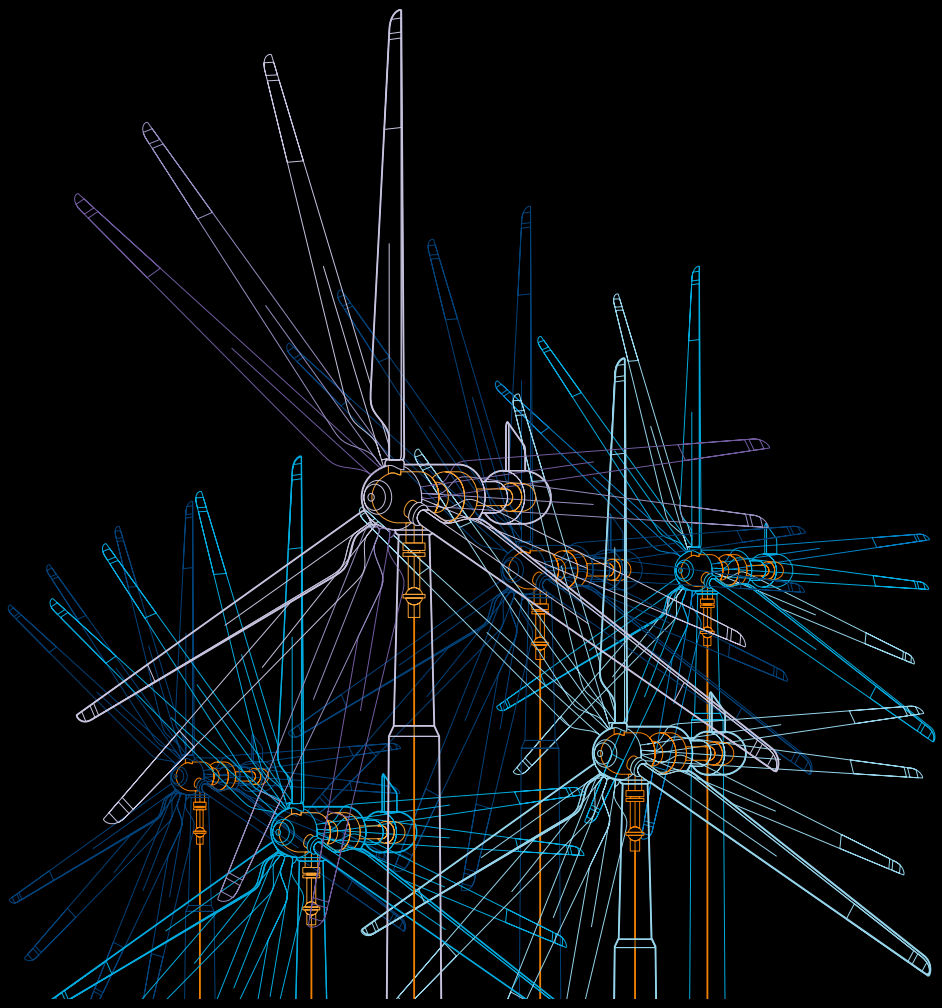


Breakers and Switches
Low Voltage Products
Protection and Control on Wind Turbine application

Power and productivity
for a better world™

ABB

Low Voltage Components in Wind Turbines

1. Introduction

Wind speed is not constant over time and rapid changes of the wind puts high demands on a wind turbine dedicated electrical and mechanical design, in order to maximize power output. For the electrical design this results in frequent operations of the control actuators (e.g. pitch adjustment) and **repeated connection and disconnection** of the power circuit with fast warm up of the conducting components as a result. In onshore installations subjected to wind gusts, it is common to reach 10-20 operations per day.

Meanwhile, the demand for **production continuity** requires high reliability during the whole life of the wind turbine. By exploiting low voltage components based on their main functional characteristics, e.g. using circuit-breakers for protection and contactors for switching, maintenance intervals can be optimized, at the same time the service continuity of the wind turbine is guaranteed, even in extreme conditions.

The need to guarantee the generated power quality during network disturbances has lately driven the definition of national grid codes. In many cases, the control of the quality of the reactive power flow under normal service conditions, as well as under disturbed conditions, calls for a **high number of operations** for the connection devices of the capacitor banks and of the filters. This continuous switching of the electrical circuits causes transient over-voltages on the components of the power and control circuits, which is also determined by the speed at which the excitation system reacts to the network disturbances.

In addition to this, also **environmental stresses**, both mechanical and climatic, have to be considered. In the nacelle low frequency vibrations are common, causing displacements, while the temperature may vary between -25°C and +50°C. In addition humidity, dust and pollution are common problems. These factors all cause a reduction in the equipment performance, and the life expectancy of low voltage components may be reduced up to 50%, compared to what would be achieved

under ideal conditions. To guarantee a reliable operation it is necessary to select conponents according to their main function and with a wider safety margin.
The wish to **minimize size and weight** due to the physical constraints in the nacelle is at the same time in conflict with the demand for high efficiency and service continuity. Trying to merge different functions into a single component and pushing its performances to the limit often leads to the detriment of its reliability in the medium and long term. Typical compromises of this kind are for instance the choice of circuit-breakers in the fixed version, which are less easy to be maintained, but offers smaller overall dimensions than the corresponding withdrawable version, or by letting the protection element (circuit-breaker) also perform the power control functions usually carried out by a contactor.
To summarize, in addition to preventing and limiting faults, the protection and control system shall be dimensioned and coordinated so that the effects of the electrical transients on the mechanical system – which accounts for around 80% of the turbine cost – can be avoided. When doing this the key points are, in order of importance:

- High switching reliability
- Reduced maintenance
- Minimized size and weight.

In the following pages the three main existing wind turbine technologies are briefly described, together with ABB's recommended solution for low voltage components:

- Asynchronous generator directly connected to the grid - Fixed Speed Induction Generator (FSIG)
- Asynchronous generator with rotor excited at variable frequency, directly connected to the grid – Doubly-Fed Induction Generator (DFIG)
- Permanent magnet synchronous (or asynchronous) generator connected to the grid through drives – Full Scale Frequency Converter concepts (FSFC).

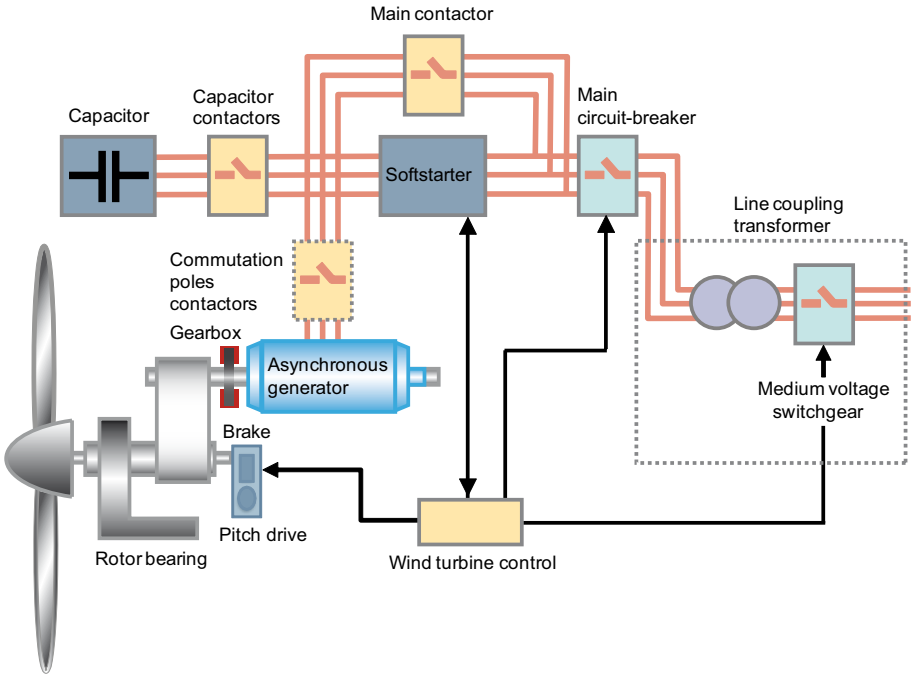
For the capacitors and auxiliary motors control system please see the paragraph 3.

Low Voltage Components in Wind Turbines

2 Main existing wind turbine technology

2.1 Fixed Speed Induction Generator (FSIG)

Brushless asynchronous generator directly connected to the grid. In this configuration, where very limited deviations from the synchronism speed are possible, the reactive power is delivered by capacitor banks, which are switched on and off relatively frequent. The start-up phase of the generator is managed through a soft starter equipped with parallel-connected contactors, which are closed once the steady state has been reached.
There is also the possibility of star-delta connection to the winding(s) of the generator for handling different wind regimes.

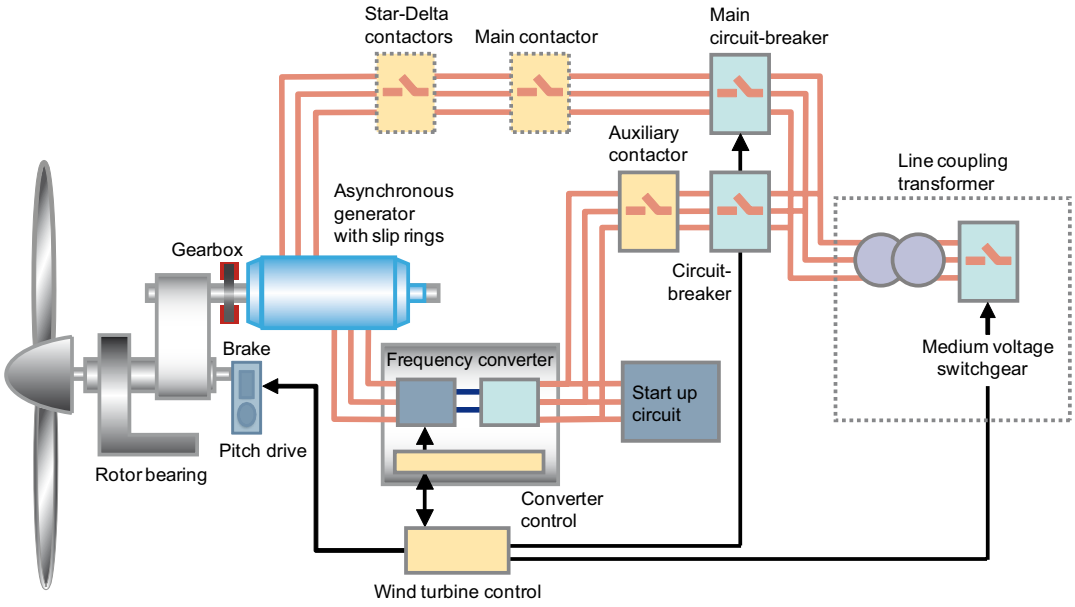


Type of circuit	Main power circuit	Main auxiliary circuit
Load current [A]	≤1800	≤320
Voltage [V]	≤690V	≤690V
Frequency [Hz]	50-60	50-60
Prospective short-circuit current [kA]	≤35@690V	
Type of load	AC1	AC3-AC6A
Presence of inrush current	no	yes
Life time [years]	20	20
Number of mechanical operations (or electrical operations at low current) to isolate the system (maintenance or out of service)	100..1000	<1000
Number of mechanical operations (or electrical operations at low current) of connection and disconnection of the generator to the network or of reconfiguration (production control)	10000..100000	not applicable
Number of electrical operations	<100 (tripping of protections or emergency stop)	<100 (tripping of protections or emergency stop)
Protection against overload and short-circuit	yes	yes
Optimum solution	**Circuit-breaker + Contactor**	**Circuit-breaker**

2.2 Doubly-Fed Induction Generator (DFIG)

Asynchronous brush generator with excitation circuit at variable frequency. In this configuration wider variations of the rotation speed of the system are possible since the excitation frequency of the rotor allows the displacements from the synchronism speed to be compensated.

In general, the excitation circuit where the power can flow in both directions is sized at 20 to 30% of the rating of the main circuit. In some cases there is also the possibility of star-delta connection to the winding(s) of the generator for handling different wind regimes.



Type of circuit	Main power circuit	Main excitation circuit	Start up circuit
Load current [A]	≤3000	≤630	≤5
Voltage [V]	≤1000V	≤690V	≤690V
Frequency [Hz]	50-60	50-60	50-60
Prospective short-circuit current [kA]	≤30@1000V	≤50@690V	≤50@690V
Type of load	AC1	AC3	AC3
Presence of inrush current	no	no	yes
Life time [years]	20	20	20
Number of mechanical operations (or electrical operations at low current) to isolate the system (maintenance or out of service)	100..1000	<1000	not applicable
Number of mechanical operations (or electrical operations at low current) of connection and disconnection of the generator to the network or of reconfiguration (production control)	1000..100000	not applicable	not applicable
Number of electrical operations	<100 (tripping of protections or emergency stop)	<100 (tripping of protections or emergency stop)	>10000 (excitation circuit insertion)
Protection against overload and short-circuit	yes	yes	yes
Optimum solution [1]	**Circuit-breaker + Contactor** (more operations per day are required) **Circuit-breaker only** (less than one operation per day)	**Circuit-breaker** coordinated with **Contactor** in parallel with the start up circuit	**Circuit-breaker + Contactor**

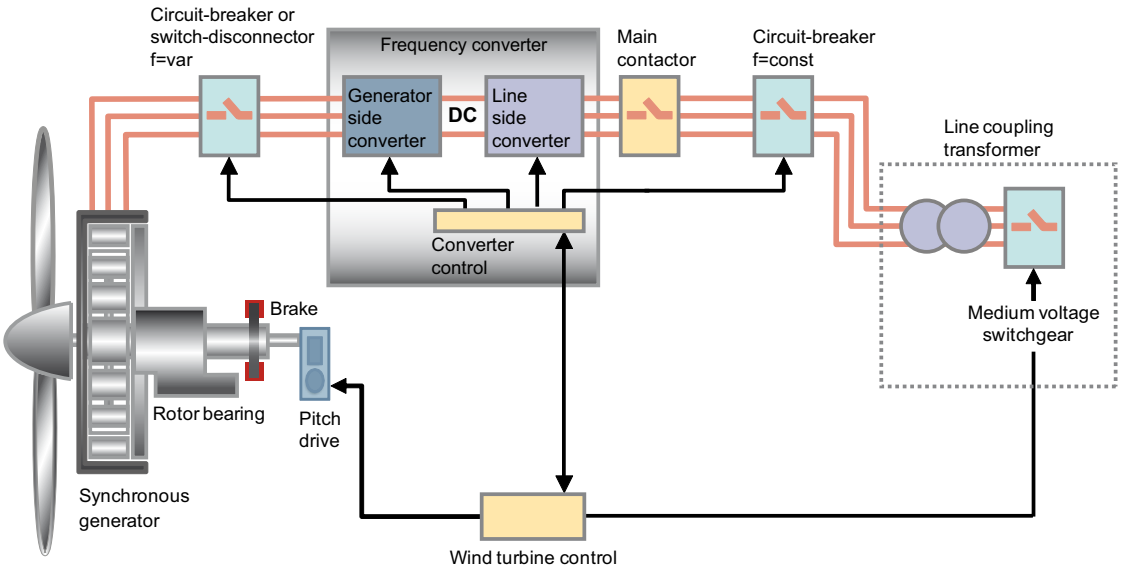
[1] **Circuit-breakers for protection of generator and cables**
ABB's air and moulded case circuit breakers offer fast and efficient short circuit protection, typically designed to handle 10.000 operating cycles at optimal conditions with hight performances.
Contactors for switching of the main generator circuit
ABB's contactors are designed to handle at least 500.000 mechanical operations, before maintenance is required.

Low Voltage Components in Wind Turbines

2.3 Full Scale Frequency Converter concepts (FSFC)

Permanent magnet synchronous (or asynchronous) generator connected to the grid through converters.

In this configuration the rotation speed may vary within a wide range since frequency variations are compensated by the converter placed between the generator and the network.



Type of circuit	Main power circuit on the variable frequency side	Main power circuit on the grid side	Main circuit auxiliary circuits
Load current [A]	≤3600 or nx700..1200	≤3600 or n x700..1200	<250
Voltage [V]	≤800V	≤ 690V	≤ 690V
Frequency [Hz]	1..16Hz 30..80Hz 40..140Hz	50-60	50-60
Prospective short-circuit current [kA]	15@800V	35@690V	
Type of load	AC1	AC1	AC3
Presence of inrush current	no	no	yes
Life time [years]	20	20	20
Number of mechanical operations (or electrical operations at low current) to isolate the system (maintenance or out of service)	100..1000	< 1000	< 1000
Number of mechanical operations (or electrical operations at low current) of connection and disconnection of the generator to the network or of reconfiguration (production control)	not available (in general the generator remains connected to the converter)	1000..100000 (according to the control strategies)	not applicable
Number of electrical operations	<500 (tripping of protections or emergency stop)	<500 (tripping of protections or emergency stop)	>500 (tripping of protections or emergency stop)
Protection against overload and short-circuit	yes if cable protection available	yes	yes
Optimum solution	**Circuit-breaker** if protection is required for connection cables or inverter input **MS switch-disconnector** if controlled by converter protections	**Circuit-breaker + Contactor** (more operations per day are required) **Circuit-breaker only** (less than one operation per day)	**Circuit-breaker**

3 Capacitor banks and auxiliary circuits

Type of circuit	Control of insertion of single capacitor banks	Auxiliary motor control/switching
Load current [A]	≤32 (but the total reactive power can reach 30 to 40% of the rated power of the generator)	≤32
Voltage [V]	≤690V (the same as the main power circuit)	≤690V (400V,480V, 600V,690V)
Frequency [Hz]	50-60	50-60
Type of load	AC6A	AC3
Presence of inrush current	yes	yes
Life time [years]	20	20
Number of electrical operations	>100000	>100000
Protection against overload and short-circuit	yes	yes
Optimum solution	**Circuit-breaker + Contactor**	**Circuit-breaker + Contactor + Overload Relay** or **Circuit-breaker + Contactor**

Contact us

ABB Oy
Low Voltage Products
P.O. Box 622
FI-65101 Vaasa, Finland
Phone: +358 10 22 11
Fax: +358 22 45708

www.abb.com/windpower

ABB SACE S.p.A.
Low Voltage Breakers
Via Baioni, 35
I-24123 Bergamo, Italy
Phone: +39 035 395111
Fax: +39 035 395306-433

www.abb.com/windpower

1SDC001018B0201 - 2010.04

ISO 9001 BUREAU VERITAS Certification

ISO 14001 BUREAU VERITAS Certification

OHSAS 18001 BUREAU VERITAS Certification

Power and productivity
for a better world™