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PROVISION OF ANCILLARY SERVICES WITH VARIABLE SPEED WIND TURBINES

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Abstract. In recent years, the amount of wind turbines in the power system has increased tremendously. As the current wind turbines do not participate in the provision of ancillary services such as frequency and voltage control, this may compromise the proper functioning of the electric power system. However, since modern wind turbines are equipped with a power-electronic converter, they can assist in the provision of these ancillary services. To achieve this, additional control loops have to be added to the wind turbine controller. In this paper, an overview of the different ancillary services is given. The ability to provide them with wind turbines is discussed. Since frequency and voltage control are the most important, these two services are further elaborated. It can be concluded that wind turbines are suited to provide frequency control, especially when they are operated slightly below their maximum power point. They can also assist in voltage control, while operation in the maximum power point is usually possible, so few energy is lost. These are important outcomes, since wind turbines which provide ancillary services can contribute in allowing a higher penetration of renewable energy in the power system without compromising its proper functioning.

Keywords: Ancillary services, frequency control, inertial response, voltage control, wind energy.

INTRODUCTION

In recent years, global environmental concerns have led to an increased use of wind turbines in the electricity production. This increase in wind power penetration raises concerns about the secure and reliable operation of the power system. Due to varying wind conditions, fluctuations in the output power of the wind turbines arise. Consequently, conventional units have to maintain additional reserves to cope with unexpected drops in the wind speed. Also, difficulties with frequency control may arise with increasing wind penetration levels, as variable speed wind turbines have little inertial response and do not participate in primary frequency control. Today, ancillary services such as frequency and voltage control are almost solely provided by conventional units, which is an unsustainable situation with increasing renewable energy penetration levels.

However, by using an appropriate control for the wind turbines, wind turbines are able to provide part of the ancillary services. In this paper, a short overview of the different ancillary services is presented. Frequency control and voltage control are discussed in detail. Then, the ability to provide frequency and voltage control with wind turbines is elaborated.

OVERVIEW OF ANCILLARY SERVICES

Besides frequency and voltage control, there exist other ancillary services such as congestion management, improvement of the power quality, black start, etc. Here, only frequency and voltage control are discussed.

Frequency control

As electricity cannot be stored easily in large quantities, the production must always equal the consumption. This balance guarantees a stable operation of the electric grid at a constant frequency of 50 Hz. To maintain the balance between production and consumption frequency control is needed, which consists of primary, secondary and tertiary control.

Primary control maintains the balance between production and consumption when a deviation (e.g., loss of a power plant) occurs. The power output of the generators is automatically increased by means of a droop controller. After the activation of the primary control, the power balance is restored at a frequency deviating from the nominal value. Secondary control is then activated to restore the frequency back to the nominal value. Tertiary control restores the operating reserves that are needed to provide primary and secondary control.

Voltage control

Another important ancillary service is voltage control. To ensure a proper functioning of the devices connected to the grid, the voltage level has to be maintained within a narrow band around the nominal value.

Contrary to the frequency, voltage is a local issue. Therefore, voltage control is strongly dependent on the characteristics of the grid where the generator is connected to. In high-voltage (HV) grids, there is a strong linkage between reactive power and voltage, whereas in low-voltage (LV) grids active power and voltage are closely linked. In medium-voltage (MV) grids, there is no decoupling between active and reactive power, so both have an impact on the voltage level.

Voltage control also consists of three different stages: primary, secondary and tertiary control, but only primary voltage control is widespread. For primary voltage control, usually a local droop controller is used.

FREQUENCY CONTROL WITH WIND TURBINES

Emulated inertial response

An important difference between frequency control in directly-coupled synchronous generators (SG) and variable speed wind turbines (VSWT) is the inertial response. In an SG, kinetic energy from the rotor is released in case of a frequency dip due to the coupling between rotational speed and grid frequency. In variable speed wind turbines, the rotational speed of the generator is usually decoupled from the grid frequency by means of a power converter. Consequently, the stabilising effect of this so-called inertial response is absent in VSWTs.

However, an additional control loop can be added to the wind turbine converter to emulate an inertial response. In case of a frequency dip, additional power is injected in the grid to mimic the inertial response of a synchronous generator. In this way, the behaviour of VSWTs and SGs in case of a disturbance is the same [1].

Primary frequency control

To achieve primary control with a wind turbine, a droop controller has to be added to the wind turbine controller which is similar to the droop controller of a conventional SG. Decreasing the power output is always possible, whereas increasing the power output is much more difficult due to the operation in the maximum power point. In order to be able to increase the power output in case of a frequency dip, power reserves have to be maintained. One option is to operate the wind turbine slightly below the maximum power point by means of speed or pitch control. A second option is to add storage to the wind farm.

VOLTAGE CONTROL WITH WIND TURBINES

Reactive power delivery capability

Especially in MV and HV grids, reactive power delivery capability is an important aspect of voltage control. Due to the power-electronic converter, variable speed wind turbines are able to inject or absorb a considerable amount of reactive power over a large range of operating points [2].

Primary voltage control

As already mentioned, primary voltage control is usually achieved by means of a local controller. Due to the differences between low-, medium- and high-voltage networks, they are discussed separately.

Voltage control with wind turbines in HV grids is equal to voltage control with conventional generators. The wind turbines measure the terminal voltage and change their reactive power output accordingly by means of an automatic Q/V droop controller. As long as the current does not exceed the rated current, wind turbines are able to provide reactive power and voltage control can be regarded as a “free” service.

In LV grids, usually overvoltage occurs when wind turbines are connected due to the strong linkage between active power and voltage. Hard curtailment is often used to tackle this problem. However, soft curtailment (P/V droop control) may result in lower energy yield losses.

In MV grids, at first instance, reactive power is controlled to solve the voltage problem. Only if this is not sufficient, the wind turbines are curtailed. A more advanced method uses a combination of both P/V and Q/V droops. Coordination of both droop controllers is essential to avoid unnecessary loss of renewable energy.

CONCLUSIONS

From this paper, it can be concluded that wind turbines are suited to provide frequency control, especially when they operate below their maximum power point. Furthermore, voltage control can also be provided, usually without much renewable energy yield losses.

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