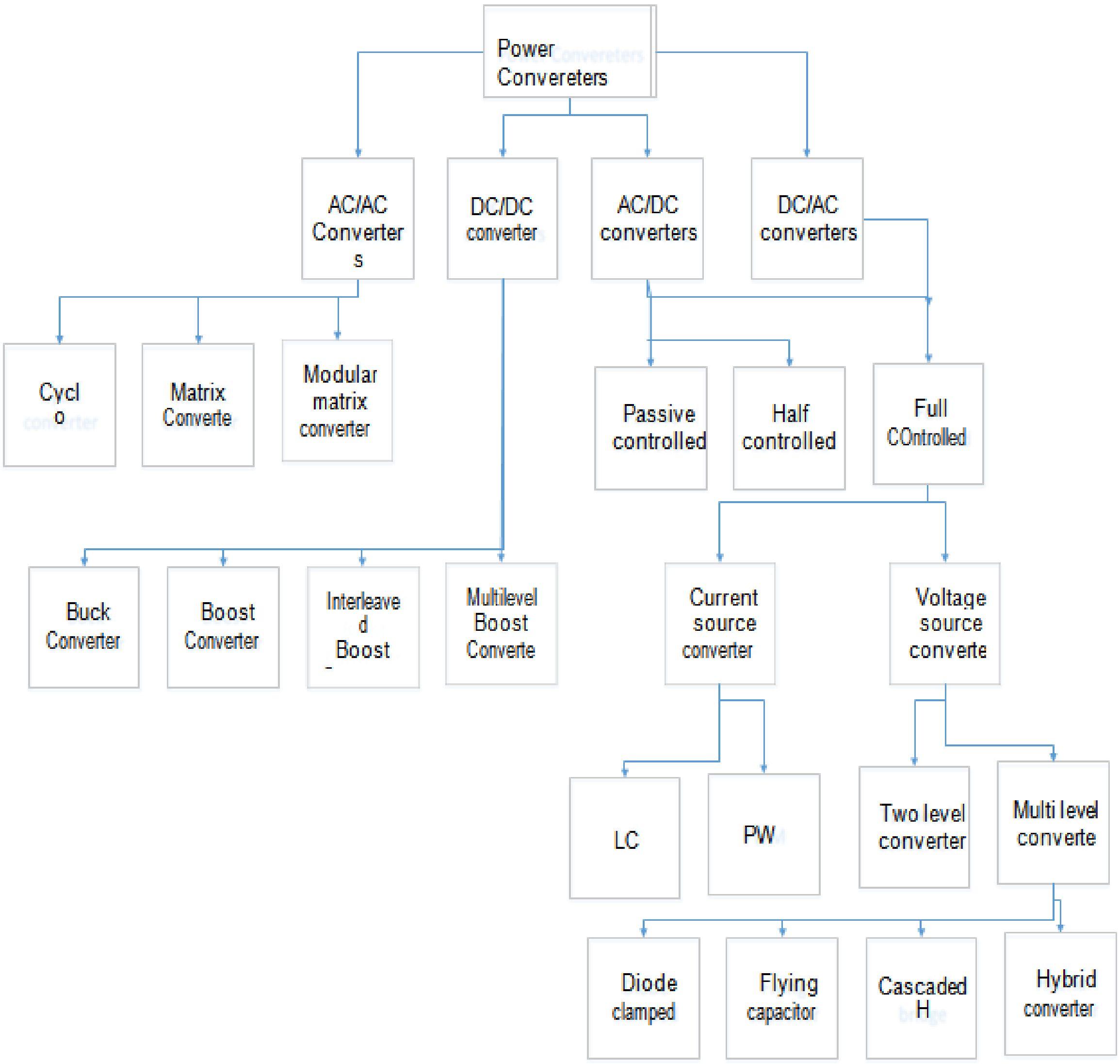


Fig. 7. Classification of power converters

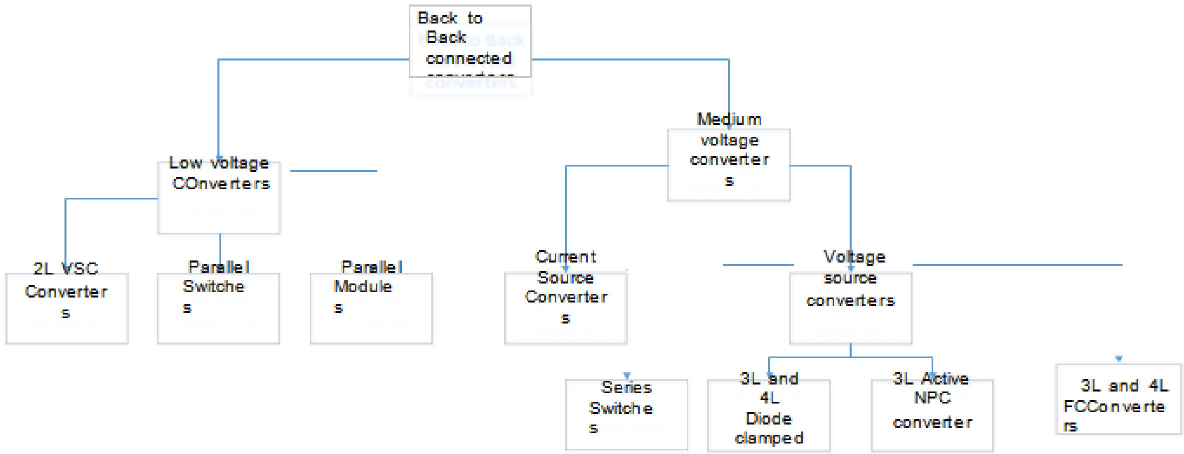


Fig.8. Classification of back to back converters

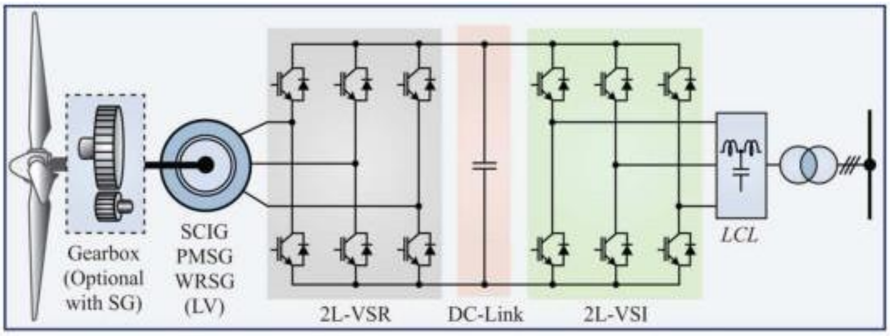


Fig.9. Full scale BTB 2L VSCs

b) Partial scale BTB 2L VSCs

Generators stator is directly connected to the grid, rotor of the generator is connected to the grid using a power converter. Converter power rating is 30% of the power generated by the generator. The output from the inverter is connected to a LCL filter to remove the harmonics[16]. Then the voltage is stepped up to grid voltage and connected to the grid by a transformer . The below figure represents the figure represents partial scale BTB 2L VSCs.

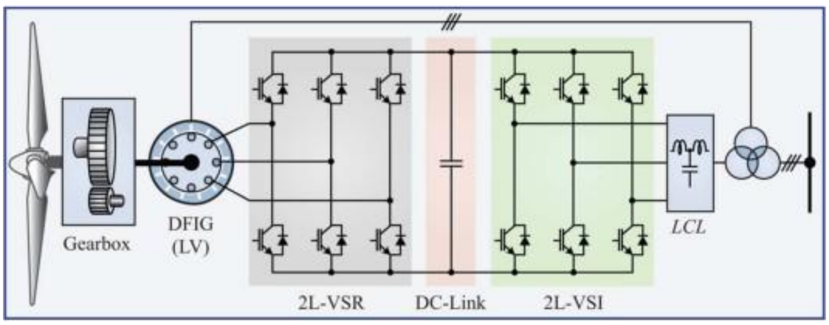


Fig.10. Partial scale BTB 2L VSCs

c) Parallel BTB 2L VSCs with common DC link:

Generators stator is directly connected to the grid, rotor of the generator is connected to the grid using a power converter . For high power application converters are connected in parallel.The output from the inverter is connected to a LCL filter to remove the harmonics [17]. Then the voltage is stepped up to grid voltage and connected to the grid by a transformer. The below figure represents the figure represents parallel BTB 2L VSCs with common.

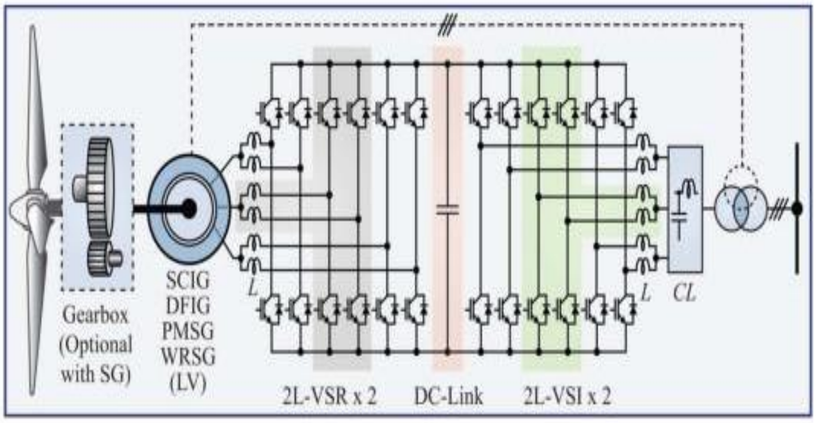


Fig. 11. Parallel BTB 2L VSCs with common DC link

d) Parallel BTB 2L VSCs with individual DC links:

To solve the circulating current issue, the dc-links are configured as individual elements as shown in the Figure. This system is of higher cost [18].

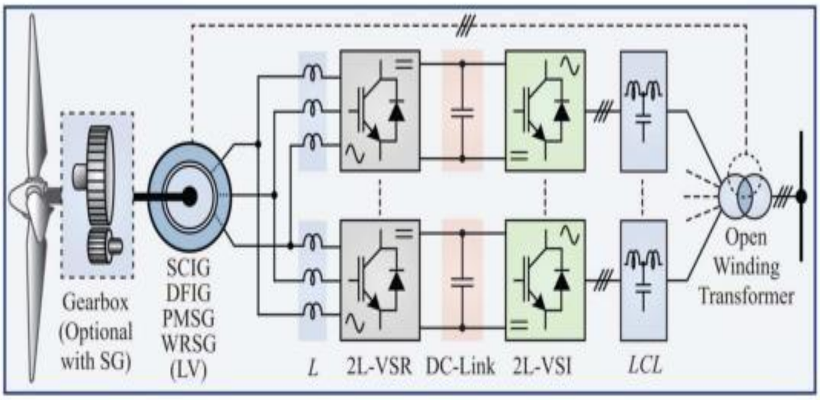


Fig.12. Parallel BTB 2L VSCs with individual DC links

B. MV converters

Medium voltage converters are used in power ratings of 3 MW. The different types of MV converters are listed below.

a) Series connected switches

It consist of a voltage source rectifier and voltage source inverter. They both are linked by a dc-link capacitor. The output from the inverter is connected to a LCL filter to remove the harmonics. Then the voltage is stepped up to grid voltage and connected to the grid by a transformer [19]. The figure below represents a series connected converter.

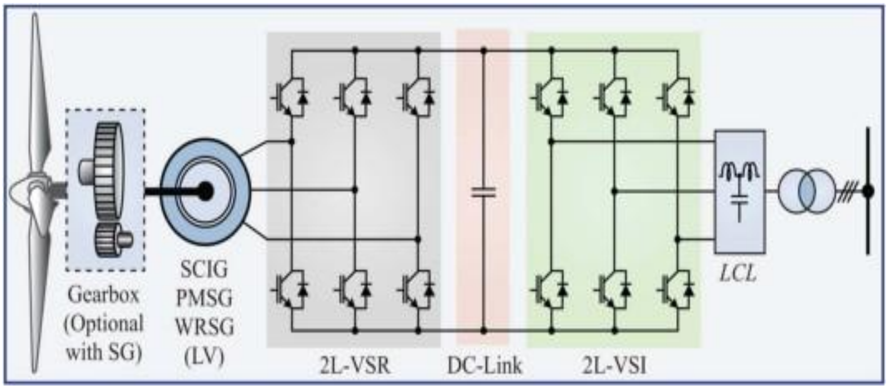


Fig.13. Series connected switches

b) BTB neutral point clamped converters

Two numbers of 2L-VSC's are piled up one over the other by using split dc-link capacitors and clamping diodes. The converter output phase voltage contains three levels[20]. The below figure represents the figure represents BTB neutral point clamped converters.

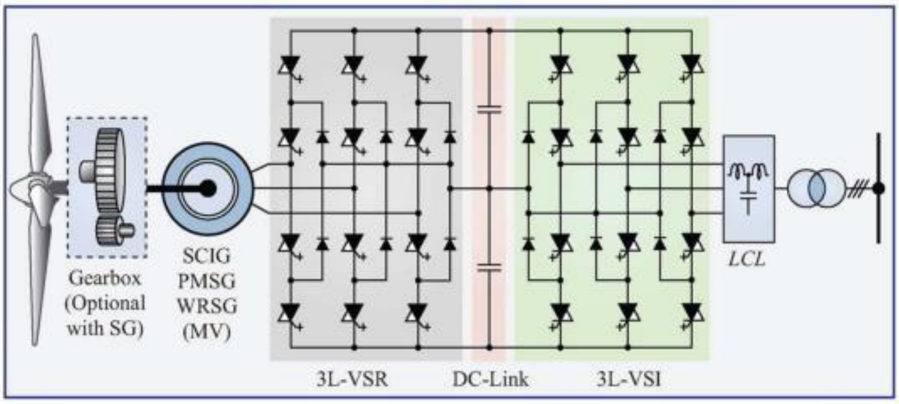


Fig.14. BTB neutral point clamped converters

V. CONCLUSION

In this review paper, current wind energy scenario, site selection for wind power plant installation, future wind power development, innovations in wind power techniques, issues related with power generation from wind energy, various types of generators used in wind energy conversion system and different types of converters used in integrating wind power generator to the grid has been reviewed.

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