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Chapter 2

Power Quality and Grid Code Issues in Wind Energy Conversion System

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/54704

1. Introduction

The aim of the electric power system is to produce and deliver to the consumer's electric energy of defined parameters, where the main quantities describing the electric energy are the voltage and frequency. During normal operation of system the frequency varies as a result of the variation of the real power generated and consumed. At the same time, because of voltage drops in the transmission lines and transformers it is impossible to keep the voltage at the nominal level in all the nodes of the power system. It is also impossible to keep an ideal sinusoidal shape of the voltage or current waveform due to the nonlinearities in many devices use for electric energy generation, transmission and at end users. That is why the electric power system require to keep the quantities near the nominal value[1]-[5].

Recently, the deregulated electricity market has also opened the door for customers own distributed generation due to economical and technical benefit. The liberalization of the grid leads to new management structures, in which the trading of energy is important. The need to integrate the renewable energy like wind energy into power system is to minimize the environmental impact on conventional plant of generation. The conventional plant uses fossil fuels such as coal & petroleum products to run the steam turbines and generate the thermal power. The fossil fuel consumption has an adverse effect on the environment and it is necessary to minimize the polluting and exhausting fuel. The penetration of renewable energy especially wind has been increasing fast during the past few years and it is expected to rise more in near future. Many countries around the world are likely to experience similar penetration level. During the last decade of the twentieth century, worldwide wind energy capacity is doubled approximately every three years.

Today's trends are to connect all size of generating units like wind farm,solar farm,biogas generation and conventional source like coal,hydro,nuclear power plant in to the grid system shown in Fig.1.0

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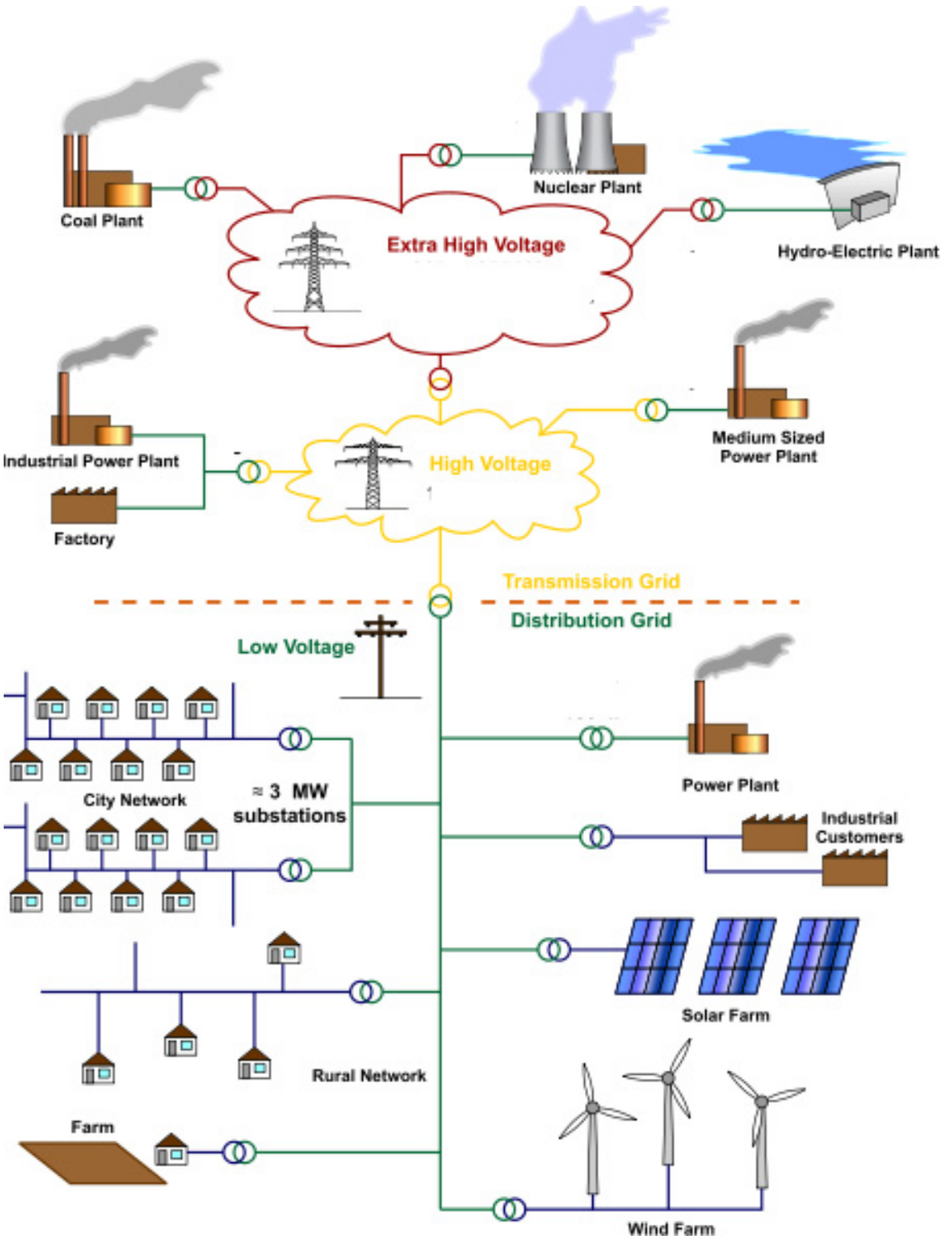


Figure 1. Grid integration of interconnected system

The critical power quality issues related to integration of wind farms have been identified by team of Riso National Laboratory and Danish Utility Research Institute, Denmark and Electronic Research and Development Centre, India in Nov.1998 .The power quality in relation to a wind turbine describe the electrical performance of wind energy generating system. It reflects the generation of grid interference and the influence of a wind turbine on power and voltage quality of grid. The issue of power quality is of great importance to the wind turbines. There has been an extensive growth and quick development in the exploitation of wind energy in recent years [6]-[7]. The individual units can be of large capacity up to 5 MW, feeding into distribution network, particularly with customers connected in close proximity. However with rapidly varying voltage fluctuations due to the nature of wind, it is difficult to improve the power quality with simple compensator. Advance reactive power compensators with fast control and power electronic have emerged to supersede the conventional reactive compensator [8]-[9].

It has been suggested that today's industrial development are related with generalized use of computers, adjustable speed drives and other microelectronic loads. It also becomes an increasing concern with power quality to the end customer. The presence of harmonic and reactive power in the grid is harmful, because it will cause additional power losses and malfunction of grid component. The massive penetration of electronically controlled devices and equipments in low voltage distribution network is responsible for further worsening of power-quality problem [10]-[13].

The problems are related to the load equipment and devices used in electric energy generation. Now a days the transmission and distribution system become more sensitive to power quality variation than those used in the past. Many new devices contain microprocessor based controls and electronics power elements that are sensitive to many types of disturbances. The wind turbine generating systems are the highly variable sources of energy and wind turbine are belonging to the source of such problem.

The wind power in the electric grid system affects the voltage quality. To assess this effect, the knowledge of about the electrical characteristic of wind turbine is needed. The electrical characteristics of wind turbine are manufacturer's specification and not site specification. This means that by having the actual parameter values for a specific wind turbine the expected impact of the wind turbine on voltage quality is important. The need for consistent and replicable documentation of the power quality characteristics of wind turbines, the International Electro-technical Commission (IEC) started work to facilitate for power quality in 1996. As a result, IEC 61400-21 was developed and today most wind turbines manufacturers provide power quality characteristic data accordingly. Wind turbines and their power quality will be certified on the basis of measurements according to national or international guidelines. These certifications are an important basis for utilities to evaluate the grid connection of wind turbines and wind farms.

The power quality is defined as set of parameters defining the properties of the power supply as delivered to user in normal operating condition in terms of continuity of supply and characteristics of voltage, frequency.

Today the measurement and assessment of the power quality characteristics of the grid-connected wind turbines is defined by IEC Standard 61400-21 (wind turbine system) prepared by IEC- Technical Committee 88.

The need of power quality in wind integration system and its issues are highlighted in further section.

2. Need of power quality studies

The power quality studies are of importance to wind turbine as a individual units can be large up to 5 MW, feeding into distribution circuit with high source impedance and with customer connected in close proximity.

With the advancement in fast switching power devices there is a trend for power supply size reduction. The current harmonics due to switching converters makes supply current distorted. The increase of electronic controllers in drives, furnaces, household equipments and SMPS are increasing the harmonic content and reactive power in electric supply. The distribution transformers apart from reactive loads draw reactive current from the supply to meet the magnetizing current. The ever-increasing demand for power is not fulfilled by increase in generation and particularly in distribution for various reasons such as environmental issues, increasing cost of natural fuel, opposition to nuclear power plants, etc. This puts excessive burden on the electric supply resulting in poor power quality. The term power quality here refers to the variation in supply voltage, current and frequency. The excessive load demand tries to retard the turbines at generation plant. This results in reduction in voltage and more severely reduction in the supply frequency. The authorities are working for power quality improvement by using reactive compensators and active filters on supply side and penalizing consumers for polluting the power grid.

The increasing problems and advances in power electronic technology, has forced to change the traditional power system concepts. Use of fast reactive power compensators can improve the power system stability and hence, the maximum power transfers through the electric system.

The reactive power in its simpler form, for a single phase sinusoidal voltages and current can be defines as the product of a phase current (reactive component) and the supply voltage. There is a simple right angle triangle relation between active power, reactive power and apparent power. But, this definition of the reactive power is not sufficient for non-linear loads where fundamental current and fundamental voltage may not have any phase difference. However, for such loads, power factor is still less than unity. The power factor definition is modified to accommodate for non-linear loads.

The overall power factor has two parts, the displacement power factor and distortion power factor. The displacement power factor defined as cosine of phase shift between fundamental supply current and voltage.

Distortion power factor “DF” or harmonic factor is defined as the ratio of the RMS harmonic content to the RMS value of fundamental component expressed as percentage of the fundamental.

$$DF = \sqrt{\frac{\text{sum of squares of amplitudes of all harmonics}}{\text{square of amplitude of fundamental}}} * 100\% \quad (1)$$

$$DF(\textit{for current}) = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_1} \quad (2)$$

2.1. Issue of voltage variation

If a large proportion of the grid load is supplied by wind turbines, the output variations due to wind speed changes can cause voltage variation, flicker effects in normal operation. The voltage variation can occur in specific situation, as a result of load changes, and power produce from turbine. These can expected in particular in the case of generator connected to the grid at fixed speed. The large turbine can achieve significantly better output smoothing using variable speed operation, particularly in the short time range. The speed regulation range is also contributory factor to the degree of smoothing with the large speed variation capable of suppressing output variations.

2.2. Issue of voltage dips

It is a sudden reduction in the voltage to a value between 1% & 90 % of the nominal value after a short period of time, conventionally 1ms to 1 min. This problem is considered in the power quality and wind turbine generating system operation and computed according to the rule given in IEC 61400-3-7 standard, "Assessment of emission limit for fluctuating load". The start up of wind turbine causes a sudden reduction of voltage. The relative % voltage change due to switching operation of wind turbine is calculated as

$$d = 100 K_u(\Psi_k)\frac{S_n}{S_k^*} \quad (3)$$

Where d - Relative voltage change,

$k_u(\Psi_k)$ - Voltage change factor,

S_n - Rated apparent power of wind turbine and S_k^* short circuit apparent power of grid. The voltage dips of 3% in most of the cases are acceptable. When evaluating flicker and power variation within 95% of maximum variation band corresponding to a standard deviation are evaluated.

2.3. Switching operation of wind turbine on the grid

Switching operations of wind turbine generating system can cause voltage fluctuations and thus voltage sag, voltage swell that may cause significant voltage variation. The acceptances of switching operation depend not only on grid voltage but also on how often this may

occur. The maximum number of above specified switching operation within 10-minute period and 2-hr period are defined in IEC 61400-3-7 Standard.

Voltage sag is a phenomenon in which grid voltage amplitude goes below and then returns to the normal level after a very short time period. Generally, the characteristic quantity of voltage sag is described by the amplitude and the duration of the sags. The IEEE power quality standards define the voltage sag when the amplitude of voltage is 0.1–0.9 p.u. value and its duration is between 10 ms and 1 min. A voltage sag is normally caused by short-circuit faults in the power network or by the starting up of Induction Generator/Motors.

The bad weather conditions, such as thunderstorm, single-phase earthed faults are the causes of voltage sags. In addition, large electric loads such as large electrical motors or arc furnaces can also cause voltage sags during the startup phase with serious current distortion.

The adverse consequences are the reduction in the energy transfer of electric motors. The disconnection of sensitive equipments and thus the industrial process may bring to a standstill.

2.4. Harmonics

The harmonics distortion caused by non-linear load such as electric arc furnaces, variable speed drives, large concentrations of arc discharge lamps, saturation of magnetization of transformer and a distorted line current. The current generated by such load interact with power system impedance and gives rise to harmonics. The effect of harmonics in the power system can lead to degradation of power quality at the consumer's terminal, increase of power losses, and malfunction in communication system. The degree of variation is assessed at the point of common connection, where consumer and supplier area of responsibility meet. The harmonics voltage and current should be limited to acceptable level at the point of wind turbine connection in the system. This fact has lead to more stringent requirements regarding power quality, such as Standard IEC 61000-3-2 or IEEE-519. Conventionally, passive LC resonant filters have been used to solve power quality problems. However, these filters have the demerits of fixed compensation, large size, and the resonance itself. To overcome these drawbacks, active filters appear as the dynamic solution.

The IEC 61000-3-6 gives a guideline and harmonic current limits. According to standard IEC 61400-21 guideline, harmonic measurements are not required for fixed speed wind turbines where the induction generator is directly connected to grid. Harmonic measurements are required only for variable speed turbines equipped with electronic power converters. In general the power converters of wind turbines are pulse-width modulated inverters, which have carrier frequencies in the range of 2-3 kHz and produce mainly inter harmonic currents.

The harmonic measurement at the wind turbine is problem due to the influence of the already existing harmonic voltage in the grid. The wave shape of the grid voltage is not sinusoidal. There are always harmonics voltages in the grid such as integer harmonic of 5^{th} and 7^{th} order which affect the measurements.

Today's variable speed turbines are equipped with self commutated PWM inverter system. This type of inverter system has advantage that both the active and reactive power can be controlled, but it also produced a harmonic current. Therefore filters are necessary to reduce the harmonics.

The harmonic distortion is assessed for variable speed turbine with a electronic power converter at the point of common connection. The total harmonic voltage distortion of voltage is given as in (4).

$$V_{THD} = \sqrt{\sum_{h=2}^{40} \frac{V_h^2}{V_1} 100} \tag{4}$$

V_h- hth harmonic voltage and V_1 –fundamental frequency 50 Hz. The THD limit for various level of system voltages are given in the table 1.0

System Voltage (kV)	Total Harmonic Distortion (%)
400	2.0
220	2.5
132	3.0

Table 1. Voltage Harmonics Limit

THD of current I_{THD} is give as in (5)

$$I_{THD} = \sqrt{\sum_{h=2}^{40} \frac{I_h^2}{I_1} 100} \tag{5}$$

Where I_h - hth harmonic current and I_1 –fundamental frequency (50) Hz. The acceptable level of THD in the current is given in table 2.

Voltage level	66 kV	132kV
I_{THD}	5.0	2.5

Table 2. Current Harmonic Limit

Various standards are also recommended for individual consumer and utility system for helping to design the system to improve the power quality. The characteristics of the load and level of power system significantly decides the effects of harmonics. IEEE standards are adapted in most of the countries. The recommended practice helps designer to limit current and voltage distortion to acceptable limits at point of common coupling (PCC) between supply and the consumer.

1. IEEE standard 519 issued in 1981, recommends voltage distortion less than 5% on power lines below 69 kV. Lower voltage harmonic levels are recommended on higher supply voltage lines.

2. IEEE standard 519 was revised in 1992, and impose 5% voltage distortion limit. The standards also give guidelines on notch depth and telephone interface considerations.
3. ANSI/IEEE Standard C57.12.00 and C57.12.01 limits the current distortion to 5% at full load in supply transformer.

In order to keep power quality under limit to a standards it is necessary to include some of the compensator. Modern solutions for active power factor correction can be found in the forms of active rectification (active wave shaping) or active filtering.

2.5. Flickers

Flicker is the one of the important power quality aspects in wind turbine generating system. Flicker has widely been considered as a serious drawback and may limit for the maximum amount of wind power generation that can be connected to the grid. Flicker is induced by voltage fluctuations, which are caused by load flow changes in the grid. The flicker emission produced by grid-connected variable-speed wind turbines with full-scale back-to-back converters during continuous operation and mainly caused by fluctuations in the output power due to wind speed variations, the wind shear, and the tower shadow effects. The wind shear and the tower shadow effects are normally referred to as the 3p oscillations. As a consequence, an output power drop will appear three times per revolution for a three-bladed wind turbine. There are many factors that affect flicker emission of grid connected wind turbines during continuous operation, such as wind characteristics and grid conditions. Variable-speed wind turbines have shown better performance related to flicker emission in comparison with fixed-speed wind turbines.

The flicker study becomes necessary and important as the wind power penetration level increases quickly. The main reason for the flicker in fixed speed turbines is to wake of the tower. Each time a rotor blade passes the tower, the power output of the turbine is reduced. This effect cause periodical power fluctuations with a frequency of about ~1 Hz. The power fluctuation due to the wind speed fluctuation has lower frequencies and thus is less critical for flicker. In general, the flicker of fixed speed turbines reaches its maximum at high wind speed. Owing to smoothing effect, large wind turbine produced lower flicker than small wind turbines, in relation to their size.

Several solutions have been proposed to mitigate the flicker caused by grid-connected wind turbines. The mostly adopted technique is the reactive power compensation. It can be realized by the grid-side converter of variable-speed wind turbines or the Static synchronous compensator connected at the point of common coupling (PCC). Also, some papers focus on the use of active power curtailment to mitigate the flicker [5].

The flicker level depends on the amplitude, shape and repetition frequency of the fluctuated voltage waveform. Evaluating the flicker level is based on the flicker meter described in IEC 61000-4-15. Two indices are typically used as a scale for flicker emission, short-term flicker index, P_{st} and long-term flicker index, P_{lt}. P_{lt} is estimated by certain process of the P_{st} values.

It is assumed that wind turbines under study is running at normal operation; hence, the long-term flicker index (P_{lt}), which is based on a 120-min time interval, is equal to P_{st} and, therefore, P_{st} is only considered in this work. The normalized response of the flicker meter described in Figure 2.0.

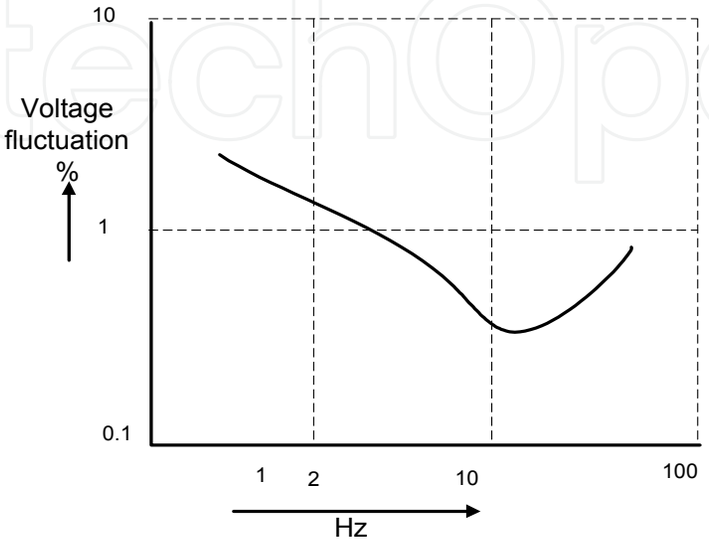


Figure 2. Influence of frequency on the perceptibility of sinusoidal voltage change

A quite small voltage fluctuation at certain frequency (8.8 Hz) can be irritable. The flicker level ($P_{st} \leq 1$) is a threshold level for connecting wind turbines to low voltage. The measurements are made for maximum number of specified switching operation of wind turbine with 10-minutes period and 2-hour period are specified, as given in (6)

$$P_{lt} = C(\Psi_K)\frac{S_n}{S_K} \tag{6}$$

Where p_{lt} - Long term flicker. $C(\Psi_K)$ - Flicker coefficient calculated from Rayleigh distribution of the wind speed. The Limiting Value for flicker coefficient is about ≤ 0.4, for average time of 2 hours.

2.6. Reactive power

Traditional wind turbines are equipped with induction generators. Induction generator is preferred because they are inexpensive, rugged and requires little maintenance. Unfortunately induction generators require reactive power from the grid to operate. The interactions between wind turbine and power system network are important aspect of wind generation system. When wind turbine is equipped with an induction generator and fixed capacitor are used for reactive compensation then the risk of self excitation may occur

during off grid operation. Thus the sensitive equipments may be subjected to over/under voltage, over/under frequency operation and other disadvantage of safety aspect. According to IEC Standard, reactive power of wind turbine is to be specified as 10 min average value as a function of 10-min. output power for 10%, 20% … 100% of rated power. The effective control of reactive power can improve the power quality and stabilize the grid. Although reactive power is unable to provide actual working benefit, it is often used to adjust voltage, so it is a useful tool for maintaining desired voltage level. Every transmission system always has a reactive component, which can be expressed as power factor. Thus the some method is needed to manage the reactive power by injecting or absorbing VAr as necessary in order to maintain optimum voltage level and enable real power flow. Until recently, this has been especially difficult to effectively accomplish at a wind farms due to the variable nature of wind. The suggested control technique in the thesis is capable of controlling reactive power to zero value at point of common connection (PCC).The mode of operation is referred as unity power factor.

2.7. Location of wind turbine

The way of connecting wind turbine into the electric power system highly influences the impact of the wind turbine generating system on the power quality. As a rule, the impact on power quality at the consumer's terminal for the wind turbine generating system (WTGS) located close to the load is higher than WTGS connected away, that is connected to H.V. or EHV system.

Wind turbine generator systems (WTGS) are often located in the regions that have favorable wind conditions and where their location is not burdensome. These regions are low urbanized, which means that the distribution network in these regions is usually weak developed. Such situation is typical for all countries developing a wind power industry.

The point of common coupling (PCC) of the WTGS and the power network parameter and structure of grid is of essential significance in the operation of WTGS and its influence on the system. WTGS can be connected to MV transmission line and to HV networks.

The WTGS connected to the existing MV transmission line, which feeds the existing customers is presented in Figure 3.

The distance between WTGS and PCC is usually small up to a few kilometers. Such connections are cheap as compare to other types of connection but greatly affected on consumers load (power quality).

If the location of WTGS is connected to an MV bus in feeding an HV/MV substation through a separate transmission line (position 1), the connection has some advantages related to low influence of WTGS on customers load. Such connection are expensive than presented above.

The location of WTGS connected to HV bus through a separate transmission line, when a relatively large rated WTGS has to be connected in the power network, where the MV network is weak. This type of connection are most expensive than other presented.

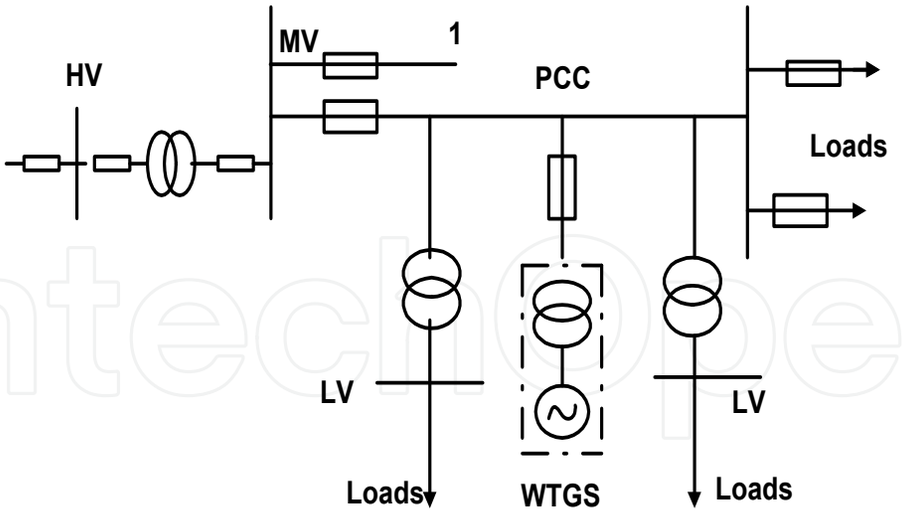


Figure 3. WTGS coupled to MV transmission-line.

2.8. Low voltage ride through capability

The impact of the wind generation on the power system will no longer be negligible if high penetration levels are going to be reached. The extent to which wind power can be integrated into the power system without affecting the overall stable operation depends on the technology available to mitigate the possible negative impacts such as loss of generation for frequency support, voltage flicker, voltage and power variation due to the variable speed

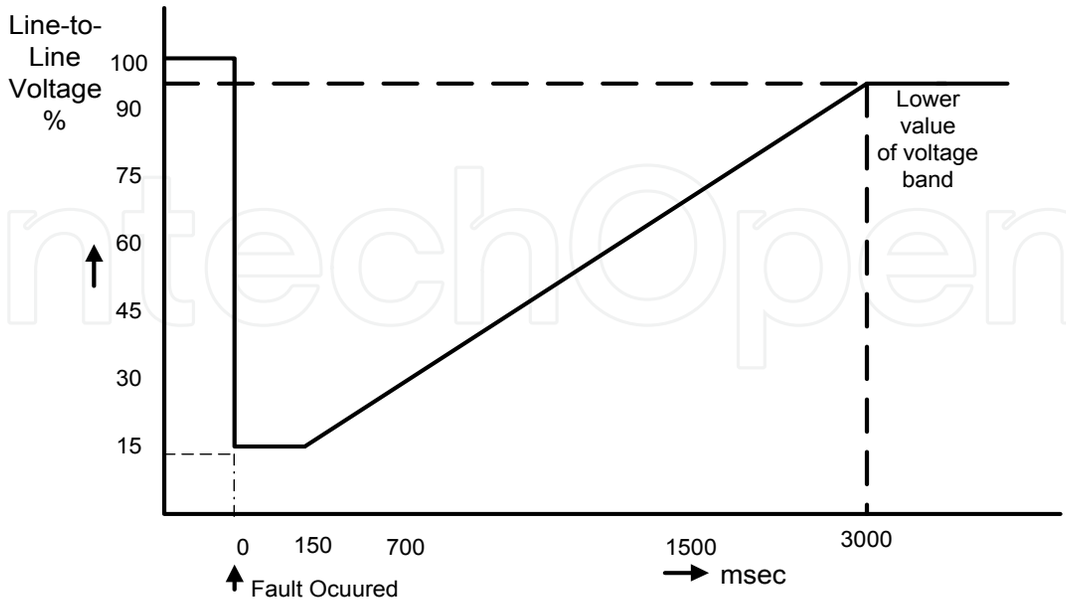


Figure 4. Low voltage ride through (LVRT) capability

of the wind and the risk of instability due to lower degree of controllability. Many countries in Europe and other parts of the world are developing or modifying interconnection rules and processes for wind power through a grid code. The grid codes have identified many potential adverse impacts of large scale integration of wind resources. The risk of voltage collapse for lack of reactive power support is one of the critical issues when it comes to contingencies in the power system. The low voltage ride through (LVRT) capability, which is one of the most demanding requirement that have been included in the grid codes and shown in Fig. 4.

It defines the operational boundary of a wind turbine connected to the network in terms of frequency, voltage tolerance, power factor, fault ride through is regarded as the main challenges to the wind turbine manufactures. The wind turbine should remain stable and connected during the fault while voltage at the PCC drop to 15% of the nominal value i.e. drops of 85% for the part of 150 msec. Only when the grid voltage fall below the curve, the turbine is allowed to disconnected from the grid.

Significant barriers to interconnection are being perceived already with the requirements of the new grid codes and there it is a need for a better understanding of the factors affecting the behavior of the wind farm under severe contingencies such as voltage sags. Wind farms using squirrel cage induction generators directly connected to the network will suffer from the new demands, since they have no direct electrical control of torque or speed, and would usually disconnect from the power system when the voltage drops more than 10–20% below the rated value. In general, fulfillment of LVRT by reactive compensation will require fast control strategies for reactive power in wind turbines/farms with cage induction generators. The LVRT requirement, although details are differing from country to country, basically demands that the wind farm remains connected to the grid for voltage dips as low as 5%.

2.9. IEC recommendation

For consistent and replicable documentation of power quality characteristic of wind turbine, the international Electro-technical Commission IEC-61400-21 was developed and today, most of the large wind turbine manufactures provide power quality characteristic data accordingly.IEC 61400-21 describe the procedures for determine the power quality characteristics of wind turbines. It is a guideline for power quality measurements of wind turbine. The methodology of IEC standard consists of three analyses. The first one is the flickers analyses. IEC 61400-21 specified a method that uses current and voltage time series measured at the wind turbine terminals to simulate the voltage fluctuation on a fictitious grid with no source of voltage fluctuations other that wind turbine switching operation. The second one is regarding the switching operation. The voltage and current transients are measured during the switching operation of wind turbine. The last one is the harmonic analysis which is carried out by FFT algorithms. Recently harmonic and inter harmonic are treated in the IEC 61000-4-7 and IEC 61000-3-6. The method for summing harmonics and

inter harmonic in the IEC 61000-3-6 are applicable to wind turbines. The inter harmonics that are not a multiple of 50 Hz, since the switching frequency of the inverter is not constant but varies, the harmonic will also vary. Consequently, the grid codes has been define to specify the requirements that the wind turbines must meet in order to be connected to the grid, including the capabilities of contributing to frequency and voltage control by adjusting the active and reactive power supplied to the transmission system.

3. Grid code for wind farms

The Electricity Grid Code is a regulation made by the Central Commission and it to be follow by various persons and participants in the system to plan, develop, maintain, and operate the power system grid in the most secure, reliable, economic and efficient manner, while facilitating healthy competition in the generation and supply of electricity.

The first grid code was focused on the distribution level, after the blackout in the United State in August 2003. The United State wind energy industry took a stand in developing its own grid code for contributing to a stable grid operation. The rules for realization of grid operation of wind generating system at the distribution network is defined as - per IEC-61400-21.The grid quality characteristics and limits are given for references that the customer and the utility grid may expect. According to Energy-Economic Law, the operator of transmission grid is responsible for the organization and operation of interconnected system. The grid code also covers some of the technical standards for connection to the grid.

To ensure the safe operation, integrity and reliability of the grid is utmost important. It is mentioned that reactive power compensation should ideally be provided locally by generating reactive power as close to the reactive power consumption as possible. The regional entity except generating stations, expected to provide local VAr compensation/generation such that they do not draw VArs from the grid, particularly under low-voltage condition. Indian grid code commission mentions that the charge for VArh shall be at the rate of 25 paise/kVArh w.e.f.1.4.2010, for VAr interchanges.

The wind farms must be able to run at rated voltage at a specified voltage range. The voltage range depends on the level of the voltage on the transmission system, which varies from country to country.

The wind farms shall have a closed loop voltage regulation system. The voltage regulation system shall act to regulate the voltage at the point by continuous modulation of the reactive power output within its reactive power range, and without violating the voltage step emissions.

Voltage fluctuations at a point of common coupling with a fluctuating load directly connected to the transmission system shall not exceed 3% at any time. The flicker contributions P_{st} and P_{lt} are defined in IEC 61000-3-7 (Electromagnetic compatibility).

The wind turbine generator (WTG) shall be equipped with voltage and frequency relays for disconnection of the wind farm at abnormal voltages and frequencies. The relays shall be set according to agreements with the regional grid company and the system operator. Following are the technical requirements to be fulfilled to integrate the wind generation system.

Voltage Rise (u) -The voltage rise at the point of common coupling can be approximated as a function of maximum apparent power S_{max} of the turbine, the grid impedances R and X at the point of common coupling and the phase angle ϕ. The Limiting voltage rise value is < 2%

Voltage dips (d) - The voltage dips is due to start up of wind turbine and it causes a sudden reduction of voltage. The acceptable voltage dips limiting value is ≤ 3 %.

Flicker-The measurements are made for maximum number of specified switching operation of wind turbine with 10-minutes period and 2-hour period are specified. The Limiting Value for flicker coefficient is about ≤ 0.4, for average time of 2 hours

$$Harmonics - The\ THD\ limit\ for\ 132\ KV\ is\ < 3\%.$$

Grid frequency- The grid frequency in India is specified in the range of 47.5-51.5 Hz, for wind farm connection. The wind farm shall able to withstand change in frequency up to 0.5Hz/sec. Thus the requirements in the Grid Code can be fulfill the technical limits of the network.

4. Conclusion

The chapter provides the challenges regarding the integration of wind energy in to the power systems. Today the worldwide trend of wind power penetration is increased. The integration of high penetration level of wind power into existing power system has significant impact on the power system operation.

The wind turbines connected to weak grids have an important influence on power system. The weak grid is characterized by large voltage and frequency variations, which affects wind turbines regarding their power performance, safety and allied electrical components. The strength of the distribution system is important from the point of power quality. The needs for consistent qualification of power quality characteristics of wind turbines, the International Electro-Technical Commission to facilitate for power quality parameters for various issues are presented. The latest grid code requirements are to ensure that wind farms do not adversely affect the power system operation with respect to security of supply, reliability and for power quality.

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