УДК 621.311

COMMON APPROACHES ANALYSIS OF WIND POWER INTEGRATING INTO THE GRID

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***Summary* – the basic problems of the integration of wind power into the grid was revealed, a number of requirements for wind power plants was proposed for their stable operation in the grid.**

***Keywords* – grid, wind power plant (WPP), integration, transmission network, grid connection requirements.**

Problem formulation. Grid integration of wind power plants (WPPs) could be defined as the technical and economic ability of WPP/wind farms to connect and operate within the electric power supply network in a manner which is compatible with the day-to-day operation and short-term security of the electric supply system as a whole [1].

Most wind farms are connected to rural, overhead distribution lines. The design of these circuits tends to be limited by consideration of voltage drop rather than the thermal constraints and this severely limits their ability to accept wind generation [2].

Usually, the grid operator is ready to accept the WPPs' feed when their amount is quite less, but when the wind power penetration crosses 10% of the total load, some form of grid adaptation needs to be done at least in some parts of the grid, before the WPPs can be connected. But when the WPP penetration crosses the 20% mark, strengthening of the existing grid becomes quite necessary [1].

*Recent research analysis.*In the past, the WPPs were of smaller capacity and their contribution to the grid was insignificant, hence the rules governing grid connection were more relaxed to encourage development of this renewable energy source. But as the amount of wind generation increased, the lack of rules, standards, and regulations for grid connection has proven to be an increasing threat to the stability of the interconnected electric power system. Therefore, new electrical norms are coming into force in several countries, thereby bringing about changes in the application of electrical generating systems for optimization of the WPPs. *Wind power pene-*

tration of a country can be defined as' *the ratio of installed wind capacity in MW to peak generation in MW, expressed as a percentage'*[1].

At present, few grid systems have penetration of wind energy above 5%: Denmark *(*~ 18%), Spain and Portugal (~ 9%), Germany and the Republic of Ireland *(*~ 6%). Fig. 1 provides a bird's eye view of the generalized WPP system and the grid. The blocks enclosed in the dashed line with regard to grid integration will be discussed here. The other blocks have already been discussed earlier. [1]

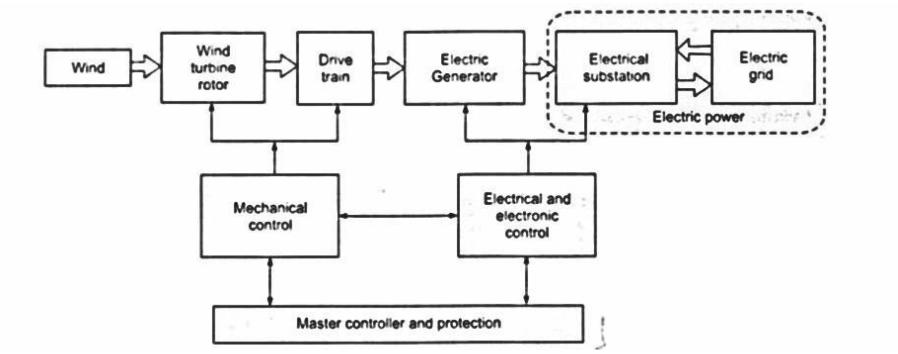

Fig. 1. WPP control overview [1].

Wind power connected to the transmission network consists of many tens to hundreds of individual WPPs spread out over a significant geographic expanse. Each of these WPPs is quite small relative to conventional power plants, but collectively in several places their contribution to the grid has become significant, thus affecting the power quality and stability of the grid network. In various places around the world the amount of wind power generation has surpassed the capability of the infrastructure for which it was originally designed [1].

Since the output power of the WPPs to the electric power system is also not steady as against the feeds from the conventional power plants like thermal, nuclear and others, how the WPP(s) should be integrated into the power system are issues that are discussed here. Hence, having an overview of the broad functions of a typical electric power system, the concept of embedded generation and other related concepts would help in understanding the peculiarities related to wind energy integration [1].

Article purpose formulation. To show the basic problems of the integration of wind power into the grid and to offer a number of requirements for wind power plants for their stable operation in the grid.

*Hard core.*The conventional function of an electrical distribution network is to transport electrical energy from a transmission system to customers' loads. This is to be done with minimal electrical losses and with the quality of the electrical power maintained. The voltage drop is directly proportional to the current, while the series loss in an electrical circuit is proportional to the square of the current. Therefore the currents must be kept low which, for constant power transmitted, implies that the network voltage level must be high. However, high-voltage plants (e.g. lines, cables and transformers) are expensive due to the cost of insulation, and so the selection of appropriate distribution network voltage level is an economic choice [2].

Table 1 gives some indications of the maximum capacities which, experience has indicated, may be connected.

Table 1 – Indication of possible connection of wind farms [2]

Location of connection	*Maximum capacity of wind farm*(MW)
Out on 11 kV network	1-2
At 11 kV bus bars	8-10
Out on 33 kV network	12-15
At 33 kV bus bar	25-30
On 132 kV network	30-60

It assumes that the wind farms are made up of a number of turbines and so the connection assessment is driven by voltage rise effects and not by power quality issues due to individual large machines[2].

The effect on the voltage magnitude depends on the ‘strength’ of the utility distribution network at the point of coupling as well as on the active and reactive power of the wind generator(s). At the point of connection, as illustrated in Fig. 3 (a), an equivalent ideal voltage source in series with an impedance Z_S may be assumed to replace the power system. Thus, the higher the fault current, the lower the source impedance. The wind farm with induction generators receives reactive power from the network and delivers real power to it [3].

The fault level at the point of connection near the wind farm without contribution from the wind generator, is

$$M = I_f V_s, \tag{1}$$

where

$$I_f = \frac{V_S}{Z_S}. \tag{2}$$

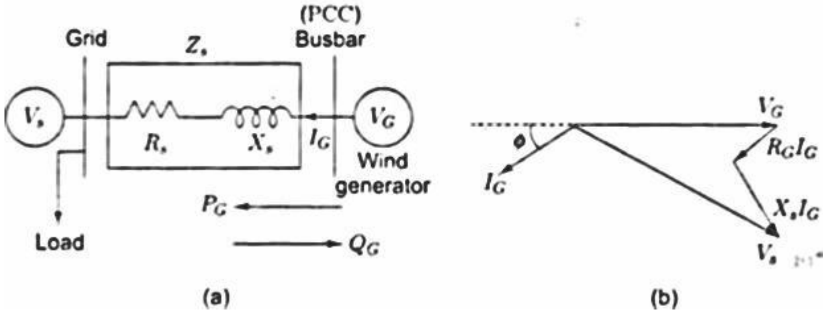

Fig. 2.(a) Schematic diagram of generator connection and distribution; (b) phasor diagram [3].

Thus the fault level and hence the network strength are indicative of the source impedance. Areas of high wind velocity are suitable locations for wind farms. These areas are usually sparsely populated. Long transmission and distribution lines are normally required for connecting wind farms with the power system network. As a result, fault levels at the wind farms are generally low, making them weak electrical systems.[3]

With reference to Fig. 3 (b), if the phase difference between V_s and V_G is not large, the voltage at the point of common coupling (PCC) will be close to [3]

$$V_G = V_s + R_s I_G \cos\varphi - X_s I_G \sin\varphi = V_s + \frac{P_G R_S}{V_G} - \frac{Q_G X_S}{V_G}. \qquad (3)$$

Soft-start systems are usually employed to minimize the transient inrush current. However, at very high wind speeds, sudden disconnection of the wind generator from the distribution network may cause the voltage to dip, which cannot be avoided[3].

In a grid network, electrical power normally flows from the *interconnection level* to the *transmission level* and then to the *distributions level*. At the WPP/wind farm level, the reverse happens. Grid operators want that grid-connected wind turbines should have a built-in capacity to actively support the grid in order to avoid a worst-case scenario, whereby instantly switching off a large chunk of wind generating capacity during an emergency could cause catastrophic grid failure and a widespread blackout. In spite of this, the transmission system operators want that WPPs should also perform the following basic functions effectively and efficiently[1]:

– generate electric power at all times;

– maintain grid stability during short-circuit situations;

– regulate the voltage so that the node voltages in the grid do not exceed their nominal values;

– prevent high voltages in case of load loss;

– remain connected to the grid without power reduction even if considerable voltage and frequency deviations occur;

– after a fault has been remedied, WPPs must resume their power feed as quickly as possible and within the specified maximum times;

– wind farms must make a contribution to the reserve power in the grid. WPPs must be able to be operated with reduced power output without any time restrictions. If the grid frequency increases, the power output of a wind farm must be reduced;

– perform short-termbalancing;

– perform long-termbalancing;

– transient/dynamic state condition-wind farms must be able to be integrated in the grid control centrelortele-monitoring and remote control of all systems in the grid;

– respond to wind forecasting plans for efficient power dispatch [1].

Conclusions. Grid connection requirements of WWPs differ from country to country and in some countries, they differ frame state to stage. The grid connection requirements have been developed to permit the development, maintenance and operation of an efficient, safe, secure, coordinated and economical transmission and/or distribution system.[1]

Since the output power of the WPPs to the electric power system is also not steady as against the feeds from the conventional power plants like thermal, nuclear and others, how the WPP(s) should be integrated into the power system are issues. Hence, having an overview of the broad functions of a typical electric power system, the concept of embedded generation and other related concepts would help in understanding the peculiarities related to wind energy integration [1].

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АНАЛИЗ ОСНОВНЫХ ПОДХОДОВ ИНТЕГРАЦИИ ВЕТРОЭЛЕКТРОСТАНЦИЙ В ЭНЕРГОСИСТЕМУ

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Аннонация

Представлены основные проблемы интеграции ветроэнергетики в энергосистему, предложен ряд требований для ветроэлектростанций с целью их стабильной работы в энергосистеме.

АНАЛІЗ ОСНОВНИХ ПІДХОДІВ ІНТЕГРАЦІЇ ВЕТРОЕЛЕКТРОСТАНЦІЙ У ЕНЕРГОСИСТЕМУ

Лисенко О.В., Адамова С.В.

Анотація

Представлені основні проблеми інтеграції вітроенергетики в енергосистему, запропоновано ряд вимог для вітроелектростанцій з метою їх стабільної роботи в енергосистемі.