EVOLUTION AND DEVELOPMENT OF MEDIUM VOLTAGE EQUIPMENT FOR SPECIAL WIND FARM APPLICATIONS

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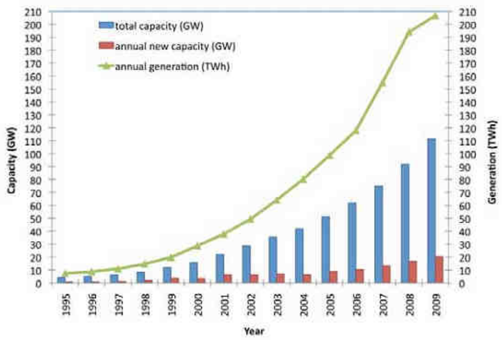
ABSTRACT

Worldwide increase of energy demand and supportive environmental and renewable energy policies have been key factors during the last decade for the renewable energies growth. Such is so, that during the years 1998-2007 the wind power installed capacity has grown each year 30,4% and international organisations are expecting similar figures of growth until the year 2030.



The expected growth of wind power along with the development of bigger wind turbines have allowed to build wind power plants in such places as in the sea, where requirements on MV equipment are very high and reliability and safety features are vital in order to guarantee the maximum continuity of supply during operation and personnel's safety while inside the wind turbine tower.

As a consequence of this new reality and particular needs, specifically designed MV switchgear has seen recent developments for this application, which operates under much harder nominal voltage, salinity corrosion, and humidity and temperature conditions than those established by IEC62271-1. This article describes the main developments within MV switchgear for this application as well as the particular type tests performed which reproduce the particular sea transport conditions all the way to the environmental conditions of operation by means of accelerated aging tests in salinity chambers, which have allowed to certify this type of MV switchgear for its use in off-shore wind farms and/or climate extreme conditions.

PARTICULAR REQUIREMENTS OF MV SWITCHGEAR DUE TO THE GEOGRAPHICAL LOCATION OF OFFSHORE WINDFARMS

Development of wind energy on a world wide scale and the construction of wind farms in very aggressive climate locations (off-shore installations, high altitudes, very low temperatures, etc…) has made necessary the re-engineering of MV equipment, which is responsible of operating and protecting the network under these conditions.

Considering SF6 full insulation technology as the best one available to face these challenges due to: compact dimensions, insensibility of the power circuit to environmental conditions, safe operation and proven reliability, the upgrade that has been made to this MV switchgear was based on three pillars:

- A new range of units 40,5 kV rated voltage, designed and tested to comply with higher insulating levels than those established by IEC 62271-200
- New designs, which are based on the consideration that the units are installed inside the wind turbine tower, will increase safety aspects in the eventual case of internal arc fault.
- The use of new materials and surface treatments which will improve resistance to the particular climate conditions of each installation.

After the design process was concluded, a specific set of type tests was implemented, which allowed to validate the new designs and materials.

Installations under very low temperature conditions

International IEC 62271-1 standard "High Voltage Switchgear. Part 1: Common specifications" establishes the normal temperature range for operation of this equipment from -5ºC to 40ºC

Meanwhile in some wind farms located in geographical places like the United States, China, Canada or Mongolia the temperature can be as low as -30ºC during operation and -40ºC while equipment is being stored. Under these conditions the operation of the driving mechanisms must be guaranteed and leakage levels from the MV gas tank do not increase.

Resistance to highly corrosive environments

IEC 62271-1 international standard for indoor switchgear states that “air must not be significantly contaminated with dust, smoke, corrosive/explosive gas, steam or salt”. The environmental conditions in any offshore wind farm obviously can not guarantee the above statement due to the high levels of salinity in the atmosphere, therefore it is necessary to apply special surface treatments for the galvanized steel elements and most important to extend the driving mechanisms lifecycle against corrosion to guarantee that it will accomplish the number of operations it was designed for inside a salinity chamber.

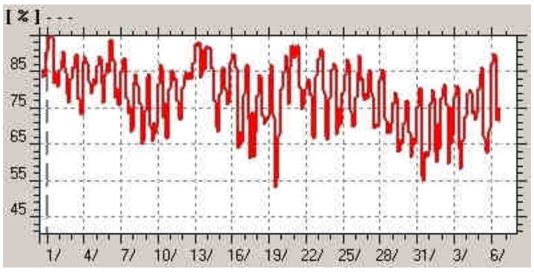


Fig. Offshore windfarm humidity data logged

The framework which establishes the resistance to highly corrosive environments and the maintenance labours is known as the EN-ISO 12944 standard. The goal was to achieve at least a C4-High classification under high corrosion levels (C4) and a long lifecycle, more than 15 years. This standard considers that the long durability concept is a technical consideration that can be helpful to the owner in order to establish correctly maintenance labours from 5 to 15 years.

Vibrations due to installation labours and transport in offshore wind farms

One of the most important parameters to be optimized during the construction of a wind farm is the installation time due to the very high costs associated from all the required resources. That’s why is very common to install the MV switchgear horizontally inside the wind turbine tower and afterwards transport the tower to the offshore platform in a special ship.

To transport the MV switchgear under these conditions adds another challenge, and the equipment must withstand horizontal forces due to the positioning of the turbine tower during the transport and in addition the vibrations that appear during sea transportation.

In order to study the behaviour under these harmful conditions of transport, simulation tools were used to establish the forces on the welding, consequences from the displacement of the centre of gravity of the equipment and a 3 dimensional horizontal vibration test to simulate all transportation conditions.

Increase on the distribution rated voltage level

The power capacity of the wind turbines as well as the total capacity of the wind farms has increased dramatically over the last years. The power capacity from the first turbines ranged in between 200 and 300 kW, while nowadays most offshore turbines have 3 MW machines and even some experimental wind farms are being developed with 6 MW machines.

In order to decrease the electrical looses within the MV wind farm’s grid, there is a clear tendency to increase distribution voltage levels, which requires higher insulating levels than those established by IEC 62271-200, which are commonly used for traditional public energy distribution. This is why a certain amount of wind farms use 40,5 kV units, which determine insulating levels of 95 kV during at least 1 minute at industrial power frequency (routine test in all compartments of the MV unit) and 185 kV for the lightning impulse test (BIL).

Labour men safety and limitation of the effects in the eventual case of internal arc

The particular position in which the MV switchgear is installed inside the wind turbine tower requires different designs in order to guarantee labour men’s safety in the case of internal arc fault. We must consider that some turbine manufacturers choose a lay out where the switchgear is installed above the ground level, making necessary an alternative design for the gas release chimney, which can not be located any longer behind the cable compartment.

Keeping in mind this requirement, the bottom of the unit was sealed (cable compartment) and a backside gas release chimney is designed, guaranteeing that nobody underneath the unit will be harmed nor anybody placed in front.

The testing of this special design was performed according to the IEC 62271-200 standard, appendix A, accomplishing a IAC AFL arc fault resistance classification for 21 kA short circuit current during 1 second.

GENERAL TESTING PLAN

Validation of new designs was achieved through a specific testing procedure, which not only accomplishes those requirements established by the IEC 62271-200 standard type tests but also accomplishes the following particular type tests:

Low temperature test

Driving mechanisms, which are constituted by mobile elements are the main devices analysed during the test. The procedure was according to IEC 62271-102 (paragraph 6.104.1), where after 12 hours inside a climate chamber with temperature -40ºC, the following must be verified:

- The three position switch operates perfectly: open, closed and earthed positions.

- Retention and tripping are verified with tripping coil under rated voltage and minimum voltage on those mechanisms used for protection function cubicles.

- It is verified that operating capacity at 85% and 110% rated voltage, registering power consumption during opening and closing manoeuvres on those mechanisms used for motorised switch-disconnectors.

Salinity chamber tests

The aim of this test is to verify the resistance of the driving mechanisms to sea corrosive conditions and that electrical and mechanical requirements are accomplished, which are tested according to ISO 12944-2 very high atmospheric corrosion conditions (up to C5-M). Therefore while the typical MV switchgear used for public distribution requires a 96 hour salinity chamber test, the aim of this new test was to achieve 720 hours successfully. The test was carried out according to the IEC 60068-2-11 standard ("Environmental test. Ka Test: Salinity fog") according to the fallowing procedure:

The test is done inside a salinity chamber where temperature is 35ºC and the fog contains a 5% amount of NaCl. The amount of fog is controlled by a special rain gauge in order to achieve a density of 1-2 cm3/h. Under these conditions the driving mechanism which operates the three position switch is introduced in the salinity chamber and every 96h, 240h, 480h and 720h the fallowing parameters are verified:

- Torque operation value (Nm), making and breaking operations and three position switch.

- Speed value (rad/s) and rebounding (mechanical degrees) for making and breaking operations are done on the three position switch.

- Consumption of tripping coils (A) and operation time in driving mechanisms associated to protection units.

- Operation time of the MV fuse tripping chain.

- Insulation test on all auxiliary circuits

- Steel elements visual corrosion analysis.

Fig. Driving mechanism after 720 hours salt-fog test

Once all these tests have been passed and completed a time cycle of 720 h in a salinity chamber test we can assure that these devices are classified under a C4-High (applicable C5-Medium, marine) category and are suitable for offshore applications under very high corrosive conditions.

Vibrations test

With the purpose of keeping to a minimum value the time installation and operations while at the offshore platform, the MV switchgear is usually installed in a horizontal position inside the turbine tower and transported in this same position to the platform. Under these conditions, units must resist new forces due to the transport position and the vibrations due to sea tide.

Values under which these tests were performed to a group of 3 modular functional units where obtained attending to

EN 22247 "Packaging – Complete, Filled transport packages – Vibration test at Fixed Low Frequency" , applying a 4Hz frequency value and an acceleration of 0,875 sc with an maximum amplitude of 27,2 mm.

Fig. MV switchgear on vibrations testing platform.

After the test was performed, the copper circuit resistance was measured in order to verify that the values did not change from those prior to the test, all joint connections, screw drive connections and the welding where also verified to successfully overpass the test.

40,5 kV dielectric tests

The validation of the range of units rated at 40,5 kV was base don the fallowing tests:

- High voltage test at power frequency 95 kV ac during 1 min, where the main circuit insulation level is verified in between phases and in between phase-earth as well as for the three position switch. Achieved for the 118 kV insulating distance.

- Lightning impulse test at 185 kV (215 kV at the insulating distance), the unit was applied 15 positive impulses and 15 negative impulses according to a 1,2 / 50 µs waveform.

- Making and breaking test of the main switch, based on IEC 60265-1, achieving 100 full active power disconnections (E3 category, Maximum) and resisting a transient recovery voltage of 69,4 kV.

Internal arc tests

Test performed according to IEC 62271-200 standard, appendix A, which is suitable for equipment only accessible to qualified personnel (accessibility type A) and front and lateral access (accessibility FL) being performed in all MV compartments of the switchgear. Short circuit value 21 kA and duration of arc 1 second.

Criteria to evaluate results of the test as follows, according to mentioned IEC standard annex:

1) Cable compartment doors and remaining structure of the unit remained closed.

2) Enclosure of the unit did not break itself into any parts; neither did it eject any pieces of more than 60 grams.

3) Arc did not perforate any accessible part below 2 meters high.

4) Testing clothes did not burn at any time due to the hot gas release during the fault.

5) Enclosure remained safely earthed after the test was performed.

CONCLUSSIONS

The continuously developing wind energy technology and the progressive construction of new wind farms in places where the operational requirements are very high due to salinity, temperature or humidity, require MV switchgear adapted to those particular conditions. This case study has concluded with the implementation of special solutions for the MV switchgear used in these kind of environmental conditions, this new product range, based upon the use of new surface treatments, materials, new designs to accomplish IAC internal arc fault resistance within different installation levels inside the wind turbine tower and new insulating levels of 40,5 kV, have been certified through a whole set of type tests which at the end offers us a new family of fully insulated MV switchgear that fully satisfies the international standard IEC 62271-200 and those special requirements needed for best performance in wind farms which are operating under very harsh climatic conditions.

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