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# Impacts of the Decentralized Wind Energy Resources on the Grid

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## SUMMARY

The Power Quality and Protection impacts of the Wind Energy resources on the Distribution System is presented. IEEE standards are addressed and various power quality and protection issues caused by step up transformer configuration, feeder load, capacitor banks, generation type and possible adjacent generation are discussed. Solutions are recommended for the identified interconnection issues.

## KEYWORDS

Distributed Generation, Wind Energy, Synchronous Generator, Power System Faults, Anti-Islanding, Self Excitation, Power Factor, Effectively Grounded System and Impedance Grounded System.

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## INTRODUCTION

Energy and environmental issues have become one of the biggest challenges facing the world. In response to energy needs and environmental concerns, renewable energy technologies are considered the future technologies of choice [1]. In the years to come, there will be more and more renewable energy generation connected to the grid. The impact of the renewable energy resources on the power quality and power system protection is becoming a concern. The short circuit behavior of Wind Turbines is studied recently [1]-[8]. Various types of wind generators will have different performance for different fault locations. Hence, designing a good protection scheme for each DG requires a good understanding of how wind turbines operate in faulted power systems. With the increasing amount of distributed generators on the distribution system, the safety and reliability of the transmission system might be impacted if the generators back feed power into the transmission system. This papers aims to address the most important impacts of the wind turbines on the grid, as well as, to recommend possible solutions

## WIND TURBINE

The U.S. wind power industry experienced a trying year in 2010, with a significant reduction in new builds compared to both 2008 and 2009. The delayed impact of the global financial crisis, relatively low natural gas and wholesale electricity prices, and slumping overall demand for energy countered the ongoing availability of existing federal and state incentives for wind energy deployment. Nonetheless, cumulative wind power capacity still grew by a healthy 15% in 2010, and most expectations are for moderately higher wind power capacity additions in 2011 than witnessed in 2010, though 2011 additions are also expected to remain below the 2009 high [9]. With the advancement of technology and the dropping of production prices, the wind resource has become a serious and important component of utility generation [2]. This section explains the structure of all five types of wind turbine generators (WTG) along with their impact on the system power quality and power system protection.

Fig 1. shows the structure of a wind turbine and how the mechanical power from the wind is converted into the electrical power.

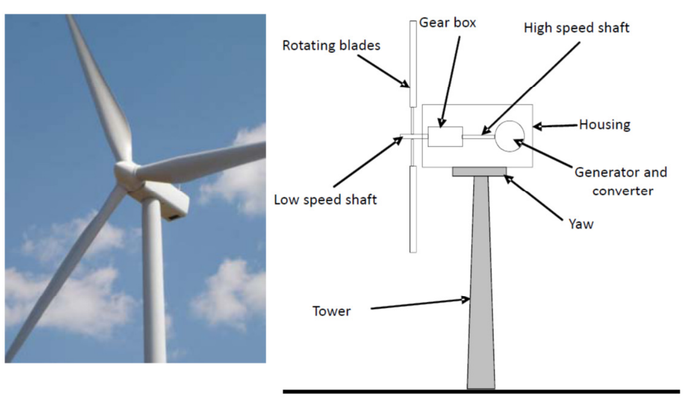


Fig. 1. Wind Turbine Structure

- TYPE I WIND TURBINE

A Type I wind turbine is a squirrel cage induction generator (SCIG) that is directly connected to the utility grid. Electric control power factor correction capacitors provide the reactive power required exciting the generator and maintaining the terminal voltage. The SCIG generates electricity when it is driven above synchronous speed. The difference between the synchronous speed and the operating speed is measured by slip. A negative slip indicates that the wind turbine operates in the generating mode. Normal operating slips for an induction generator are between 0% and -1%.

What follows are the power quality and protection concerns with regards to the type I wind turbines:

**A)** Flicker: Varying active power generated by the wind turbine might impact the system voltage and create flicker on the distribution feeder. [10]- [12] are the most common flicker standards. Most utilities are mandated to comply with those standards. Voltage/VAR control at the Point of Common Coupling (PCC) can be used to mitigate the flicker issues.

**B)** The active power generated from the wind turbine might decrease the ratio of the active to reactive power flowing from the grid to the feeder load. Hence, the feeder Power Factor (PF) might be impacted. PF correction is recommended to be used at the PCC. The wind turbine actively monitors the PF at the PCC and injects/absorbs VAR to the system to maintain an acceptable PF at the PCC.

**C)** Self-excitation: This will occur when an isolated generator is connected to a feeder or a line having capacitors to inject enough VARs for the magnetizing reactance requirements which will create Over Voltage (OV) on the system. These OVs are produced by charging and discharging of the islanded system capacitance through the magnetizing reactance of the induction generator. If the minimum active power load on the feeder is greater than maximum generation active power (kW), the OV will not occur even if there is enough islanded capacitance connected to the generator. The OV must be sensed by protection relays and the wind turbine must be tripped off within an acceptable period of time.

**D)** OV due to Single Line to Ground Fault (SLG): Power system grounding should be studied to determine the type of system grounding. If the utility side of the step up transformer is delta, for a SLG fault there will be OV on the un-faulted phases after the utility breaker opens. Protection relays shall be capable of detecting this OV. Possible solutions are either changing the transformer configuration or installing a grounding transformer to meet the effectively grounded system requirements.

**E)** OV due to the unintentional utility breaker opening: If the utility breaker opens and the generation is much higher than the feeder load at the time of islanding, there will be OV on the feeder even if the system is effectively grounded. If the voltage rises slowly such that it gives enough time for the regular relays to isolate the generator, there is no need for high speed protection. But, if voltage rises high enough to damage customer appliances during the minimum possible relay clearing time, high speed protection i.e. Direct Transfer Trip (DTT) is required. The approximate time delay for the DTT to send the signal and open the remote end interrupting device is 8 cycles, in some cases the voltage has raised enough to damage the customer's appliances within this short period of time. A possible solution would be to initiate the DTT a few cycles before the utility substation interrupting device opens. The trip coils gets energized simultaneously with the DTT signal. This is a feasible practice in the new reclosers and relays.

## TYPE II WIND TURBINE

A Type II wind generator is a wound rotor induction generator (WRIG) that is shown in figure 2. The resistor R on the dc side of the rectifier determines the output power [3].

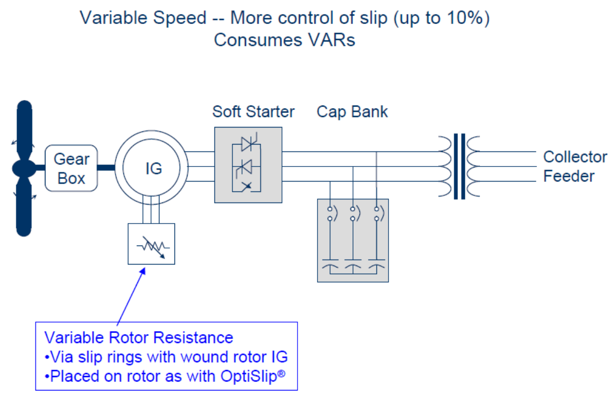


Fig. 2. Type II wind turbine (Wound Rotor Induction Generator) [3].

Figure 3 shows the short circuit current of a type II wind turbine for a three phase fault on the generator terminals. It is observed that the oscillation after fault decreases as rotor resistor increases.

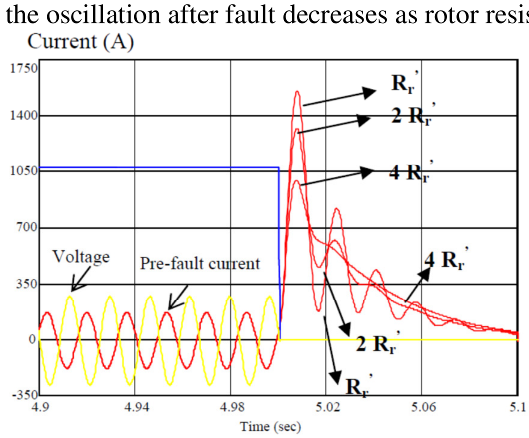


Fig. 3. Type II wind turbine fault current contribution for a 3LG fault [3]

The SC contribution of a Type II is similar to a Type I. When the external rotor resistance is shorted, (i.e., operation below rated slip), the SC current is similar to the squirrel-cage induction generator. Operation in higher slip than the rated slip requires that the external rotor resistance is adjusted higher than zero. Operating at higher rotor resistance produces a lower SC current than that of a squirrel-cage induction generator (Type 1 WTG).
Over/Under (O/U) voltage and O/U frequency protection follows the same rules indicated for Type I. The power quality issues are also similar to those of the type I.

### TYPE III WIND TURBINE

A Type III wind generator is a doubly fed induction generator (DFIG) where the rotor flux is being created through three terminal voltages as indicated in figure 4.

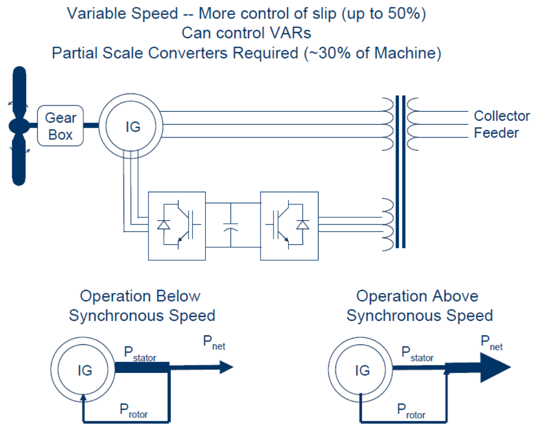


Fig. 4. Type III wind turbine (Doubly Fed Induction Generator) [3]

The rotor speed is allowed to vary between 0.3 slip to - 0.3 slip, thus, the power converter can be sized to about 30% of rated power (partial rating). The use of the power converter allows the rotor speed to rotate at a different speed with respect to the synchronous speed, thus the rotor speed is not synchronized to the air-gap flux. The power quality concerns are similar to those of the type I.
What follows is an additional protection concern with regards to the type III wind turbines:

A) Type III wind turbine might keep contributing to the 3LG fault if the fault is on the utility side of the step-up transformer regardless of the transformer configuration. The impedance of the transformer is big enough to create a voltage that is being fed to the rotor to excite the machine. In order to detect this situation, voltage controlled OC relay (51C) must be used to detect the low fault current contribution of the wind turbine. The current pick up of the 51C relay can be set below the nominal current, which makes it feasible to detect fault current that is less than the nominal rating of the generator.

## TYPE IV WIND TURBINE

Type IV is a synchronous or induction generator that is connected to the grid through a full power converter as depicted in figure 5.

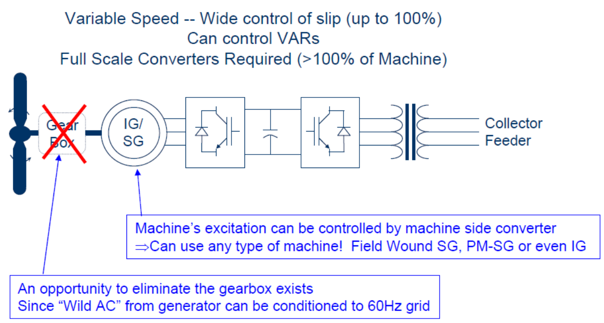


Fig. 5. Type IV wind turbine [3]

The full power conversion allows separation between the WTG and the grid, thus, the mechanical dynamic can be buffered from entering the grid and the transient dynamic on the grid can be buffered from entering the wind turbine dynamic. Permanent magnet synchronous generator is the most common generator for this type of application. Hence, this type of generator will always contribute to any type of fault current because the flux is being created continuously by the permanent magnets.
Most power electronic converters are limited to carry 110-120% of nominal current. Hence, it might be difficult for a relay to detect the fault current as it is close to the actual current rating of the generator. A voltage controlled over current relay (51C) can detect the faults when the fault current is limited. The Power Quality impacts/solutions of a Type IV wind turbine are similar to those of the Type I.

**TYPE V WIND TURBINE**

Fig. 6 shows the block diagram of the type V wind turbine. The control scheme is on the mechanical part of turbine (Shaft speed control). The power quality and protection impact of the type V wind turbine is similar to those of the Type I.

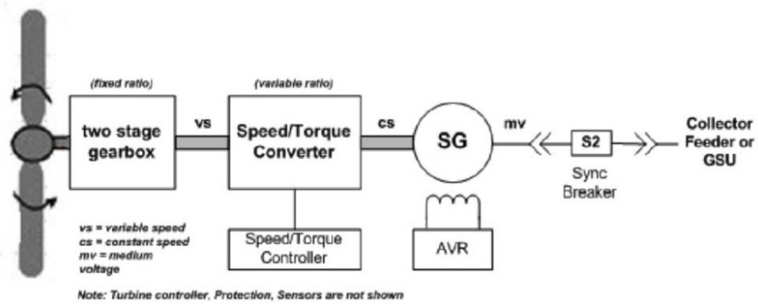


Fig. 6. Type V wind turbine [13]

**CONCLUSION**

In this paper, the impact of the wind energy resources on the power quality and protection of the distribution system is discussed. As expected, all types of wind turbines can be self excited if there is enough reactive power on the feeder.

Multi-generation on a feeder is problematic from power quality and protection perspective also. The most important protection concerns with regards to wind turbine installations are presented as well. DTT is recommended for the islanding and severe OV conditions. Due to the cost of the DTT, the author recommends thorough research on new techniques to detect the islanded conditions locally at the PCC. i. e. inter-harmonics Power Line Carrier.

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