A technological review of wind power generation

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Abstract: Due to developing population, economic improvement, and monetary development, strength is the most fundamental dearth and may assist in lessening the usage of fossil fuels. Around the world 86.4% of strength is introduced through fossil fuels. All inclusive, India positions fourth a few of the international locations that create wind power. The maximum current 5 years development in wind strength in India is nearly 16%. Wind is the aberrant kind of solar orientated electricity and is usually being recharged by way of the solar. It has been assessed that approximately 10 million MW of electricity are persistently accessible in the earth’s wind. Wind strength gives a variable and environmental pleasant opportunity and countrywide electricity security even as diminishing global stores of fossils products debilitates the long haul manageability of worldwide economic system. This paper introduces with a technological review of wind strength conversion structures. Right here numerous wind mills, generators and electricity converter topologies are mentioned with their classifications, technical features and latest developments. On this evaluation paper an excellent in magnificence is centered on constitutive factors, structure and manipulate of wind era structures and the state-of-the-art studies traits in wind electricity conversion system.

1. Introduction
In recent years, with the expanding interest of electrical energy and rising ecological problems, it became the high demand of time to look for the alternatives of fossil fuels. The wind driven energy system has been a better alternative and turning attention as a better electricity sources. The non renewable energy sources are undermining with high speed and also produce huge contamination so the use of non conventional sources of energy for electricity generation is turned into the enormous request of time [1-2]. Among all the inexhaustible sources, wind has been used as an asset of energy era. In the field of electricity production wind is by and large most prudent, clean and discharge free innovation .Therefore proficient and steady use of wind energy in power generation has become an important issue.

A Wind Power Conversion Method (WPCM) is an association that adjustments over the active vitality of the upcoming wind circulation into electric energy. On this system the transformation of energy takes place in two degrees. In first step the energy of wind in the shape of air float rotates the turbine due to which kinetic energy of wind converts into mechanical power. In 2nd step the mechanical strength of turbine rotates the generator which converts mechanical strength into electrical energy. So the essential components of a wind strength conversion framework are a turbine, a gearbox, an alternator and power converter configurations [1-2]. Sometimes a transformer is also required for grid connection. Strength converter is placed between the grid and the generator. There are numerous viable technical configurations of wind strength conversion systems. In some configurations gear arrangement is present and in some it may not be. Same happens with power converters it may be present and may not be. The power output can be both types it may be dc or ac.
Straight interfacing of wind energy conversion system to the power grid is generally not feasible due to mismatching of magnitude and frequency, hence proficient power converters are needed for connecting wind energy conversion system to power grid. Earlier best investigated choices of power converters was ac-dc-ac converter [1-5] but recently best choice of power converter is matrix converter [6-11]. The ac-dc-ac converters also called traditional converters or back to back converters. The merit of traditional converters is its high power concentration and moderately low cost. But presence of bulky dc link increases its dimensions so its heaviness and volume also increases which leads to its untimely breakdown [10], [12]. Another serious drawback of traditional converters is its sensitisiveness to communications signals and unwanted signals due to which there may be fault in the system.

The matrix converter (MC) has enormous advantages over back-to-back converters. The main advantages are superior voltage magnification, swift control mechanism, absence of dc link capacitor, enormously quick transient response [10] and no commutation problems. Likewise, it has a provision of smooth control system which can change frequency, phase angle, voltage and input power factor as per requirement. In WECS, energy surge is towards power grid hence matrix converter which has energy surge in both direction is not so much beneficial in all applications. So here another topology of matrix converter is used which has a little bit change in configuration and called indirect matrix converter. Also, in matrix converter there is no requirement of extra inactive circuit parts or transformer to enhance voltage level.

In generators, doubly fed induction generator (DFIG) needs a gear mechanism for changeable pace turbine. Since the gear mechanism is very sensitive to faults hence its application in WECS is unreliable. It is also very costly. In comparison to doubly fed induction generator permanent magnet synchronous generator (PMSG) has huge advantages for WECS. These are its reduced mass, much improved power factor, high energy concentration, absence of gears, own excitation property and most important is its best performance. PMSG becomes more trustworthy due to its high accuracy and uncomplicated controls mechanism. PMSG has only drawback of its heavy capital expenditure [13-14]. Recently manufacturing price of PMSG also goes down since there is a significant development in the area of magnetic materials.

2. General Review of Wind Power in India

The non conventional power production in all the countries has been increasing at very fast rate since the past few years. In non conventional power resources wind power is among world’s fastest growing power generation resources. In the course of the most recent twelve years, wind power sector has enlarged speedily. According to Oct 2018 report of government of India the total available wind energy potential in India was 34,293MW as comparison to 6,270 MW in 2005.

Wind power is likely to participate in perpetually imperative job in the upcoming national energy panorama [15, 16]. According to Greenpeace around 10% of electrical power will be provided from the help of wind potential till upcoming year 2020 [17].

In present times the total renewable energy generation potential in India is 72 GW. Among all the renewable energy resources the total power generation by wind potential is 34 GW in India at present. The future plan of Government of India is to increasing the wind power generation from present capacity of 34 GW to 60GW till the year 2022. Among all the countries of the world it was the India where a separate ministry was set up in 1980[18-19] for the fast development of renewable energy from renewable energy resources. The gap of electrical energy demand and electrical energy generation only can be minimize by promoting renewable energy resources for world’s growing energy demands.
electricity requirements [20-21]. Extreme utilization of conventional resources leads to global warming which is very much dangerous for environment. That’s why encouragement of non conventional energy resources is ardently essential [22].

3. Components of Wind Power Generation System

3.1 Turbine. A rotational mechanism which transforms the driving force of air steam into motion energy is called wind turbine. According to their blades turbines are divided into two types. First type is vertical axis turbines (VAWT) and second type is horizontal axis turbines (HAWT).

In VAWTs the movement of blades is normal to the earth surface and in HAWTs the movement of blades is alongside with earth surface. Although the function of both the turbines is same but they have different configurations. Normal placing of blades in VAWTs makes it operative in all directions. So this is also called omni directional and hence this type turbine can generate electricity even if winds reaching to it from any angle. These are mostly useful for low power projects and also very much effective in unsettled wind speed.

In HAWTs blades are placing on alongside axis due to which this type turbine gets less air intensity capture by its blades. But there is a big advantage of this turbine that this can generate large amount of electrical power because its blades produce more movement in comparison to VAWTs. These are used for generating large amount of power.

There is also some more some more sub classifications of turbines. The VAWTs turbines are divided into two types one is Savonius and second is Darrieus. Advantage of Savonius turbine are its large torque, low air resistance and more movement of blades.

Darrieus turbines have blades in aerodynamic shapes so that these can produce large wind speed. It can bear upto 220 km/h wind speed. The type of Darrieus turbines are Darrieus, Darrieus H and Helicoidale. The shape of blades in these turbines are oval, H shaped and Helix like respectively. The disadvantage of Darrieus turbine is its low efficiency.

3.2 Generators

The kinetic energy of wind turbines is converted into electrical power by some means called generators. There are four different kind of generators which convert the kinetic energy of turbine into electrical power and these are Wound-rotor Induction type generator (WRIG), Doubly-fed type Induction generator (DFIG), Squirrel cage Induction generator (SCIG) and Permanent magnet synchronous generator (PMSG). So this part is fundamentally consist of brief introduction of different types of machines applied for conversion of energy [23].

3.2.1 Squirrel Cage type Induction Generator (SCIG) – This form of machine is likewise known as settled momentum type generator. The straight version of SCIG almost utilized in Danish by way of specific researchers in Eighties & Nineties, hence this type known by concept of Danish [23]. This machine is straightforward, strong and additionally cost-effective for large scale manufacturing. Since there is no change of frequency hence there are not any present day harmonics in it [24, 25]. Major downside which comes into picture are low effectiveness, pricey gear arrangement protection and it will become very tough task to balance the turbine tempo with the air glide pace for reaching maximum productivity [24, 25].

In irregular rotor pace theory WECS, SCIG is in a straight line connection with turbine by a multiple step gear mechanism. In this type of generator stator winding output goes to an uncontrolled rectifier.
Output of uncontrolled rectifier given to the force commutated PWM inverter and finally it goes to the power grid. Here the main concern is that the energy stream should travel from direct current connector. As a substitute for capacitive structure and smooth starter complete end-to-end power converters are used.

Advantage of uneven rotor pace concept WECS using SCIG [26]: It apprehends higher power in comparison of firm pace SCIG theory. It has no requirement of capacitive structure. Uneven pace theory minimizes the rotational strain from the turbine. There is electrical isolation between it and grid.

Drawbacks of irregular rotor pace theory WECS with SCIG [26]: Preservation of gear system is very difficult issue in it. Collecting of field current from stator connection is also a very difficult task. Large capacity Converters becomes very costly.

3.2.2. Doubly-Fed Induction type Generator (DFIG)-
Here rotating conductor configuration is given power by the power grid with the help of a revolving or stationary suitable power converter. Here stator winding is in a straight line connection with power grid terminals while rotating winding connection is given by slip rings associated with power grid circuit by the assist of bidirectional power converters. Since converter capacity is near about 30% of the whole scheme capacity hence minimize converter price. This configuration becomes more efficient. Even in the absence of capacitive structure, PF improvement is achieved with lesser price. Active as well as reactive powers both are swiftly controllable.

3.2.3. Permanent Magnet type Synchronous Generator (PMSG):
This type of generator has a permanent magnet which gives the field current for excitation. It has a special type of configuration in which there is no requirement of gear system and it also curtail the dimensions of WECS. Its cost is low as comparison to others also here minimum preservation is needed. In this WECS system which is based on magnetic effect, the electrical quantities which are output voltage and output current are depend on rotor pace and the torque which developed electromagnetically. It has an ac to dc conversion circuit and a direct current capacitive path which comes after inversion network. This converter is highly acceptable when PMSG is used in WECS. This has simple structure which is its plus point and rectification end has not any requirement of control action. There are some few restraints in it. The direct current capacitive path is massive and its working term is also very limited. Inverter output has a lot of ripples [27].

We can use a direct current to direct current swell step (using rectification) instead of direct current capacitive path. By varying the duty cycle of switching signals, the generation end dc voltage is swiftly controlled. When there is increase in switching step, its price goes up and performance goes down [27].

The traditional two stage conversion topology having the first place in well approved conversion topologies for wind energy conversion system in which PMSG is used. Advantages: It imparts real as well as non real power adjustment and due to application of PWM switching method, here angle between voltage and current becomes bigger. This configuration becomes less in weight as well as compact in dimensions. Due to negligible loss in this device it becomes more efficient. This device has not any requirement of outside field current. There is also not any requirement of gear system [28, 29].

Drawbacks: Application of this type is in small power WECS and not for big wind power systems. Here bigger dimension magnet is needed. Earth’ surroundings circumstances makes very difficult for reverse process of magnetization of permanent magnet [28, 29].
Although wind energy conversion system having PMSG has so many drawbacks yet it is more efficient in comparison to others. Hence researchers have more attraction towards this configuration in the field of WECS.

3.3 Various Power Conversion Configurations

A WECS has different power electronics converters which act like an imperative function for converting wind generator output power in changeable voltage and changeable frequency form and finally send it to the preset voltage and preset frequency grid system. A distinctive arrangement of power electronics converters consists of alternating current to direct current converter at generator side & direct current to alternating current converter at grid side interconnected with the help of a component called dc link. This component can be capacitive in voltage source converter and inductive in current source converter [30].

Advancement of technology in electronics at power level is doing an imperative job for enhancement the efficiency of turbines as well as in designing efficient generators used in WECS. The different configurations of power conversion are given as [31].

3.3.1 Non controllable ac to dc converter

This type of converters are made of diodes also called rectifier and generally applied in transform the given ac power in the form of dc power by a non controllable way. Advantage of being uncomplicated, vigorous, and less price can be achieved with this rectifier. But it has many drawbacks like one direction energy flood, very less power factor and extremely indistinct current waveform and in addition a massive dimension dc link is also needed [32].

3.3.2 Non controllable ac to dc converter with Direct current Boost

In boost category power conversion configuration this is a straightforward option. The main plus point of this configuration is its significant amplification in dc voltage at output side. Only negative aspect in this configuration in comparison to normal ac to dc converter is the pressure upon switching element used for boost the voltage [33].

3.3.3 Phase Controlled Converter

In this configuration of converter power thyristor are taken in use. Major drawback of this configuration is that the higher harmonic content is injected in generation part angle between voltage and current is also small which creates disruption in waveforms of its line voltages [34].

3.3.4 Entirely Controllable PWM Ac to Dc Converter

This type of converter configuration is also the highly admired among all. This converter configuration is more beneficial because there is a low cost three phase unit which has ability of power surge in both directions. This also gives best in class controllable direct current output potential difference [35]. The movement of current in this configuration happens in positive as well as negative cycle. Here at every duty cycle there are three power electronic tools in active state so this configuration produces larger power losses. The cost of this configuration is also high [36].

3.3.5 Matrix Converters

This is an AC power to AC power conversion topology where energy conversion takes place in a single stage. There is no direct current element and inductive coil in this type of power conversion technique. The configuration of matrix converters made of 9 bidirectional switching elements. Here half of switching elements from the same output circuit should not be switched on at the similar timings [37]. The main benefit of this type of power conversion topology is nonexistence of direct current element due to which there are remarkable increment in efficiency and natural life of the converter. Also matrix converter has advantage of reduced size and less cost in comparison to PWM-
VSI converter. Another advantage of this type of power conversion technique is its thermal characteristic since maximum temperature withstands by this converter is 300°C.

![Fig. 1 Schematic circuit of a three-phase to three-phase matrix converter. [71]](image)

Its drawbacks are the restriction on the produced voltage which is 86 percent to total applied voltage, speedy altering in applied voltage, compassion in grid circuit instability, larger on state loss and large priced elements used in on off process [37]. Now days the various configurations of matrix converter which are in practice described here.

### 3.3.5.1 Three Phase to Three Phase Matrix Converter
This configuration of the conventional matrix converter is explained in [38]. Here exclusion of direct current element for energy storage increases the trustworthiness of the power converter and also decreases its size. Besides these two merits of matrix converter there are also many more which attract its application in wind power generation. This type power conversion technology gives perfect sine wave of incoming current and outgoing voltage, zero phase difference between voltage and current waveforms and two dimensional energy stream. This power conversion technology can be implemented for the permanent magnet synchronous generator fed wind power conversion system [39]. This configuration of power conversion is applied in a DC wind park power system as an energy source division [40]. This configuration is also used with the PMSG in wind power generation having MPPT control technique.

### 3.3.5.2 Sparse Matrix Converter
Double leg configuration of the traditional matrix converter having less quantity of switching elements is called sparse matrix converter [41]. It has no passive components. There are three types of this matrix converter which are sparse matrix converters [42] as well as very sparse matrix converters [43] and ultra-sparse matrix converters [44]. All three configurations have the merits of the traditional basic matrix converters and also contain some extra and very beneficial features. Here converter size decreases due to decrement in quantity of power electronics elements. These converters have no complexity in design and cost is also less.

In PMSG fed wind energy generation system a very sparse matrix converter is used in a two and half MW system as explained in [45]. This type arrangement is also taken in application for miniature size wind energy generation system where transformer is absent [46]. Super sparse matrix converter is used in a medium scale wind energy generation system which is explained with simulation in [47]. Application and advantages of ultra-sparse matrix converters in wind power generation system is described in [48].
3.3.5.3 Three Phase to Single Phase Matrix Converters

There are only six switching elements in this type of power converter configuration. The switching elements can operate in both directions. Its highly compressed structure and easier switching system makes it more useful. This configuration is used in straight drive housing societies wind turbines as described in [49]. This configuration is widely used by researchers for large capacity wind energy generation plants.

This configuration of reduced matrix converter is introduced in [50]. The usefulness of one-phase matrix converter encouraged these reduced type of configurations of converter which have a little bit dissimilar fundamentals. Here non reactive component of power is unvarying and one-phase electrical quantities do not have sine waveform. The main application of this type of configuration of power converters is in coastal wind energy generation plants. On comparing to three AC to AC traditional power conversion topology, this topology of power conversion is highly proficient and has more energy concentration [51].

One more practical implementation of this power conversion configuration at large power rating is explained in [52], in which multi-modular matrix converter is considered as a single unit. In wind power conversion system this topology is also simulated and experimentally adapted to 1.5 MW as discussed in [53].

3.3.5.4 Z Source Matrix Converter

The most negative aspect of Conventional matrix converters is its restricted voltage gain that is less than 0.866 for all traditional configurations of matrix converter whether it is direct or indirect type of matrix converter. To overcome this voltage gain limitation problem of the traditional matrix converter Z source matrix converter is proposed. In Z source matrix converters buck and boost operation occur with reduced number of switch. So these have less cost, maximum efficiency and high reliability in comparison to conventional back to back converters.

4. Control Methods for Matrix Converter

Power switching in matrix converter can be in both directions so it becomes necessary to have proper switching functions so that the proper control operation of each controllable semiconductor device may occur swiftly. These switching functions are called modulation techniques. Switching functions are calculated in a manner so that that the waveform of electrical quantities at both side of the converter having perfect sine wave in nature. Various switching techniques for matrix converters are explained in [54]. In PMSG-based wind systems the Pulse Width Modulation (PWM) switching method is highly accepted. Among all PWM switching methods the space-vector switching technique [55] has advantages over carrier-based modulation method [39,56,57]. There are various algorithms which were developed for space-vector method to diminish the switching losses so that output current distortion can be minimize by optimization techniques of zero vectors [58-59]. MPPT system along with these modulation methods are used to achieve the appropriate execution of the wind power generation system in accordance with the power grid [40,50,60,61]. To generate grid circuit current with the help of active and reactive components of the generation circuit current a new switching procedure in accordance with factorization of a real or complex matrix has been implemented in [62] recently.

Advantages of matrix converters in power conversion system can be practically proved by a simulation model in which a three phase ac supply is given at input circuit and a three phase ac supply is taken at output circuit of the matrix converter. Here a three phase to three phase matrix converter is used for ac to ac power conversion.

Control method used in this three phase to three phase matrix converter is carrier based modulation method.
Fig. 2 Matlab/simulink model for the matrix converter using carrier based scheme[71]
Fig 3 Simulink model for the calculation of duty ratio and switching function[71]
As can be observed from the Fig. 4 and Fig. 5 for input phase voltage amplitude of 100V, the peak amplitude of output phase voltage is approximately 87V which shows that the maximum possible output voltage of the converter is limited to 86.6%.
Fig. 6 shows the harmonic spectrum for the filtered output voltage. The spectrum shows that there is a fundamental component of the output voltage obtained at 50 Hz frequency and the magnitude is 59.85 r.m.s. (84.6489 peak) voltage. The THD is 0.67% of the fundamental and the WTHD is 0.47% of the fundamental. It shows that the quality of the output voltage is pure sinusoidal.

5. Recent Trends in Converter Technology

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6. Conclusion
There's no doubt that renewable sources of energy could expect primary element in ensuring energy protection of the country. There may be tremendous capability to create energy from sustainable assets like solar powered and wind. Technology of energy from wind energy has turned out to be massively appeared into studies region. This evaluate paper summarizes the distinct kinds of turbines, distinctive converters topology with their advantages and disadvantages utilized in WPCM. Latest studies trends in general focused on diverse matrix converter configurations used in wind strength generation schemes. There are so many benefits of matrix converters due to which researchers promoting its utility in wind energy era systems. However there are some primary constraints on which researchers are operating enthusiastically. Those are the limit in amplification of voltage, the intricacy of the manage circuit and the large amount of energy electronic gadgets. Consequences of this comparative analysis have a lot ability for in addition research, there's a totally wide scope of research on novel configurations of strength converters, novel switching techniques, novel manage techniques and gentle computation for you to make the matrix converter extra talented and extra trustworthy in assessment to the traditional converters. The modern-day research trends may be on control algorithms of matrix converters in order that maximum performance can be accomplished.

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