The new Philosophy for Grid Connection in some of the European Countries and how to verify the behaviour of Wind Farms

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Summary:

In the last few years the philosophy for grid connection of (large) wind farms changed in some, but important countries. The new philosophy is, that wind farms shall support the grid, especially in case of grid faults. New guidelines, like in Denmark, Germany and UK, are established. This paper gives an overview of the new utility guidelines and shows differences of the guidelines of the different countries. The focus is given on the procedures, how to check wind turbines and wind farms concerning these new requirements, with the aim to initiate similar procedures and to start discussions also in the other countries. The aim should be to harmonise the new requirements of the utility guidelines as far as possible as well as the procedures for the verification and certification of the wind turbines and wind farms concerning these new guidelines.

1 Introduction

The new philosophy for grid connection of wind farms, to support the grid in case of grid faults and to help to keep the voltage and power stable, is laid down in some national guidelines, e.g. in Denmark, Germany and UK. Due to the fact that these guidelines are not harmonised the manufacturers of wind turbines must have special versions of there wind turbines for each country, sometimes for each part of a country.

Up to now the new utility guidelines are established in countries with, let's say more industrial strong grids with already high penetration of wind energy. But the new philosophy of these guidelines would also be usefull in other countries with weak grids. Here the wind farms could help to support and to stabilize the grid as well.

One of the main problems of course is to ensure that wind farms will keep the new requirements. Therefore in Germany a new guideline was established, which gives procedures how to check the behaviour of the wind turbines and wind farms concerning the new requirements. In some cases this verification can be performed as a type certification at a single wind turbine. Other items must be checked at the whole wind farm for each specific installation. The behaviour of the wind turbines during large voltage drops, which is one of the requirements of the utility guidelines, can only be checked on a generator test stand. Partly the already existing procedures must still be improved. But the existing procedures in Germany could be a base for similar procedures or for common procedures for the verification of the wind farm behaviour concerning the requirements in other countries.

2 Requirements

Within the last few years new guidelines of grid operators were established in many countries. The main aim of these guidelines is, that wind farms shall support the grid. Some of these countries with new guidelines are:

- Germany
- Denmark
- UK
- US
- Australia

In Germany there are three new guidelines from VDN (association of grid operators), E.ON and Vattenfall.

The main requirements of these guidelines are as follows:

- Limits for voltages in a wide voltage range, depending on the voltage level of the grid connection point.
- Limits for frequencies: the wind farm shall operate down to about 47.5 Hz and up to 51.5 Hz. In case of overfrequencies the output power must be reduced.
- Active power reduction is required in case of extreme grid situations.
- Reactive power control: Wind farms shall control reactive power or the power factor within a wide range (inductive and capacitive).
- Fault ride-through: in case of short voltage dips the wind turbines shall not be disconnected. They shall support the voltage during the grid fault by generating reacting power.
- Power quality limits, e. g. for flicker, harmonics, voltage changes, are also required.

All the requirements are in general valid for the grid connection point of the whole wind farm.

2.1 Reactive power

The requirements concerning reactive power in some countries is given in figure 1. Reactive power is required in the inductive range as well as in the capacitive range. Figure 1 gives the requirements of some of the guidelines of the grid operators. In general the

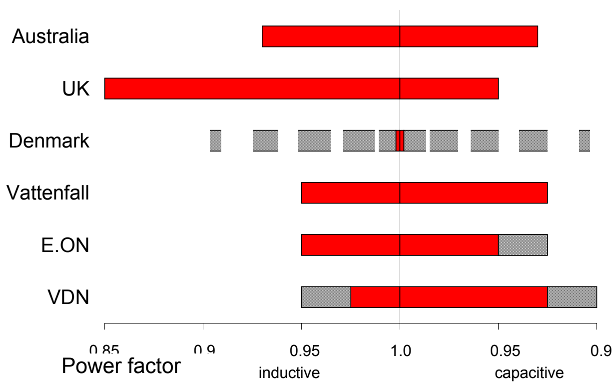

Figure 1: Reactive power requirements of some of the guidelines.

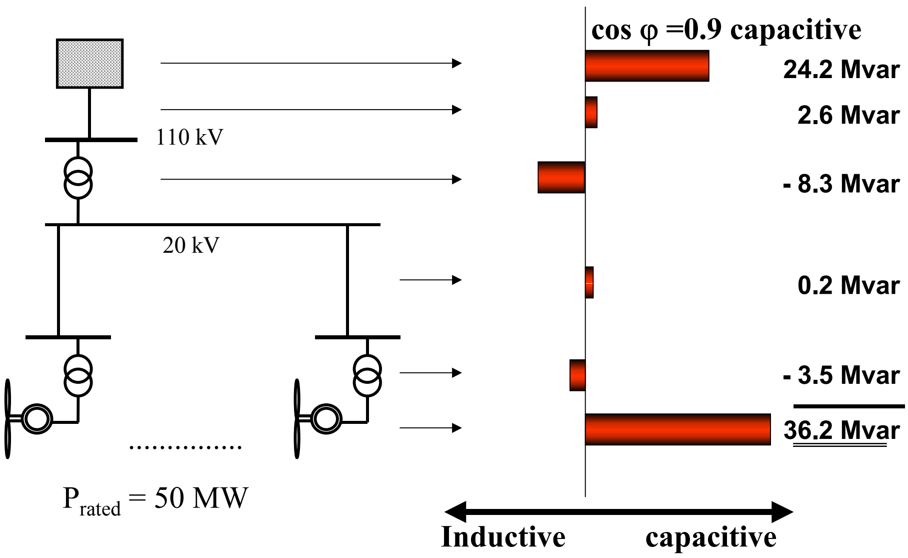

Figure 2: Simulation of a wind farm of 50 MW rated power. The reactive power of the transformers and cables are given as well as the reactive power to the grid for a power factor of 0.9 capacitive and the reactive power, which must be generated by the wind turbines.

requirements are within the range of power factor of 0.9 capacitive and 0.9 inductive. In Denmark the wind farm shall have a power factor of 1.0, that means no reactive power, but if the wind farm is able to have a power in the inductive or capacitive range, this can be used.

In some countries the grid operator gives an online signal to the wind farm, specifying the power factor or the amount of reactive power, which the wind farm shall have. This specification of the grid operator varies with the actual grid situation within the given range of figure 1. Another possibility is, that the reactive power depends on the actual voltage, which means a voltage control. In other countries the reactive power, which the wind farm shall have, may be fixed or time dependent.

The amount of reactive power of the wind farm, which is fed into the grid, is different from the amount of reactive power of the wind turbines and of possibly capacitor banks, due to the influence of the cables and of the transformers within the wind farm. Cables behaves capacitive, transformers behaves inductive. Especially the transformer at the substation from high-voltage to me-medium voltage needs a lot of inductive power. An example of the reac-reactive power of a wind farm is given in figure 2. The wind farm has a rated power of 50 MW and is equipped with several wind turbines, connected to a 20 kV medium voltage. The wind farm is connected to the 110 kV high-voltage system by the substation. The transfomer of the substation needs a reactive power of 8.3 Mvar inductive and the transformers at the wind turbines needs 3.5 Mvar. The cabling at the medium voltage system within the wind farm only has low influence on reactive power. But a possible cable at the high voltage system gives a certain amount of capacitive reactive power, depending on the length and on the type of this cable. To have a power factor of 0.9 capacitive of the wind farm at the grid connection point, which means an amount of reactive power of 24.2 Mvar, the wind turbines or possibly capacitor banks must generate a reactive power of 36.2 Mvar. The difference between these two numbers is the influence of the transformers and of the cabling. The reactive power, which must be generated by the wind turbines or possibly capacitor banks, is depending on the actual active output power of the wind farm. This dependency is given in figure 3, where the reactive power of the wind turbines of the above example is given as well as the reactive power, which is fed intor the grid for a power factor of 0.9 capacitive and for 0.9 inductive.

2.2 Fault ride-through

The requirements of the grid operators concerning the fault ride-through during voltage dips gave the main discussions between manufacturers of wind turbines and grid operators. The requirements for some of the countries are given in figure 4. For a voltage dip at the grid connection point above the curves given in figure 4, the wind turbines are not allowed to switch off. It must be taken into account, that the voltages directly at the wind turbines are in general higher than at the grid connection point due to the influence of the transformers and cables. Thus a voltage dip down to 15% of nominal voltage at the grid connection point could mean a voltage dip down to about 30% at the wind turbines.

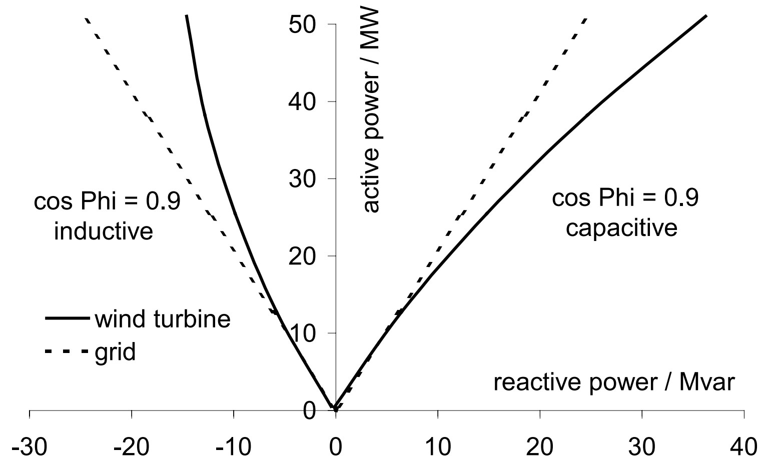

Figure 3: Reactive Power for a power factor of 0.9 capacitive of the wind farm with a rated power of 50 MW. The broken curve gives the amount of reactive power, which is fed into the grid. The other curve gives the amount of reactive power, which must be from the wind turbine ore from capacitor banks.

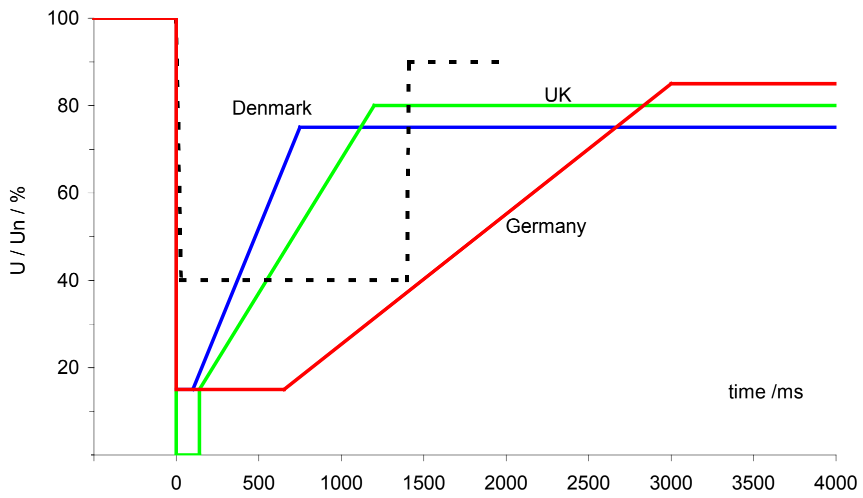

Figure 4: Fault ride-through: In case of voltage dips, above the given curves, the wind turbines are not allowed to switch-off.

3 Verification of the Requirements

There are several new guidelines of grid operators with the above requirements. But in many cases it is not clear how to verify the behaviour of the wind farms, to ensure that the wind farms fulfil the requirements. There is one new guideline in Germany [6], giving procedures, how to verify the behaviour of wind farms.

Depnding on the type of wind turbine the verification can be done at a single wind turbine, like a type certification. Or it must be done at each wind farm project.

This guideline gives procedures as follows:

Voltage and frequency limits:

This can be verified like the conventional testing of the grid protection. A three-phase voltage will be given to the grid protection device or the control of the wind turbine. The voltage and the frequency will be varied, to check the release levels and the release times. This test only verifies the control of the wind turbine. It does not verify, if the whole wind turbine is really able to run at the given voltages and frequencies. It must be taken into account, that the voltage range at the wind turbine can be different from the voltage range at the grid connection point due to possibly tap changers at the substation.

Reactive power:

The capability of the wind turbine concerning reactive power can be measured by two measurements. At the one hand the wind turbine must produce as much capacitive reactive power as possible. This reactive power is measured over the whole active power range of the wind turbine. At the other hand the wind turbine is set to behave as inductive as possible. This is also measured over the whole power range. As a result of the measurements the wind turbines reactive power capability over the whole power range is measured. But it must be taken into account, that also transformers and cabling influence the reactive power of a whole wind farm (see before). This must be calculated and simulated for each wind farm project.

Active power reduction:

The wind farm shall reduce active power in case of extreme grid situations. Therefore the grid operator gives an online signal to the wind farm, specifying the maximum amount of active power. The verification of the behaviour of the wind farm or of the wind turbine can be done by giving a set-point value to this input of the wind farm or wind turbine. By varying this set-point value, the capability of the wind turbine or wind farm can be measured in the range from 100% to 0%.

Fault ride-through

The verification of a wind turbine concerning the fault ride-through is most difficult. The best would be to have a real voltage dip within the grid and to measure the behaviour of the wind turbine on this voltage dip. But nobody can wait for a voltage dip, which goes down to about 15%. They are too rare in the real grid. Thus there are the following other solutions:

Real wind Turbine

The verification at the real wind turbine can only be done by forcing a voltage dip in the grid. But this voltage dip shall only be seen by the wind turbine, but not in the rest of the grid. Thus inductive impedances must be inserted in the grid in front of the tested wind turbine. This allows to make a short circuit directly at the connection point of the wind turbine, but the rest of the grid is decoupled by the inductive impedances and only sees a small voltage dip of only a few percent.

To perform such a test a lot of expensive equipment is necessary and it needs a lot of effort. The impedances must be inserted into the grid, the short circuit must be created (may be thyristor controlled) and the grid must be stiff enough to avoid large voltage dips in the rest of the grid. Thus it is obvious that this can not be a standard test. At the other hand the wind turbine only sees a very week grid due to the inserted impedances. Thus the behaviour of the wind turbine may be different.

Test bench

The generating system of the wind turbine including possibly inverter systems can be installed at a generator test bench. A short circuit at the generating system can be created thyristor controlled, giving the voltage dip. Or the voltage dip can be created by switching transformers.

This more practicable test is required by [6] and a procedure for this is given in the guideline. But it must be taken into account, that only the generating system is tested, not the whole wind turbine with it's dynamic effects.

Simulation

Another possibility to verify the behaviour of a wind turbine are simulations. This is for example required in Denmark. By simulations you can test each situation of the grid, also very extreme situations. Also the guideline [6] allows simulations in case there is a test at a test bench at the same type of generating system, but with different rating. In general manufacturers of wind turbines have simulation models of their wind turbines. But the main problem of course is the verification of the simulation models.

Event logging

To verify simulation models in Denmark wind turbines are equipped with measurement systems, which continuously measure relevant parameter of the wind turbine and of the grid. In case of real voltage dips the behaviour of the wind turbine on this voltage dip will be measured and thus give a base for the verification of simulation models.

4 Conclusion

The new requirements of the grid operators, regarding the support of the grid by wind farms, will be more and more relevant in many countries. It will be important not only for strong grids, it may be more important for weak grids. In all cases, where wind energy has a relevant influence on the grid, such requirements are important.

The verification of the behaviour of the wind farms and wind turbines is in some cases relatively difficult, for example for the fault ride-through. Simulations will help for the verification.

A standardisation of the requirements of the grid operators would be most welcome. But due to the different situations in the grids, a standardisation of the requirements will be very difficult or impossible. But it seems that a standardisation of the procedures for the verification of the behaviour of the wind farms and wind turbines may be possible. An actual discussion of this standardisation is just going on at the working group of the IEC61400-21 guideline.

5 Literature

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