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Technical issues on integration of wind farms with power grid- A review

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Abstract: The unceasing and phenomenal rise in oil prices and drastic need to reduce gas emissions causing to craft policies to boost the energy generation through the renewable energies. The non-conventional energy sources like wind power, mini-hydro, solar, etc having a significant contribution in energy production. The empathy and effective use of renewable energy resources are the plunge areas in the development of energy sector. Among all these wind energy is one of the utmost atmosphere pleasant, clean and benign energy assets. The wind energy will remain to be the chief in renewable energy sector in any country. The assimilation of wind energy into current power system boons technical challenges of power quality measurements such as variation of voltage, reactive power, flicker, harmonics, and electrical behavior of switching operation. So to have consistent renewable energy it is necessary to reduce these problems associated with the addition of renewable energy into the power grid. So the major purpose of this paper is to study the practical encounters that affect quality of power included: voltage flicker, Impact of nonlinear load on harmonics generation, reactive power, switching operation in the power system and the damages caused by these issues.

Keywords: Wind Generation, Voltage Flicker, Harmonics, Voltage Stability

1. Introduction

Precisely the present world is energy state of affairs; it has become obvious that there is an immediate need for a tangible solution to its imminent deficiency, where wind energy has outstretched as a perfect solution thus far. In recent years, renewable energies plays most vital and encouraging role specially wind energy, but it demands extra transmission capability and better means of stabilizing system reliability. Renewable Energy (RE), specifically from all renewable sources the wind energy is one of the most encouraging renewable energy sources free from release of Green House Gases (GHG), and it has prospective in regard with demand of energy because of its obtainability which increases interest worldwide. It is one of the firmest emerging and lucrative resources of RE from all the other resources that have been used for ecological environment friendly power systems [1,2]. There have been pungent advancement in wind energy technologies in recent years, and wind energy is progressively becoming an essential source of energy. Integration of wind energy into power system is to make it conceivable to minimize the environmental impacts [3]. But the integration of wind with power grid creates technical issues that affect power quality (Voltage flicker, harmonics, power system transients etc) due to variable nature of wind energy [4-6]. Electricity generated from wind power can be highly variable at several different timescales: hourly, daily, or seasonally. It only functions when there is a wind flow around. In fact, there is a slightest and a extreme speed for a wind turbine to start functioning, which are called cut in and cut out. For most wind turbines, the 'cut in' speed is 4m/s while the 'cut out' speed is 15m/s. Wind turbines are usually recommended to operate at the speed of 7–10m/s [7]. Because of this rapid electrical generation and consumption must remain in balance to retain grid stability, this inconsistency can present substantial challenges in incorporating large amounts of wind power into a grid system [8]. Therefore, it is foremost need that these issues must be condensed for effective integration of wind generation with power grid. To absorb power quality disturbances it depend on the fault level at the point of common coupling (PCC) [9]. The dynamic variation in the power system caused by wind turbine or by load produces voltage flicker. Thus the fluctuating power from wind turbine occurs during continuous operation. The grid strength, network impedance, power factor and phase angle controls the amplitude of fluctuated voltage [10]. The interconnection of wind with power is grid is limited by the flicker level and this should not exceed standardized value. Utilization of power electronics converters are also the main cause of generating current harmonics.

The fitness of electrical power to consumer devices is measured from power quality. Electrical systems can work in their intended manner with significant performance and without reduction in their life span if voltage, frequency and phase angle all are managed. The operation of electrical devices and their proper functioning relate to electrical power. Without the proper electrical power, an electrical device (or load) may malfunction, fail prematurely or not operate at all and also produce great harm to power system [11]. The important factors to be considered are voltage flicker, voltage fluctuation, harmonics, active power, reactive power, electrical behavior due to switching operation.

2. Technical Issues Affecting Power Quality

The key practical factors that affect the performance of power system in sense of power quality while integrating wind farms with power grid are:

2.1. Voltage Fluctuation

The voltage spikes, surges, sag, noise as well as voltage fluctuation and instability of power system are the leading problems which come across during integration of large-scale wind energy farms into the power grid, as shown in Fig. 1.

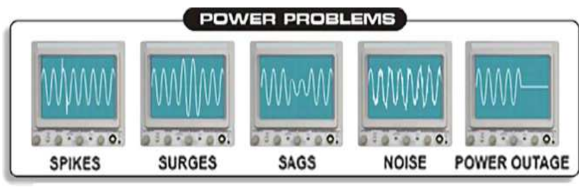

Fig. 1. *Power problems due to Voltage fluctuation*

Voltage fluctuation does not affect most of the connected loads, but these fluctuations may cause flicker due to changes in the illumination intensity of light sources. Unpleasant visual sensation produced due to flicker may lead to complaints from utility customers. Another main source of flicker generation includes heavy industrial loads as arc furnaces or lighter loads with regular duty cycle such as welding machines or electric boilers. From the power generation side, fluctuations result from wind turbines has tuned the attention of researchers in recent years. Variable wind speed produce fluctuating power, which in return at the point of common coupling lead to voltage fluctuations, thus produces flicker [12]. Slow dynamic or transient situations classify the voltage stability in power system. Gradual increase in load on power system relates to slow dynamic stability and deals with active and reactive power supply. Sudden major changes in power system like integrating wind turbine with the grid cause transient voltage stability problems which can lead to problems with the voltage control or the stability of power systems [13,14,15].

The short term flicker severity (P_{st}) and long term severity (P_{lt}) evaluate the voltage flicker level. The periodic voltage fluctuations with frequencies of less than about 30–35 Hz that are small in size consist voltage flicker in most cases. Flicker emission from fixed speed wind turbines are higher than the flicker generated from variable speed wind turbines [16]. The IEC standard 61000-3-7 is the basis of flicker evaluation having guidelines for emission limits for fluctuating loads in medium voltage and high voltage networks [17]. Table.1 shows the recommended values for voltage flicker. Voltage fluctuations lead to great reduction in life span of much sensitive electric and electronic equipment [18]. The IEC standard 61400-21 deals with the techniques how to measure and assess the power quality features of grid-connected wind turbines.

Table 1. *Flicker compatibility and Planning levels*

	Compatibility Levels	Planning Levels	
Voltage Level	**LV and MV**	**MV**	**HV and EHV**
Pst	1.0	0.9	0.8
Plt	0.8	0.7	0.6

2.2. Harmonics

50Hz or 60Hz is the fundamental frequency of typical power system and harmonic of a wave is a constituent frequency of the signal that is an integer multiple of the fundamental frequency, i.e. if 'f' is the fundamental frequency, 2f, 3f, 4f,....etc are the harmonics frequencies. The sum of harmonics is periodic at fundamental frequency because harmonics have the property that they are all periodic at the fundamental frequency. Harmonic frequencies can be found by repeatedly adding fundamental frequency because harmonics frequencies are equally spaced by the width of the fundamental frequency. For example, if 50 Hz is fundamental frequency, the consecutive harmonics frequencies are: 100 Hz, 150 Hz, 200 Hz etc [11]. It can be expressed as:

$$F_h = h.F \tag{1}$$

Where,
F_h= Harmonic Frequency
F= Fundamental Frequency
h= denotes order of harmonic (h=1,2,3,....)

2.2.1. Harmonics Generation

The alternating current power system which is operating normally having the current waveform at a specific frequency is varying sinusoidally. A linear electrical load draws sinusoidal current at the same frequency as of voltage when it is connected to the power system (though usually not in phase with the voltage) [11].

Non-linear loads causing harmonics. A non-linear load, such as power electronic equipment and loads which consume only some part of sinusoidal current and voltage rather than consuming full wave, this causes harmonic current because distortion in the current might distort the voltage waveform and ultimately causing harmonics issues. Non-linear apparatus inject harmonic currents or voltages into the power system and are the main source of harmonics generation. The harmonic current sources are mainly considered as harmonic sources [19]. Common used equipment such as fluorescent lightings, battery chargers, computers and printers and also variable-speed drives are some other examples of non-linear loads.

2.2.2. Harmonic Causes in a Wind Turbine

The connection of wind turbine with power grid is most often consists of an electronic converter and in all cases of a transformer and a substation containing circuit breakers and measurement and control devices. If the wind turbine is directly connected to the grid, the rotor speed will be fixed to the frequency of the grid. This is a so called fixed speed turbine as shown in Fig. 2a. When a power electronic converter is included a possibility of effective speed regulation through frequency regulation is gained. This is so called variable speed turbine shown in Fig. 2b. The use of power electronic converters is usually recommended as the advantages are large. Variable speed is a necessity to enable the wind turbine to have a maximum power production at all times, with consideration of the wind. Other advantages are reduction of stresses on the power train, reduction of acoustical noise and improved power quality in the form of a more even production [20].

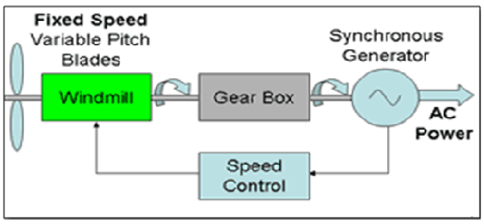

Fig. 2a. *Fixed speed wind turbine*

As previously mentioned, a power electronic converter in the wind turbine introduces some problems. If the connection is made through a power electronic converter, the produced supply voltage would not be perfectly sinusoidal. It might in fact be quite complex since it is produced by the switching action as shown in Fig. 3.

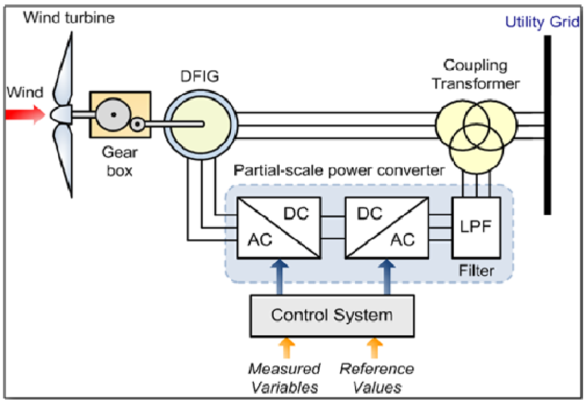

Fig. 2b. *Variable Speed Wind Turbine*

The produced power is first inverted into dc and then inverted back to ac with the grid frequency. In Fig. 2 an ac/ac converter is presented. The converter consists of two switch-mode inverters. The theory behind the controlled switching is relatively simple and various switching patterns can be used. One of them is PWM (pulse width modulation), there are also other kinds of control signal setups such as six-step operation, which in fact is an over modulated PWM.

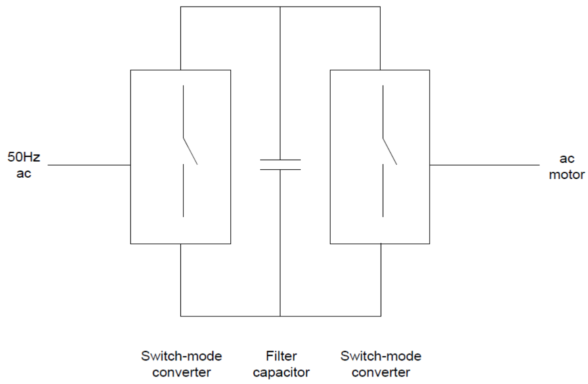

Fig. 3. *Example of Power Electronics Setup in Wind Power Plants*

Whatever switching technique used, the use of power electronic equipment with switching always leads to harmonic disturbances causing power quality issues in the grid [21]. Fig. 4 shows how the shape of the produced voltage might look; where Vfundamental is the fundamental signal. As can be seen in Fig. 4, this is not the actual voltage curve, where the voltage consists of long and short voltage pulses with a magnitude of ±Vd.

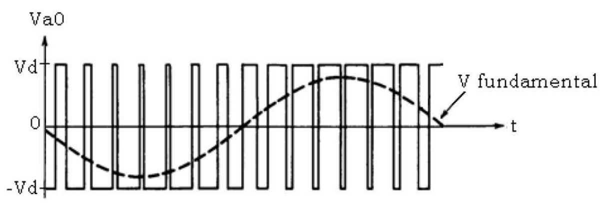

Fig. 4. *Voltage output from power electronics converter*

The harmonic emissions of wind turbines can be classified as characteristic and non-characteristic harmonics. The characteristic harmonics depend on the converter topology and switching strategy used during an ideal operation (with no disturbances). For a six-pulse converter, the characteristic harmonics are the harmonics of the harmonic order $6n \pm 1$, where n is a positive integer. Similarly for a twelve-pulse converter the characteristic harmonics are of the order $12n \pm 1$. Apparently, the non-characteristic harmonics are the harmonics that are not counted as characteristic harmonics. They are not depending on the converter topology, but the operating point of the converter. This type of harmonics can be as large and as significant as the characteristic harmonics [9].

Voltage source converter high voltage DC links are coming more and more popular as connections between an off shore transformer and an on shore substation, this can lower the harmonic emission levels of wind turbines. Mostly voltage source converter high voltage DC converters utilize two-level topology, but the multi-level and the multi-pulse converters can also be utilized by connecting several six-pulse converters in parallel. The low order harmonics are deleted correspondingly to the increment in pulse numbers.

2.3. Issues Related to Reactive Power

Generator operators normally regulate voltage on the large system, and transmission system operator usually provide voltage schedule. In the past years, as compared to conventional generating plants renewable generation plants were considered very small, and were typically either induction generator (wind) or line-commutated inverters (PV) that have no inherent voltage regulation capability. Synchronous generators exclusively provide bulk system voltage regulation. In recent years, the growing level renewable generation and its penetration with the power grid especially wind need to contribute power system voltage and reactive power regulation more significantly. New wind generation plants having considerable reactive power and voltage stability because they use full-conversion machines or doubly-fed induction generators (DFIG) with self-commutated electronic interfaces, FACTS controllers (SVC, STATCOMS, UPQC) and other reactive support equipment at the plant level can be added if there is need of meeting interconnection requirements, the reactive power capability of wind plants.

However, the voltage support in the system like wind generation which are often installed at remote sites having weak transmission connection and is common to have short circuit ratios is a vital additional service to avoid voltage instability and ensure good power transfer [22].

2.4. Damages Caused by These Issues

There are many adverse effects of the issues discussed above in a power network. The foremost part of the components is mainly designed for fundamental frequency used in power networks. The components operate under those conditions which have not optimal environment, can have hostile effects on the equipment life span and its operation. Harmonic emissions are a commonly recognized problem in wind power plants. Almost certainly the overheating and extra losses in many components, like cables, capacitor banks, generators, transformers, reactors and any kinds of electronic equipment all having significant concern that is harmonic currents [9]. Overheating shortens useful lifetime of equipment, and can lead to destruction of components especially capacitor banks in some extreme cases. The probability of the existence of resonances increases when a power system has components with large a capacitance or inductance, as explained before.

If harmonic currents or voltages are high enough, they can provoke an unnecessary tripping of protective relays. They can also degrade the interruption capability of circuit breakers. If the filtering is not well designed, harmonics may cause adverse effects on the measuring devices that are not made for taking into account the existence of distorted waveforms. These errors can have an effect on measured results although devices might be equipped with filters. The functioning of many electronic devices is based on the determination of the shape of voltage waveform, for example detecting the zero crossing point. As harmonic distortion can shift this point, the risk of system malfunction is evident. Especially important is to mention the drawback of harmonics on impedance measurement that is used in distance relays. The power transferred in power networks and communication networks is in a totally different scale (megawatt versus mill watt), so even a relatively small amount of current distortion in the power network can easily provoke significant noise in a metallic communication circuit at harmonic frequencies.

3. Conclusion

Energy shortage, global warming issues, emission of GHG demand development of renewable energies resources to play their role, from which wind energy is one of the auspicious renewable energy source due to its clean and environmental friendly features. Wind energy has some technical issues that affect the power quality of the system while integrating it with power grid. This paper is a thorough review over the technical issues and to explore the impact of those on power system.

As discussed in the paper, it seems that wind generation have technical issues related to power quality which should be addressed so as to make this more efficient, reliable and stable source of power generation. From the review following conclusions can be obtained:

i. Great reduction in the life span of some sensitive electric and electronic equipment can occur due to continuous variation in wind speed which results voltage fluctuation at PCC and generating voltage fluctuation and ultimately voltage flicker.
ii. Utilization of power electronics converters

produces harmonics in the system due to switching action and it have many adverse effects on power system.

iii. Relatively small amount of current distortion in the power network can easily aggravate significant noise in a metallic communication circuit at harmonic frequencies.

References

[1] Gol,O, Renewable energy–panacea for climate change? In Proceedings of the International Conference on Renewable Energies and Power Quality, Santander, 2008.

[2] Wind-grid integration brief, Technical Report, Caribbean Renewable Energy Development Programme,2005.Availableat: /http://www.caricom.org/ jsp/projects/wind-grid_integration.pdfS, 2012, [access10.07.12].

[3] S.W Mohod, M.V Aware, "A STATCOM control scheme for grid connected wind energy system for power quality improvement", IEEE System Journal, Vol.2, issue 3, pp.346-352, Sept.2010.

[4] Ming, Z,Lixin, H,Fam, Yand Danwei, J,Research of the Problems of Renewable Energy Orderly Combined to the Grid in Smart Grid. In: Proceedings of the Power and Energy Engineering Conference,2010.

[5] Liserre M, Sauter T, Hung JY. Future energy systems: integrating renewable energy sources in to the smart power grid through industrial electronics. IEEE Industrial Electronics Magazine 2010;4(1):18–37.

[6] Cartwright P. Connecting renewables: the challenge of integrating large offshore wind farms. Journal of Refocus, ELSEVIER2006;7:24–6.

[7] Hasan, Nor Shahida, Mohammad Yusri Hassan, Md Shah Majid, and Hasimah Abdul Rahman. "Review of storage schemes for wind energy system s", Renewable and Sustainable Energy Reviews, 2013.

[8] Golovanov, Nicolae; Lazaroiu, George Cristian; Roscia, Maria cristina and Zaninelli ,Dario. "Power Quality Assessment in Small Scale Renewable Energy Sources Supplying Distribution Systems", Energies (19961073), 2013.

[9] K.L.Deshmukh, S.M.Shembekar, D.U.Adokar. Problems Associated With Wind Power Generation INTERNATIONAL JOURNAL OF ADVANCED ELECTRONICS & COMMUNICATION SYSTEMS, 2014 (CSIR-NISCAIR ISSN NO: 2277-7318).

[10] V Sujatha and M Bhaskar Reddy 'MITIGATION OF POWER QUALITY PROBLEMS IN GRID CONNECTED WIND GENERATION PLANT BY USING STATCOM' ISSN 2319 – 2518 www.ijeetc.com Vol. 2, No. 4, October 2013.

[11] http://en.wikipedia.org/wiki/Power_quality

[12] J.J. Gutierrez, J. Ruiz, A. Lazkano and L.A. Leturiondo, Measurement of Voltage Flicker: Application to Grid-connected Wind Turbines, University of the Basque, Spain

[13] Wind-grid integration brief, Technical Report, Caribbean Renewable Energy Development Program, 2005. Available at: http://www.caricom.org/jsp/projects/wind-grid_integration.pdfS, 2012, [access10.07.12].

[14] Rosas, P, Dynamic Influences of Wind Power on the Power System, PhD Thesis, Orsted Institute, Technical University of Denmark, Denmark, March, 2003.

[15] Integrating Wind Power into the Electric Grid, Technical Report, National Conference of State Legislatures, Available at: http://www.nationalwind. org/assets/publications/WINDFORMATTED5.pdfS, 2012, [access15.06.12].

[16] Thiringer T, Petru T, Stefan L. Flicker contribution from wind turbine installations. IEEE Transactions on Energy Conversion 2004; 19: 157–63.

[17] IEC 61000-3-7, Assessment of emission limits for the connection of luctuating load installation to MV, HV and EHV power systems, 2008.

[18] Linh, NT, Power Quality Investigation of Grid Connected Wind Turbines. In: Proceedings of the 4th IEEE Conference on Industrial Electronics and Applications, 2009.

[19] Arrillaga and W. Neville," Power System Harmonics", ISBN: 0470851295,West Sussex: Wiley & Sons, 2003.

[20] 'Analysis of high frequency harmonics injected by wind turbines in a local grid' Master´s Thesis in the Master Degree Programme, Electric Power Engineering, Jacob Eriksson, Department of Energy and Environment Division of Electrical Engineering CHALMERS UNIVERSITY OF TECHNOLOGY Göteborg, Sweden, 2012

[21] Mohan, Undeland, Robbins: POWER ELECTRONICS, CONVERTERS, APPLICATIONS AND DESIGNS Third edition 2003 John Wiley & son Inc

[22] Reactive Power Performance Requirements for Wind and Solar Plants, A. Ellis, Senior Member, IEEE, R. Nelson, Member, IEEE, E. Von Engeln, R. Walling, Fellow, IEEE, J. MacDowell, Member, IEEE, L. Casey, Member, IEEE, E. Seymour, Senior Member, IEEE, W. Peter, Member, IEEE, C. Barker, Member, IEEE, B. Kirby, Senior Member, IEEE, J. R. Williams, Member, IEEE