



Grid of the Future Symposium

Impacts of the Decentralized Wind Energy Resources on the Grid



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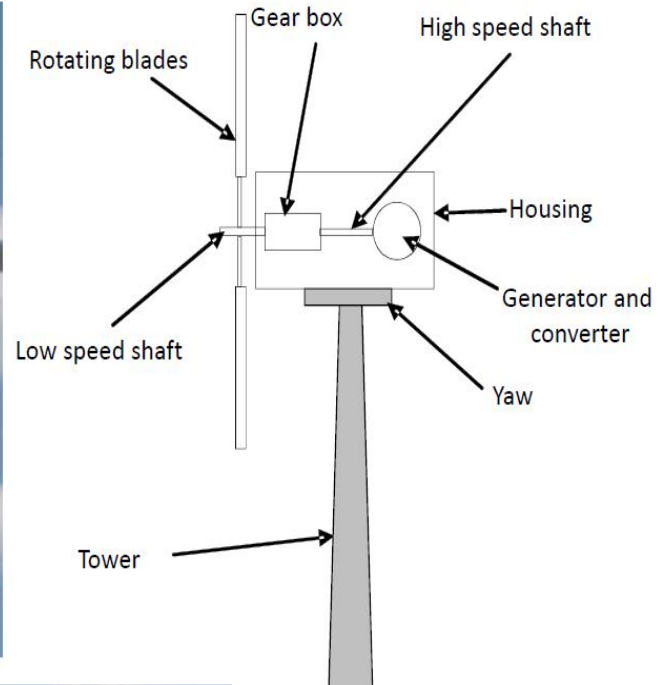
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Topics

- **Wind Turbine Structure**
- **Type I Wind Turbine: Squirrel Cage Induction Generator (SCIG)**
- **Impacts of Type I Wind Turbine on the Grid**
- **Type II Wind Turbine: Wound Rotor Induction Generator (WRIG)**
- **Type III Wind Turbine: Doubly Fed Induction Generator (DFIG)**
- **Type IV Wind Turbine**
- **Type V Wind Turbine: Shaft Speed controlled**
- **Conclusion**

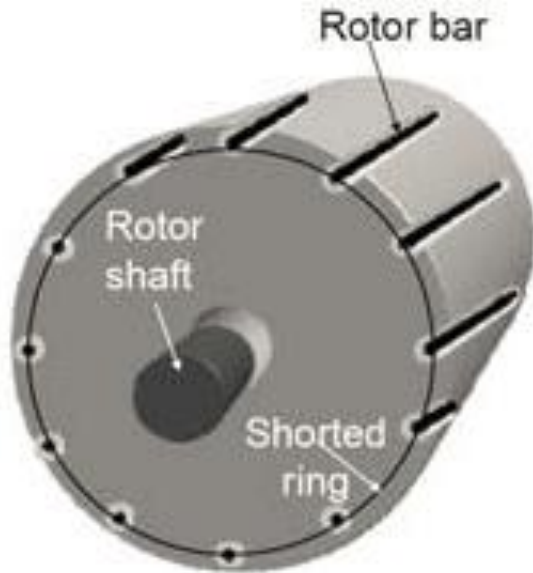
Wind Turbine Structure



GE 3.6MW



Type I Wind Turbine: Squirrel Cage Induction Generator (SCIG)



- 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.
- Normal operating slips for an induction generator are between 0% and -1%.
- No control on the rotor current

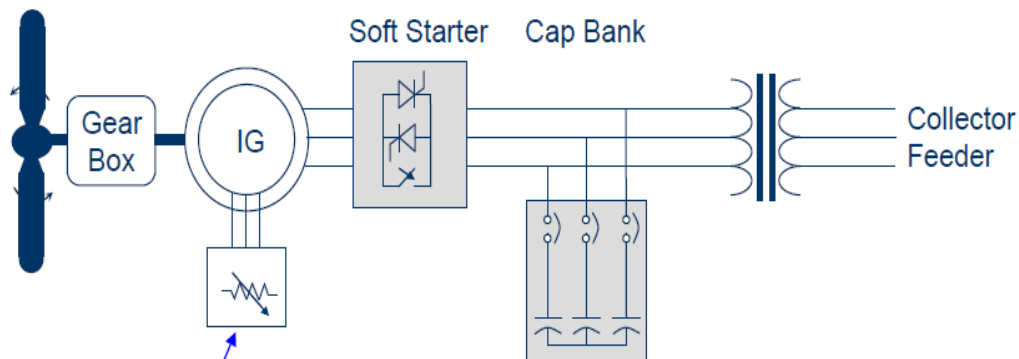
Impacts of Type I Wind Turbine on the Grid

- Flicker
- Power Factor
- Self Excitation in the island condition
- OV on the ungrounded systems (during L-G faults)



Type II Wind Turbine: Wound Rotor Induction Generator (WRIG)

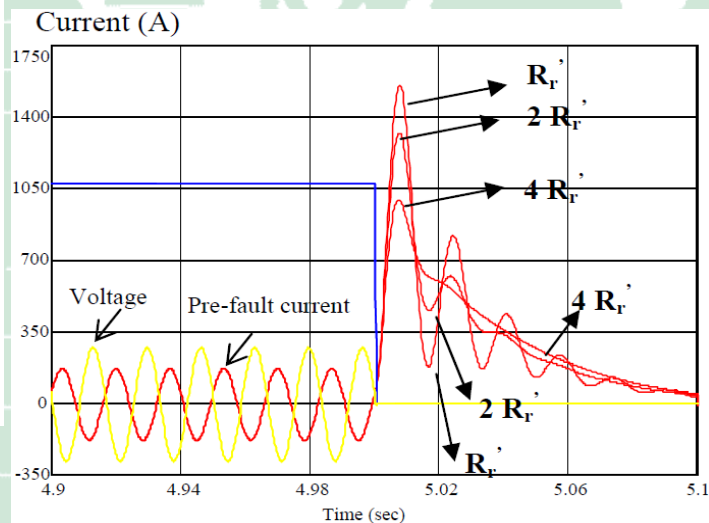
Variable Speed -- More control of slip (up to 10%)
Consumes VARs



Variable Rotor Resistance
•Via slip rings with wound rotor IG
•Placed on rotor as with OptiSlip®

Type II wind turbine (Wound Rotor Induction Generator)

- SCIG is a WRIG with shorted resistance.
- The impacts of WRIG on the grid are similar to those of the SCIG.



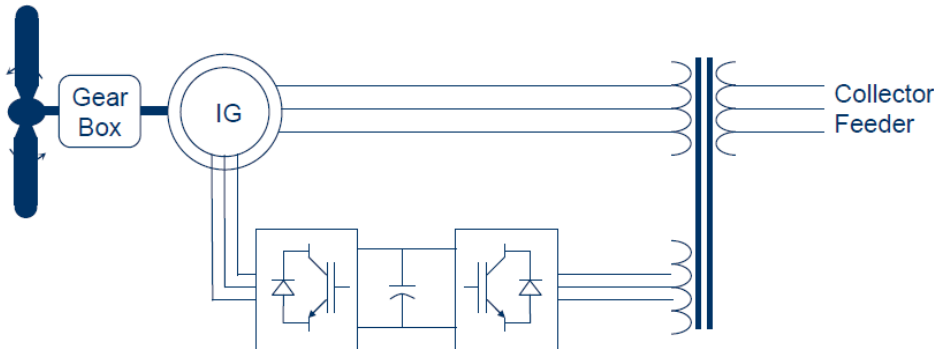
Type II wind turbine fault current contribution for a 3LG fault

Type III Wind Turbine: Doubly Fed Induction Generator (DFIG)

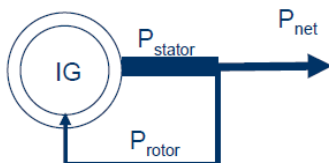
Variable Speed -- More control of slip (up to 50%)

Can control VARs

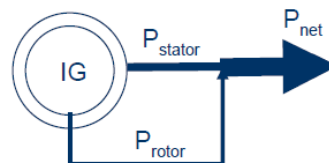
Partial Scale Converters Required (~30% of Machine)



Operation Below Synchronous Speed



Operation Above Synchronous Speed



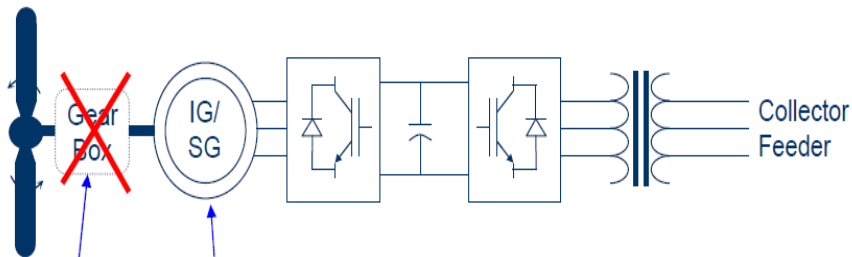
- The rotor speed is allowed to vary between 0.3 slip to - 0.3 slip, thus, the power converter can be sized to about 30% of rated power (partial rating).
- The power quality concerns are similar to those of the type I.
- Additional protection concern: Type III wind turbine might keep contributing to the 3LG fault

Type III wind turbine (Doubly Fed Induction Generator)

Type IV Wind Turbine

Synchronous or induction generator connected to the grid through a full power converter

Variable Speed -- Wide control of slip (up to 100%)
 Can control VARs
 Full Scale Converters Required (>100% of Machine)



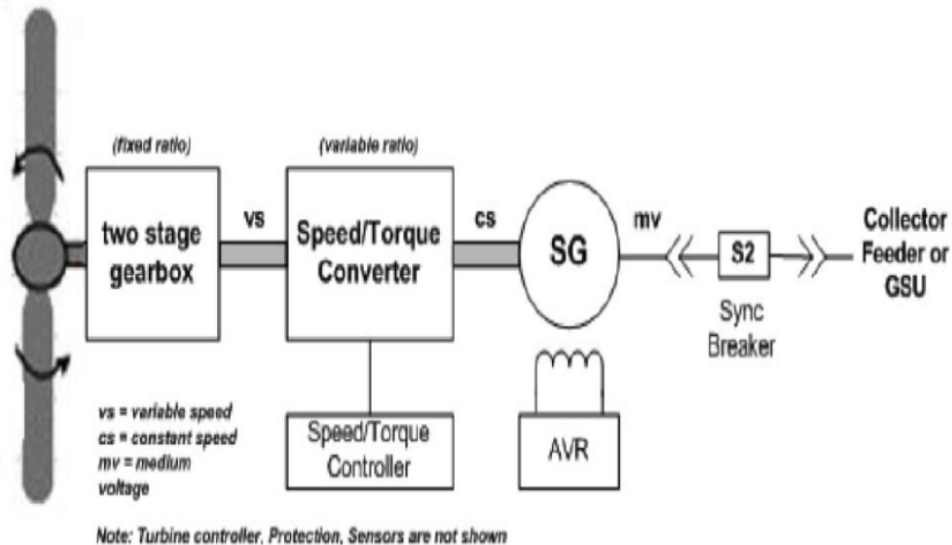
Machine's excitation can be controlled by machine side converter
 ⇒ Can use any type of machine! Field Wound SG, PM-SG or even IG

An opportunity to eliminate the gearbox exists
 Since "Wild AC" from generator can be conditioned to 60Hz grid

- Permanent magnet synchronous generator is the most common generator
- Generator will always contribute to any type of fault because the flux is being created continuously by the permanent magnets
- Voltage Controlled Over Current (51C) relay is recommended to detect the fault.
- The power quality concerns are similar to those of the type I.

Type IV wind turbine

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 IV.

Conclusion

- **The structure of a Wind Turbine is presented.**
- **Various types of Wind Turbine Generators are discussed.**
- **The impacts of the Decentralized Wind Generators on the system power quality and protection are addressed.**
- **Solutions to resolve the adverse impacts of the Wind Generators on the grid are recommended.**

Thank You
Questions?