POWER ELECTRONICS FOR INTEGRATION AND CONTROL OF WIND TURBINES

Soft-Starter for Fixed-Speed Wind Turbines

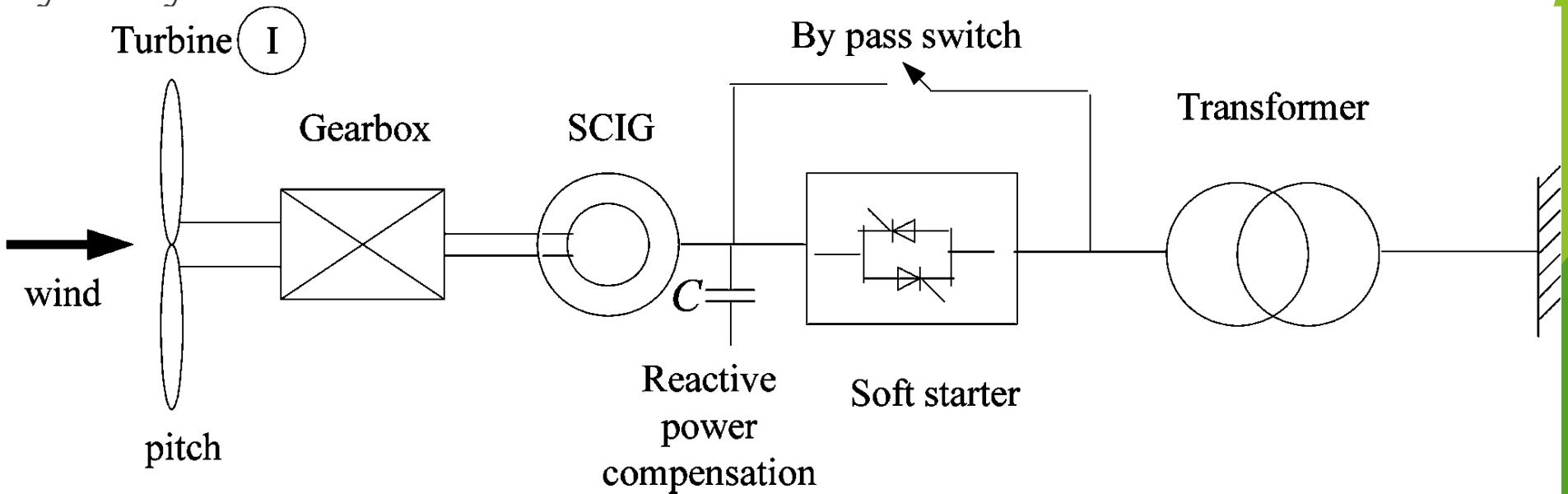
- The advantages of wind turbines with induction generators are the simple and cheap construction, in addition that no synchronization device is required.
- These solutions are attractive due to cost and reliability.
- Some drawbacks are:

  1) the wind turbine has to operate at constant speed

  2) it requires a stiff power grid to enable stable operation

  3) it may require a more expensive mechanical construction in order to absorb high mechanical stress, since wind gusts may cause torque pulsations on the drive train.

- Connecting the induction generators to power system produces transients that are short duration with very high inrush currents, thus causing disturbances to both the grid and high torque spikes in the drive train of wind turbines with a directly connected induction generator.
- Such a transient disturbs the grid and limits the acceptable number of wind turbines.
- The high starting currents of induction generators are usually limited by a thyristor soft-starter.



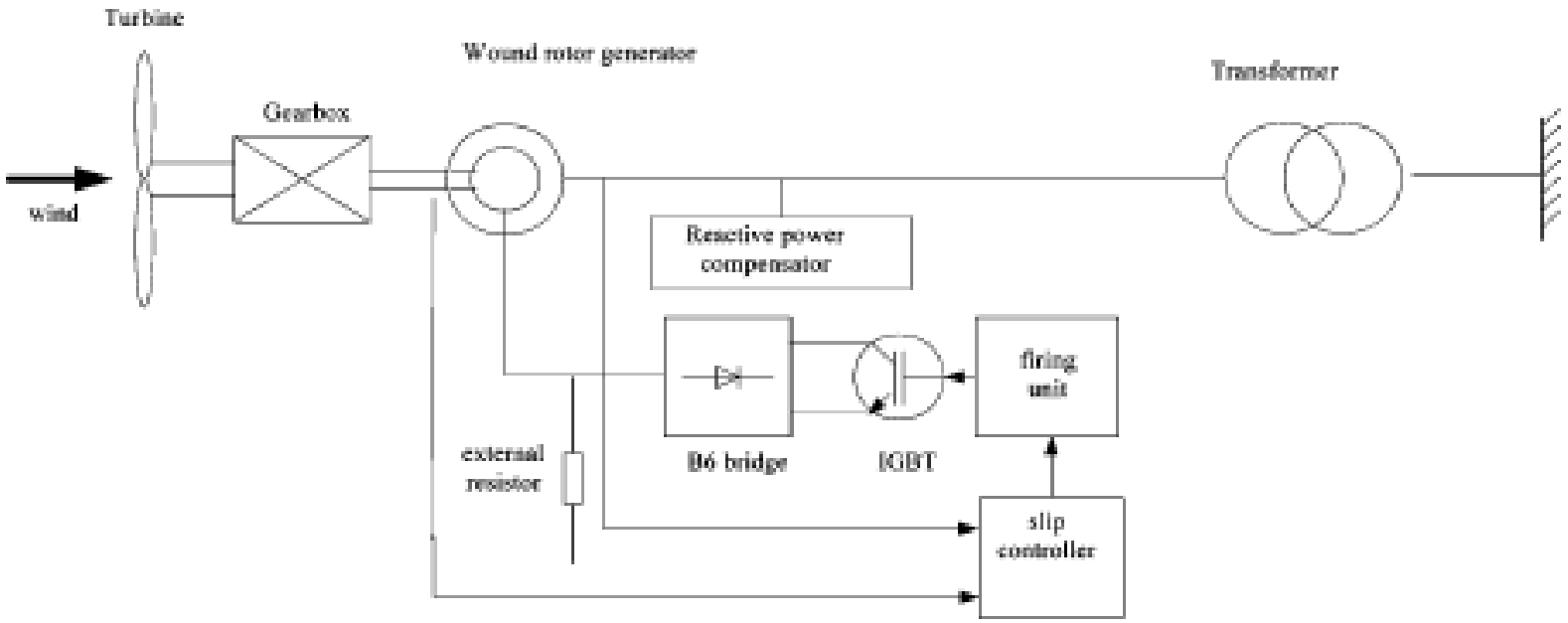
- The current limiter or soft-starter, based on thyristor technology, typically limits the rms value of the inrush current to a level below two times of the generator rated current.
- The soft-starter has a limited thermal capacity and it is short circuited by a contactor, which carries the full-load current, when the connection to the grid has been completed.
- In addition to reduce the impact on the grid, the soft-starter also effectively dampens the torque peaks associated with the peak currents, and hence reduces the loads on the gearbox.

Power Electronics for Variable-Speed Wind Turbines

- Variable-speed operation of a wind turbine system has many advantages.
- For instance, the wind turbine can increase or decrease its speed if the wind speed and torque vary.
- This means less wear and tear on the tower, gearbox, and other components in the drive train. Also, variable-speed systems can increase the production of the energy and reduce the fluctuation of the power injected into the grid.
- In variable-speed systems, the generator is normally connected to the grid through a power electronic system.

- For synchronous generators and induction generators without rotor windings control, a full rated power electronic system is connected between the stator of the generator and the grid, where the total power production must be fed through the power electronic system.
- For induction generators with rotor windings, the stator of the generator is connected to the grid directly, and the rotor is connected to a power-electronic-controlled resistor or connected to the network through slip rings and a power electronic converter.

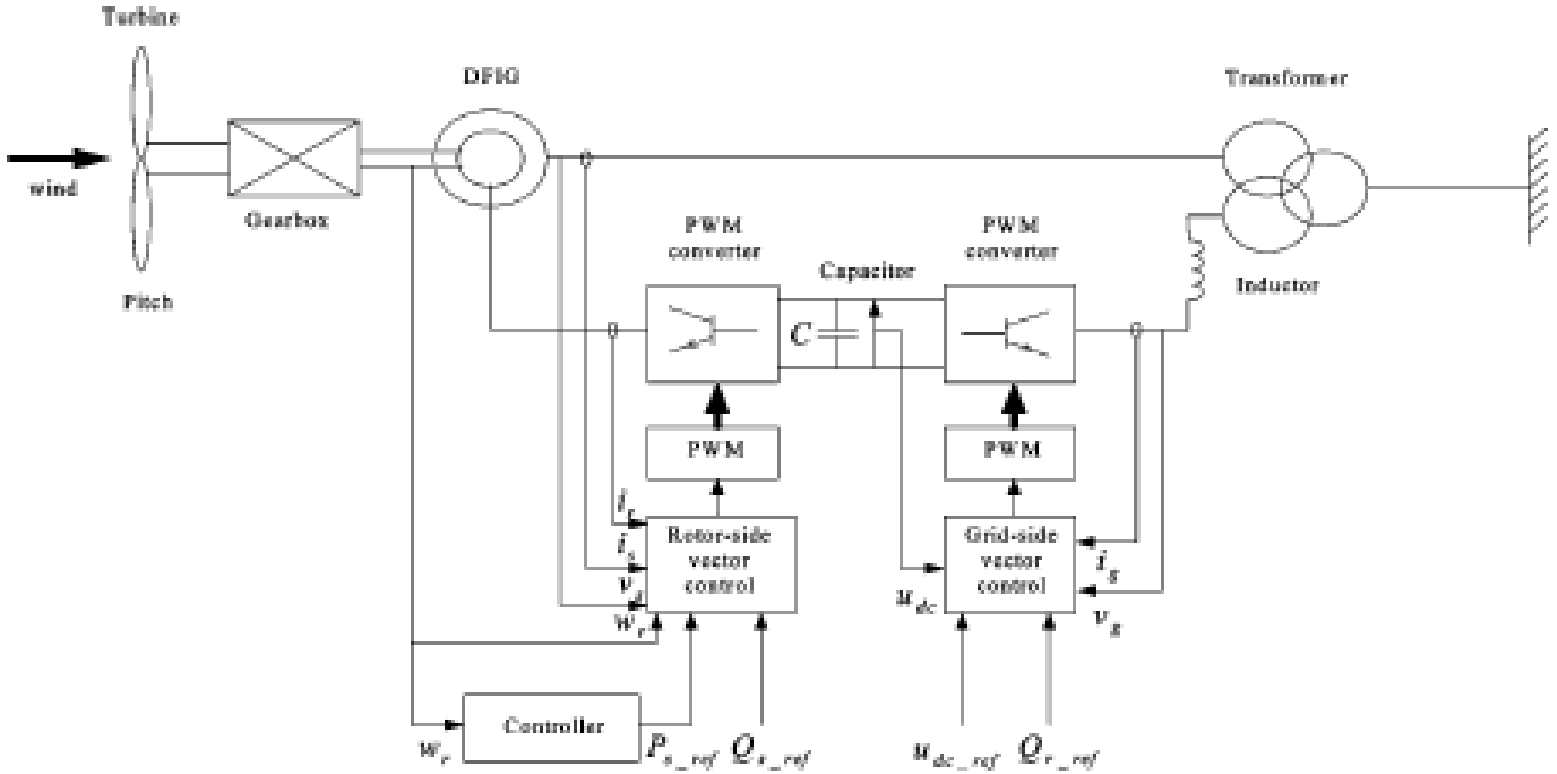
Wounded Rotor Induction Generator With Rotor Resistance Control (Dynamic Slip Control)



- In this scheme, the rotor windings are connected with variable resistors. The equivalent resistance in the circuit can be adjusted by an electronic control system.
- The higher the resistance of the rotor windings, the higher the slip is. In this way, the generator speed can be varied in a limited range.
- Conventionally, the connection is usually done with brushes and slip rings, which is a drawback in comparison with the simple technical design of a cage rotor induction machine.
- It also introduces parts, which raise the maintenance requirements.
- This solution still needs a soft-starter.

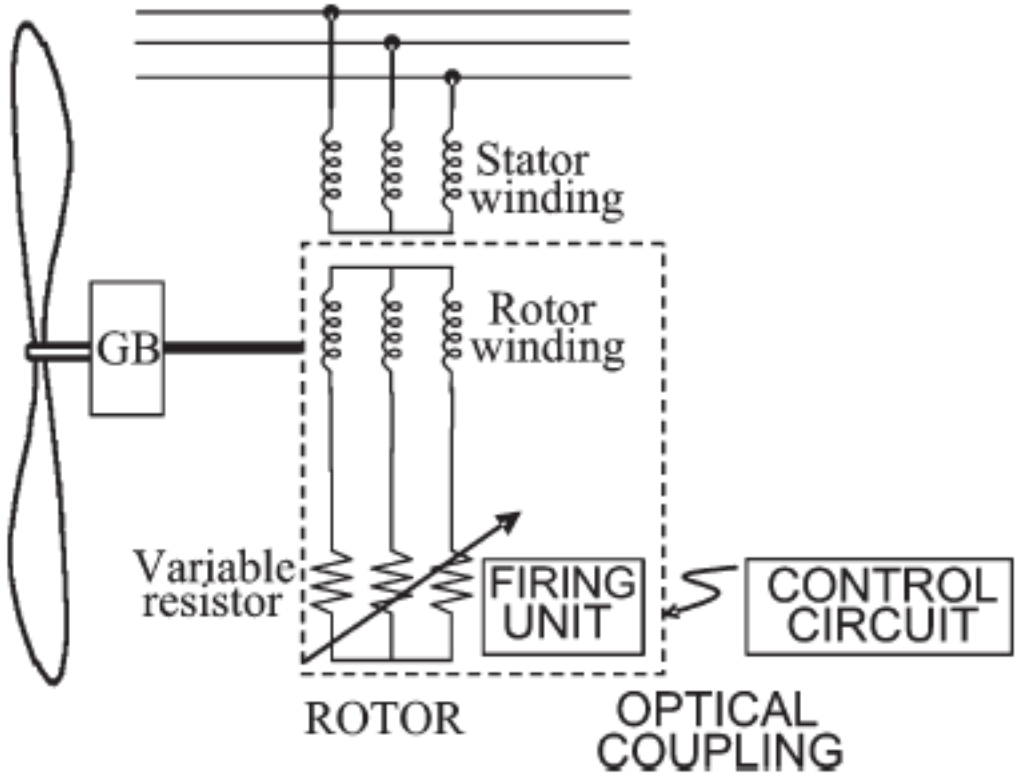
Doubly Fed Induction Generator

- The stator of a doubly fed induction generator (DFIG) is connected to the grid directly, while the rotor of the generator is connected to the grid by electronic converters through slip rings.

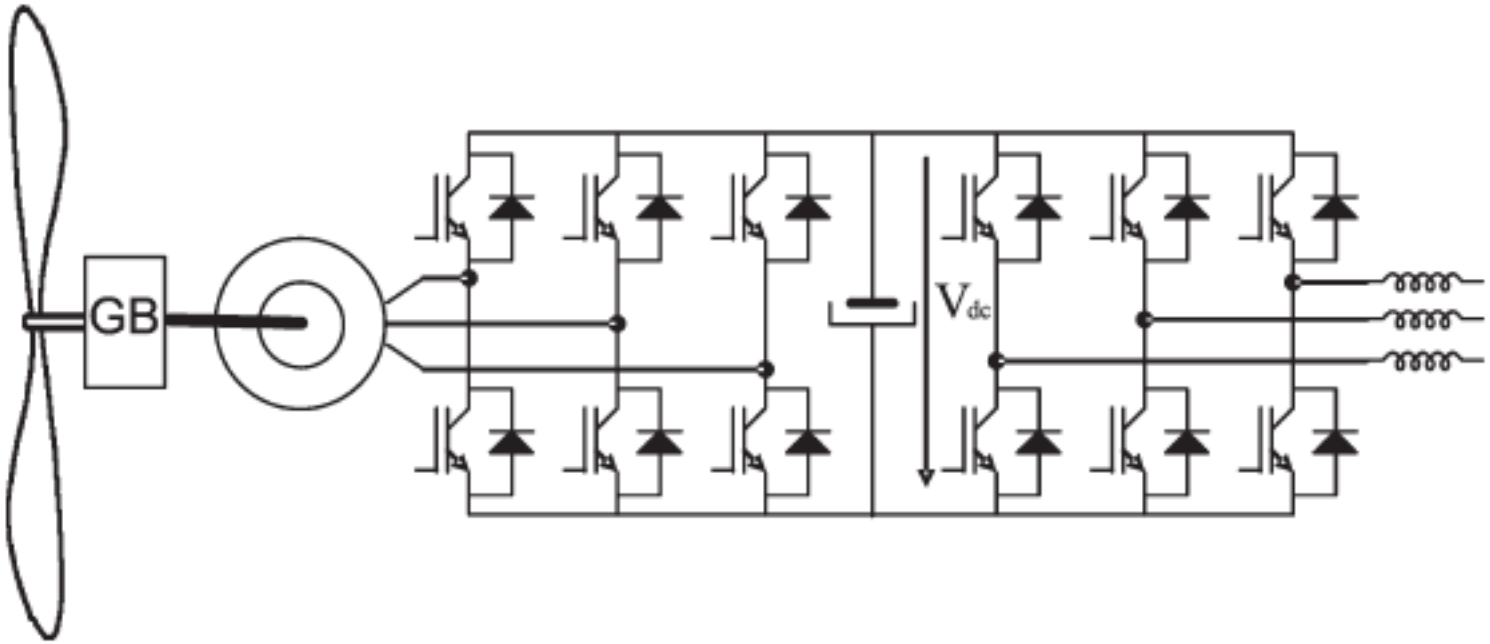


- The generator can deliver energy to the grid at both supersynchronous and subsynchronous speeds.
- The slip is varied with the power flowing through the power electronic circuit.
- The advantage is that only a part of the power production is fed through the power electronic converter. Hence, the nominal power of the power electronic converter system can be less than the nominal power of the wind turbine.
- By controlling the active power of the converter, it is possible to vary the rotational speed of the generator, and thus the speed of the rotor of the wind turbine.

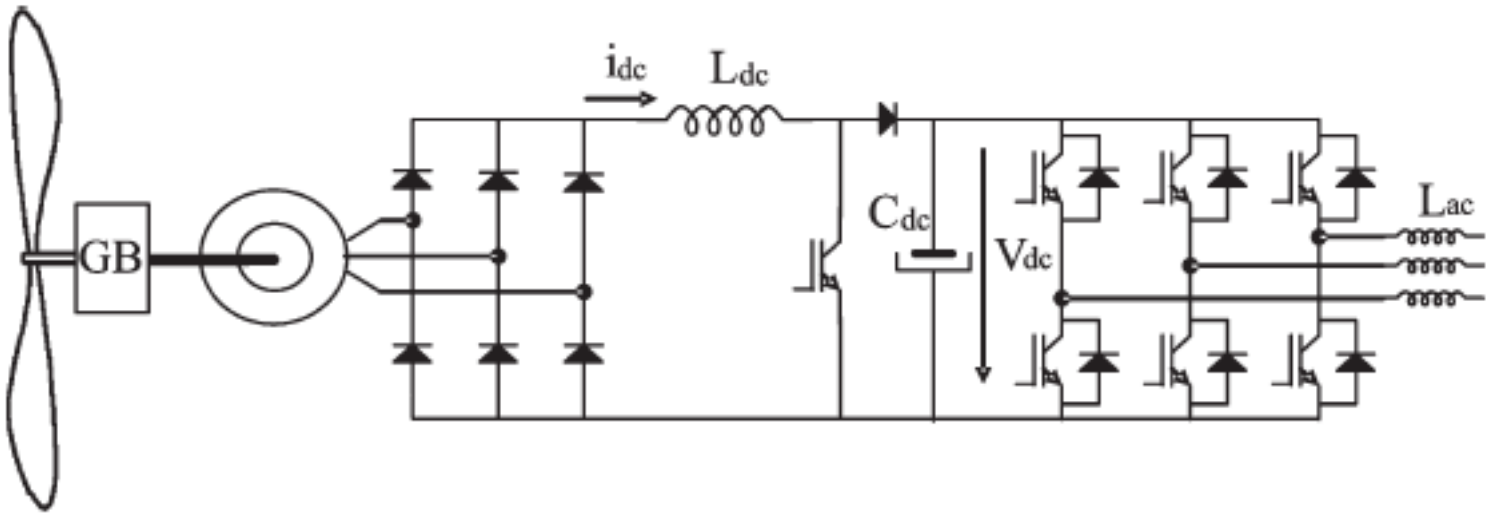
- Self-commutated converter systems, such as IGBT-based switching converters, are normally used for this type of system.
- The DFIG normally uses a back-to-back converter, which consists of two bidirectional converters sharing a common dc link, one connected to the rotor and the other one to the grid.
- The power electronic converters for variable-speed generators have the ability to control both the active and reactive power delivered to the grid.
- This gives potential for optimizing the grid integration with respect to steady-state operation conditions, power quality, voltage, and angular stability.
- The reactive power to the grid from the generation unit can be controlled as zero or to a value required by the system operator within the converter rating limit.



Single doubly fed induction machine controlled with slip power dissipation in an internal resistor.

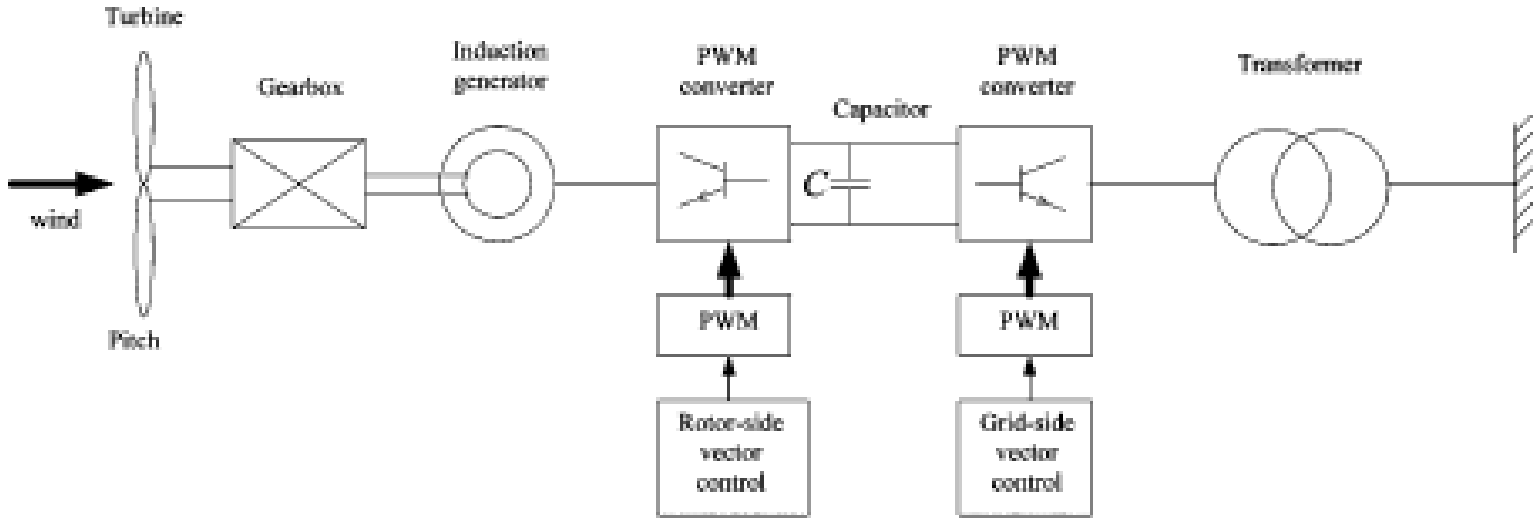


Double three-phase VSI

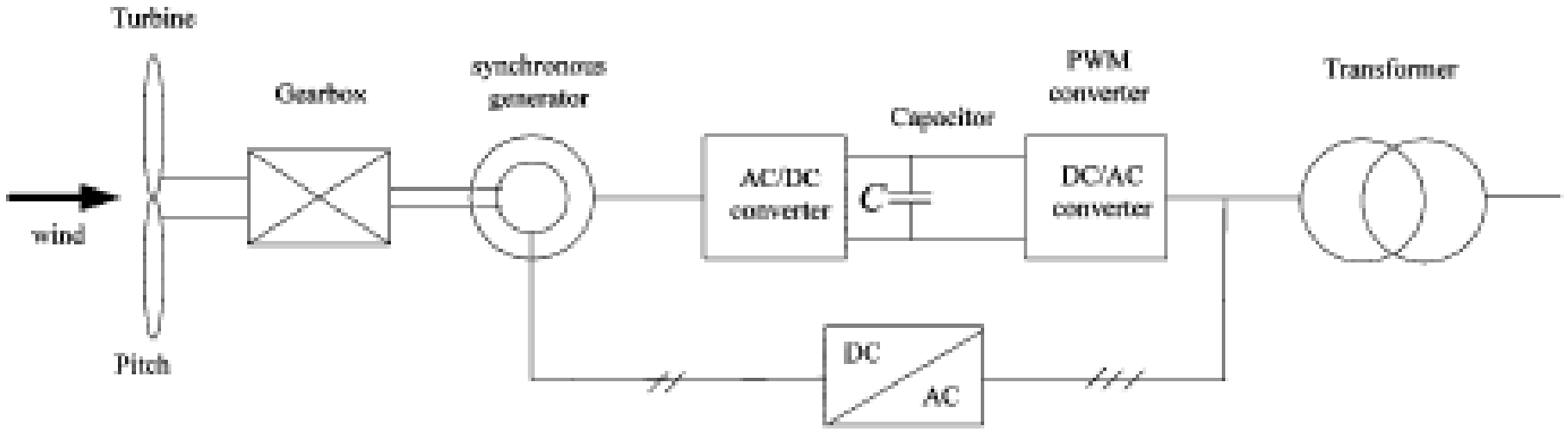


Step-up converter in the rectifier circuit and full power inverter topology used in wind-turbine applications

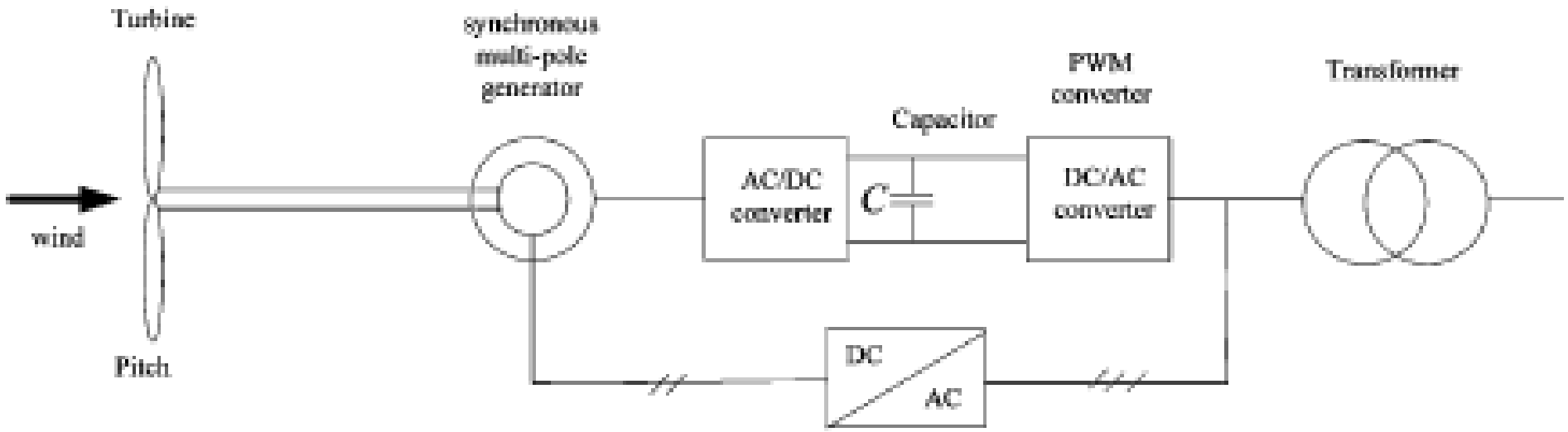
Wind Turbine Systems With Full Rated Power Electronic Converters



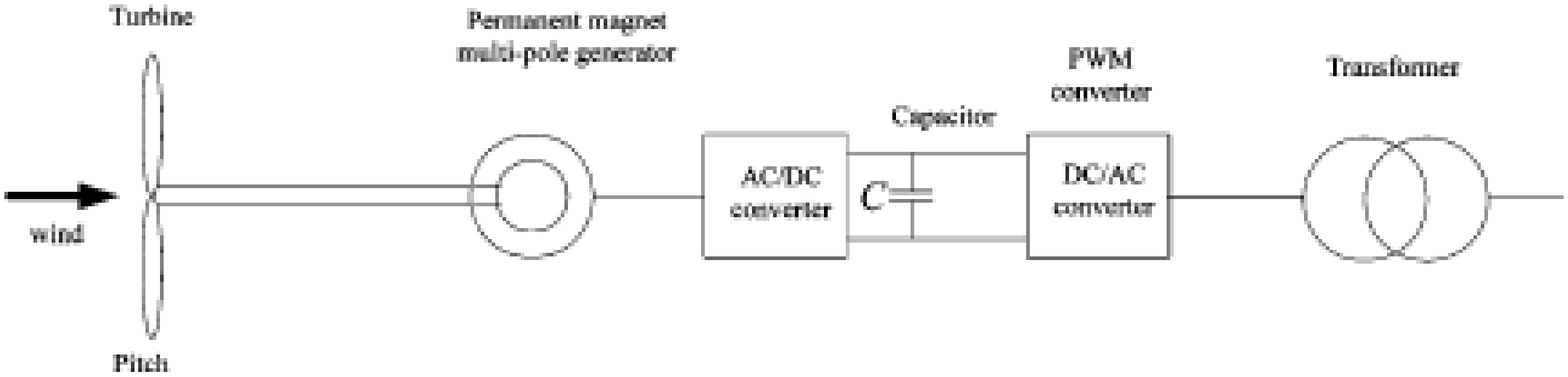
Induction generator with gear.



Synchronous generator with gear



Multipole synchronous generator



Multipole PM synchronous generator