36 KV VACUUM CIRCUIT BREAKER PANEL
- THE PERFECT SWITCHGEAR FOR WIND

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ABSTRACT
For the wind industry, generator ratings in turbines are often above 2 MVA. Typically large wind farms are built and connected via a common transformer to the collection grid. Such high energy input in the network should preferably be done at a voltage higher than 24 kV. In large wind farms the optimum voltage level can be selected as the installation is new and is connected to the collector system. For these new installations, 36 kV is a good candidate. To make a cost optimized connection to the transformers in the wind towers, special switchgear components are required. To secure a good fit of components for wind towers, special requirements in the wind segments must be included when new products are developed. For ratings above 2 MVA, circuit breaker is often the preferred transformer protection. Circuit breaker panels must therefore be designed with dimensions suitable for wind tower doors. This requires a slim design to allow easy handling through narrow wind tower doors. To secure a good fit of circuit breaker panels for distribution networks and wind farm applications, personnel safety and service continuity are critical success factors.

INTRODUCTION
As the wind turbine size has increased during the last decade, the rated voltage level in wind farms has also increased from 24 to 36 kV. The most optimum/economic voltage level is now 36 kV for large wind farms with big wind turbines. New products tailor-made for wind farm applications with functional units designed to fit in the wind segment have recently been launched by several switchgear manufacturers. Circuit breaker panels and switch-fuse combinations are available to protect the cable and transformer of each wind turbine. Switch-disconnector panels or direct busbar connections can be used to connect the wind turbines to the “network”. These panels can be supplied either as single extendable panels with a busbar extension or as a compact switchgear where the panels are supplied in one piece and the switch functions are mounted in one common gas enclosure which also has internal bus bars between the panels. The panel width is critical due to the wind turbine door dimension. The “answer” is a fully modular switchgear concept with busbar extension for connections between the different modules. “Sealed-for-life” gas-insulated and metal-enclosed equipment virtually guarantees a maintenance-free installation with high reliability, even in environments polluted with humidity or dust as the pollution can not directly access high voltage parts. These products are also typically type tested according to the new IEC 62271-200 requirements ensuring high operational safety. This paper will focus on the current market situation, future trends, technical solutions used, the inventive steps as well as the flexibility of switchgears for wind farm applications.

MARKET
Rising energy demands and its impact on the environment are some of the big challenges of the 21st century. Wind power has a huge potential in countries where other renewable energy sources are limited, and therefore it is an important source if suppliers are to fulfil their obligations to increase the production of renewable energy. With an annual growth rate of more than 20%, wind power is the fastest growing sector of the renewable energy industry. At the end of 2007, a total of 94 GW of wind power had been installed globally. Out of this 1 GW was attributed to offshore installations.

Planned investments in renewable energy
From a global perspective an annual growth rate of 16% in renewable energy is expected up to 2013. The current global economical downturn is expected to have limited effect on the wind power industry as it is largely driven by well capitalised investors with the ability to finance investment on their balance sheets. In fact several countries are aiming for a large increase in renewable energy [1], [2].

Wind grid setup
In a wind farm, the switchgear is used mainly in network switching and to protect the system against possible electrical failures. To protect the step-up transformer, a switch-fuse combination or a circuit breaker cubicle is used, depending on the power of the transformer. Tailor-made switchgears for wind farms can be equipped with a direct incoming cubicle without a switching function, optionally equipped with an earthing switch, and switchgear with metering cubicle. As wind farms are no longer considered “negligible” by the grid operating companies, smart solutions are needed. The manufacturers are working hard to develop efficient and reliable product solutions for a rapidly changing market. For a wind farm application, this typically means compact gas insulated switchgears. With continuously increasing wind turbine ratings, now often above 2 MVA
and therefore increased transformer ratings, circuit breakers are typically required.

**Special wind requirements**
A typical challenge for switchgears in wind farm applications is the restricted space, such as in compact substations and tower installations. For tower installations, small physical dimensions are critical to allow components to be replaced inside the tower. The tower door limits what components can be placed inside. This is a very challenging requirement to fulfil for metal enclosed switchgears.

Often the switchgear and other electrical systems are placed on the concrete foundation and afterwards the wind tower is mounted over the installation. Pre-defined configurations, including the busbar connections can be assembled in the factory. Factory assembled and tested busbar connections not only allow for quicker installation but the risk of failure during the on-site installation is minimized. Wind farms by nature are generally located in harsh operating environments. A completely sealed system where all live parts and switching functions are protected in a stainless steel enclosure ensures climatic independence, high reliability and a long life-span.

**TECHNOLOGY OF 36 KV VACUUM CIRCUIT BREAKER PANELS**

During the development phase of new 36 kV switchgear components, wind farm requirements should be taken into account to secure future fit in wind farm applications.

**Slim design – a challenge to achieve**
Inside the wind tower, the space available for the switchgear is limited and the transportation inside the tower may be complicated. A slim design is therefore favourable for easy handling and installation. In addition, the narrowest wind tower doors are only 500 mm wide and the panel or its replacement must be able to fit through such a door, as shown in Figure 1.

A slim switchgear design introduces the possibility of installing the switchgear after the tower has been constructed as well as a simplified future replacement or extension of the switchgear. This is challenging targets for a 36 kV circuit breaker panel.

Normally, the breaker poles are placed side-by-side for 36 kV gas insulated circuit breaker panels. A significant reduction in the panel width can be achieved by arranging the poles in the depth of the panel as shown in Figure 2.

![Figure 2: Side view of circuit-breaker panel with poles arranged in depth](image)

![Figure 3: Dielectric simulation of vacuum circuit breaker poles](image)
Flexibility for wind
Switchgears used in wind farms require different panel types which can be flexibly combined with few restrictions to form complex switchgear arrangements. A typical wind grid setup, as shown in Figure 4, can be comprised of different switchgear arrangements that use either modular or compact panels or a combination of both.

Figure 4: Typical wind grid setup

In Figure 4, the numbers 1, 2 and 3 refer to the different switchgear configurations as shown in Figure 5.

Figure 5: Typical switchgear arrangements

In Figure 5, the symbol “C” is used to designate a cable panel. The cable entering this panel is connected to the next wind turbine. This panel has a switch-disconnector and an earthing switch. The symbol “V” is used to designate a circuit breaker panel. The cable entering this panel is connected to the wind turbine. This panel has a vacuum circuit breaker, a disconnector and a downstream earthing switch. The symbol “<>” is used to designate a direct busbar connection. In a wind farm the cable from the previous wind turbine is connected directly to the busbar at this point of connection. Finally the symbol “+” is used to designate a busbar extension for modular switchgears.

Personnel safety
The vacuum circuit breaker panel needs a disconnector connected in series with the vacuum interrupter. By arranging the earthing switch downstream, as can be seen in Figure 6, it is not necessary to close the circuit breaker again after the earthed position has been selected as is the case for panels with an upstream earthing switch. Downstream earthing switch is therefore an important safety advantage as operators may forget to close the circuit breaker after selecting the earthed position.

Figure 6: Single line diagrams for alternative circuit breaker panels. The left one with upstream earthing switch and the right one with downstream earthing switch

The downstream earthing switch must be designed and tested with full short circuit making capacity according to IEC 62271-102 class E1/E2 (2/5 short circuit making operations). Upstream earthing switches are normally class E0 (0 short circuit making operations) as the making duty is taken care of by the circuit breaker.

For optimum operator safety, switchgears for wind farms should be fully tested and IAC classified according to the new IEC 62271-200 requirements.

FUTURE – TREND FOR OFFSHORE WIND
Twenty-six offshore wind projects with an installed capacity of roughly 1,200 MW are now in operation in Europe. Most of these projects are installed in water depths of less than 22 m. However, one demonstration project in Scotland is installed at a depth of 45 m. Although some projects have been hampered by construction overruns and higher-than-expected maintenance requirements, projections show strong growth in many European Union (EU) markets.
For example, it is estimated that offshore wind capacity in the United Kingdom will grow by 8,000 MW by 2015. Similarly, German offshore development is expected to reach 5,600 MW by 2014 (BSH; BWEA). As a consequence of this trend a better understanding of the harsh climate conditions in offshore wind farms and its influence on switchgears will be required. It is often mentioned that the switchgear will be installed in a controlled environment inside the offshore towers. But is the environment similar to an indoor environment onshore? Is condensation and dripping water possible inside the towers? To what extent can sea water and salt enter the tower? For switchgear manufacturers to design and adapt switchgears for such applications it is necessary for wind turbine and tower manufacturers to define these controlled environments very precisely.

CONCLUSION
To design a 36 kV vacuum circuit breaker panel perfect for wind, requirements in wind farm applications must be taken into account such as slim design, flexibility and personnel safety.

It has been proven that it is possible to design switchgears well suited for fitting through the narrowest wind tower doors by utilizing dielectric simulations. This allows easy handling and installation as well as future extension or replacement of the switchgears placed inside the wind tower.

REFERENCES