Integration Criteria of Turkish Wind Energy Generation Plants and Assessment of the Criteria by Analysis

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Abstract

Renewable Energy Sources (RES) are essential of today's world. Wind power is at the forefront one when RES are considered. This paper presents integration of wind energy generation plants (WEGP) criteria to Turkish system and evaluates these criteria by PSS SINCAL and PSSE simulation softwares on a sample model which is connected to distribution system. In this perspective, simulation results are interpreted.

1. Introduction

Renewable Energy Sources (RES) like wind, solar, hydro, biomass etc., are necessary to meet sustainable growth in energy demand. Wind energy is one of the forefronts one in recent years and investment is encouraged by governments. At Energy and Natural Resources Strategic Plan 2010-2014 of Turkey, it is aimed to increase wind energy generation 20 GW by the year 2023 means 30% of national energy production [1]. The total installed wind capacity of Turkey was just 20.1MW generated by 34 turbines in 2005s. Today, it is 3.974GW [2]. Figure 1 shows cumulative distribution of wind power plant [3].

Fig. 1. Cumulative installations for Wind Power Plants in Turkey

In parallel to the strategic actions above, efficient and stable integration to grid of wind energy generation plants (WEGP) phenomena has been arisen. As has been recognized many other countries having high levels of renewable generation penetrations is fundamental to have international harmonisations. Additionally, synchronization of Turkish power system with the interconnected power systems of Continental Europe on 18 September 2010 by two 400 kV lines to the Bulgarian system, and to the Greek system by one 400 kV line increased significant of regulations and control mechanism of compliance to them [4]. Thus, in 2008 first regulation regarding WEPG has been published by Turkish System Operator (TSO) named Annex-18 (grid code), and revised in 2013. Obviously, new revisions will appear in future by means of new investments.

This paper presents main criteria in the latest Annex-18 for WEGPs, assessment of these criteria on a sample wind power plant model integrated to distribution level by simulations, and interpretation of the simulation results including further recommendations for distribution integrated of WEGPs.

2. Requirements of Wind Power Plant Integration

The requirements are not mainly interested in single turbine but contributions at connection point (PCC - point of common coupling) [5].

a. Reactive Capability

The WEGP should be capable to operate all points inside of blue bold curve given in Figure 2. This capability should be ensured in the range between 0.95 – 1.05 pu PCC voltage. Instead 0.9 – 0.95 pu and 1.1 – 1.05 pu PCC voltage 80% of maximum reactive power is required. Maximum reactive power corresponds to 0.95 power factor of installed active power [4].

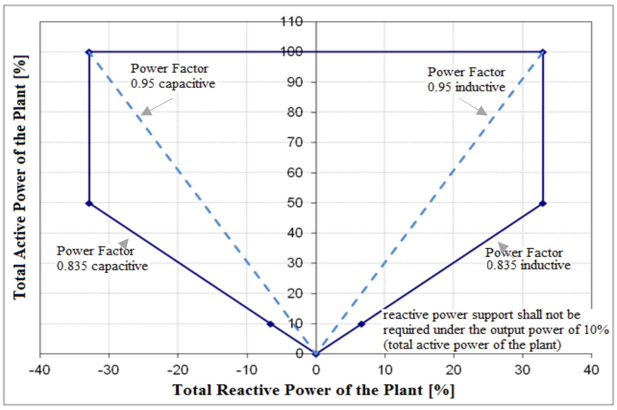

Fig. 2. Required reactive capability curve in Annex-18

b. LVRT (low voltage ride through)

Wind turbine generators have to stay connected to the grid at any PCC fault, which causes retained phase to phase voltage in Area 1 and Area 2 in Figure 3. After the fault is cleared, following ramp rates are required [4]:

▪ 0.2 *Prated*/s up to the available active power if the fault is in area 1, and

▪ 0.05 *Prated*/s up to the available active power if the fault is in area 2

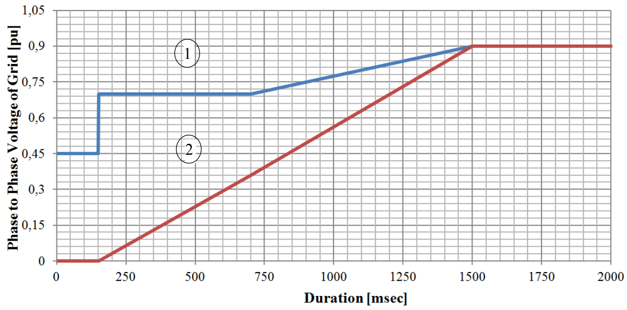

Fig. 3. Required low voltage ride through capability curve in Annex-18

c. Reactive Power Support

WEGP, normally operating under conditions of PCC voltage 0.9 pu – 1.1 pu values, constantly response to changes in the balance of in accordance with Figure 4. Reactive power support depends on droop value set. Defined droop value is between 2% and 7% [4].

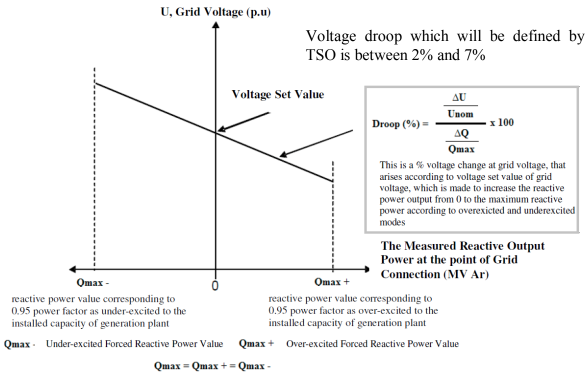

Fig. 4. Required reactive power support capability curve in Annex-18

d. Frequency Response

Annex-18 refers active power output of all turbines at PCC as a function of frequency, is given in Figure 5. Between 47.5Hz and 50.3 Hz, WEGP must be able to produce all of the available power. In case of exceeding 50.3Hz, the plant must reduce its output in proportion to the frequency deviation with fixed droop of 4%, and must shut down if the grid frequency exceeds 51.5Hz [4].

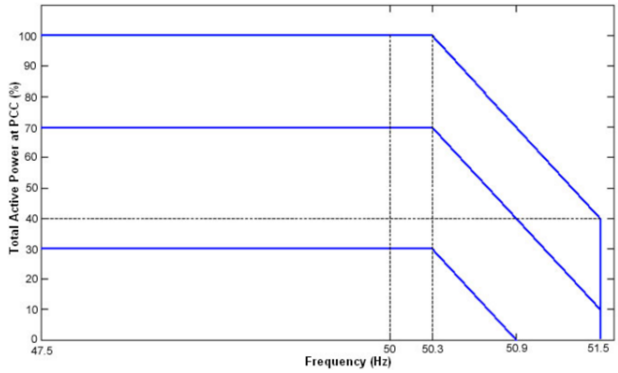

Fig. 5. Frequency response

3. Distribution Integrated WEPP Results

Compliance of Annex-18 should be evaluated for all WEGPs. In case of assessment before installation put in front one step ahead. A sample WEGP model is taken into consideration for evaluation of Annex-18. The system definitions are given below:

- Installation capacity of the plant is 20MW and the system includes 10x2.3MW wind turbine generators
- System voltage levels are 34.5 kV and 0.69 kV
- Each turbine is connected to two 34.5kV collector systems via 34.5/0.69 kV turbine transformer and the collector systems are commoned at 34.5 kV bus bar
- Minimum short circuit power of 34.5 kV point of common coupling is 517 MVA

a. Reactive Power Capability

Reactive power capability of WEGP is simulated for two cases. In Case 1, the plant is connected to the distribution system via 34.5/34.5 kV 30 MVA transformer, which is located by automatic voltage regulator (AVR). Figure 6 shows reactive power capacity simulation results for 95%, 100% and 105% PCC voltage as follow condition:

AVR is activated, all turbine transformer tap position is set to “1”.

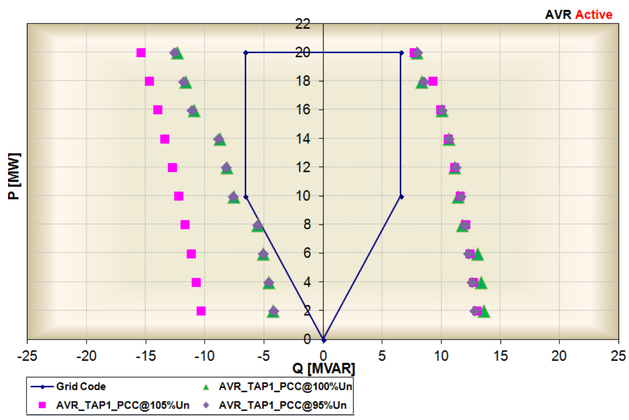

Fig. 6. Reactive power capacity results–connection via 30 MVA 34.5/34.5 kV transformer to the distribution system (with main transformer)

In Case 2, the plant is directly connected to the distribution system (without 34.5/34.5 kV transformer), means 34.5 kV bus bar voltage control is not possible. Figure 7 shows reactive power capacity simulation results for 95%, 100% and 105% PCC voltage as follow condition:

All turbine transformer tap position is set to “1”.

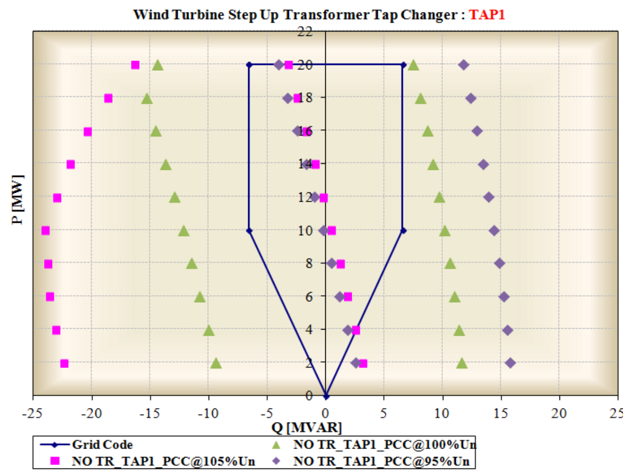

Fig. 7. Reactive power capacity results – directly connected to the distribution system (without main transformer)

When figure 6 and figure 7 is compared it is obvious that installation of the main transformer located with AVR gives advantage of voltage control as a result of reactive power control. Uncontrolled voltage in distribution level limits reactive power benefits of WEGP.

b. LVRT (low voltage ride through)

LVRT simulations are performed for 0% and 30% retained voltage at PCC. Figure 8, figure 9 and figure 10 show voltage and active & reactive power at PCC. As observed during low voltage at PCC, the turbines remains connected to the system and during the fault depending on retained voltage, the turbines decrease active power in order to increase reactive power level.

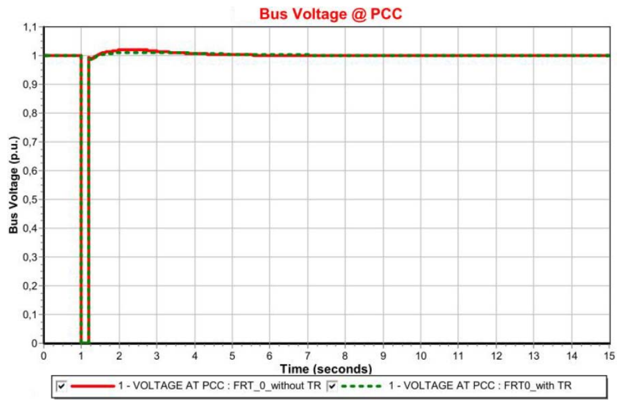

Fig. 8.LVRT-0% retained PCC voltage – voltage variation

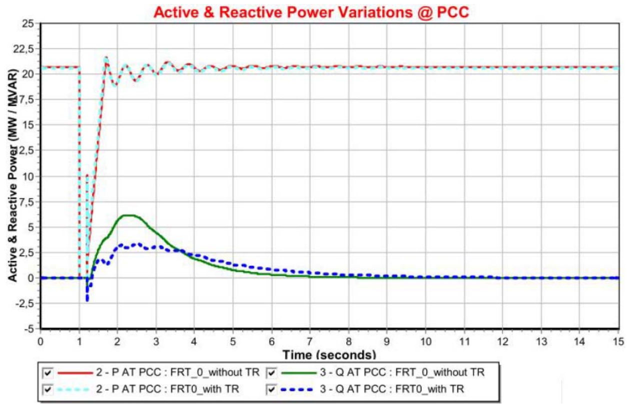

Fig. 9.LVRT-0% retained PCC voltage– active&reactive power

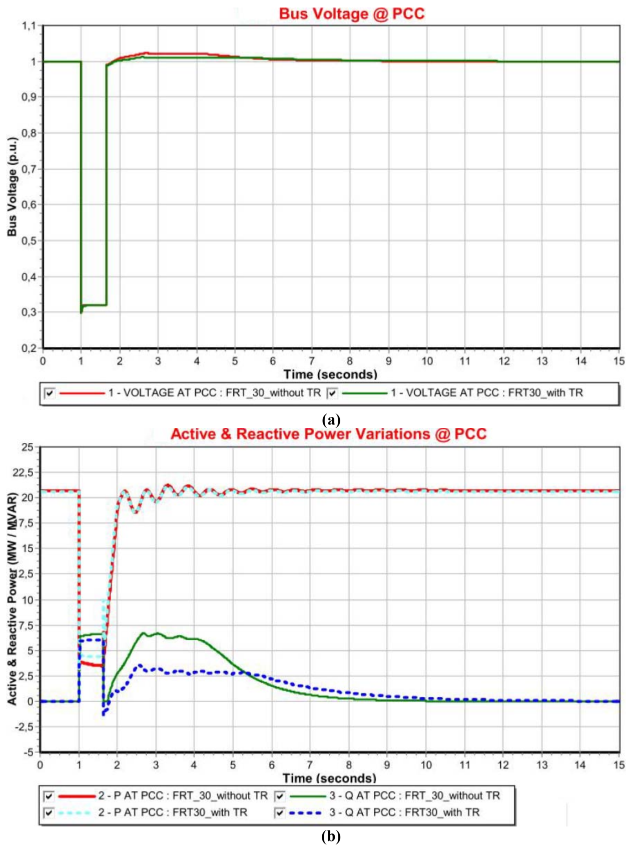

Fig. 10.LVRT-30% retained PCC voltage – (a) voltage and (b) active&reactive power

c. Reactive Power Support

In order to observe reactive power support in PCC, ±5% voltage step changes has been done at PCC. Reactive and active power results in case of voltage changes at PCC are given in figure 11.

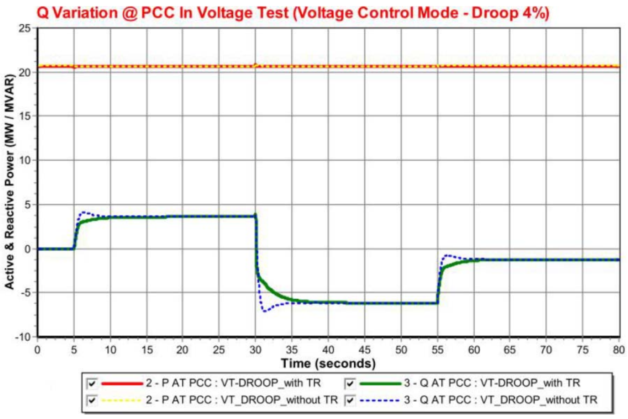

Fig. 11. Voltage test-4% droop – reactive&active power

d. Frequency Response

A frequency test case is created by changing step-wise of PCC equivalent voltage source frequency in order to analyze the power reduction response of the wind turbine plant. The frequency changes and reduction of the active power are given in figure 12 for 100% active power generation. In order to obtain shutting down at 51.5Hz, controller parameterization change can be made.

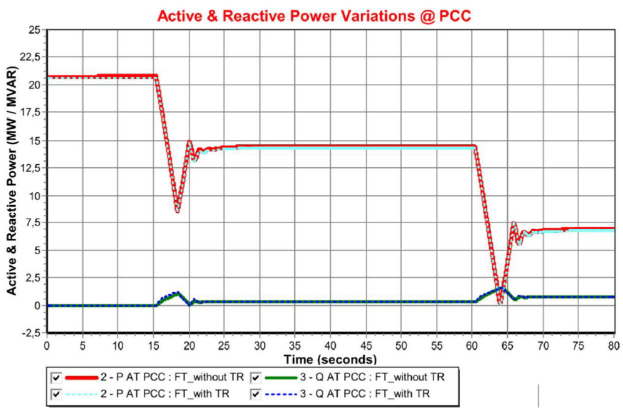

Fig. 12. Frequency response – reactive&active power

4. Conclusions

This paper presents WEGPs integration requirements. Comply with these criteria is highly significant in order to provide synchronization, balance and general power system stability, sustainability and quality without causing any trouble at grid and/or the wind turbine generator side. In parallel with the changes in the power system structure, the pertinent regulations and technical requirements also change and improve. For this reason, the changes in the pertinent regulations and additional demands should be followed-up closely. Therefore; evaluation of the criteria before installation put one step ahead of awareness and consideration of improvements earlier.

This paper presents assessment of the criteria on a sample WEGP connected to the distribution system by PSS SINCAL and PSSE software simulations. Aim is to gain interpretation perspective of analysis results and evaluates integration to distribution system.

5. References

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[4] Turkish Electricity Market Grid Regulation, 07.05.2015

[5] IEEE, IEEE Application Guide for IEEE Std 1547™, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems, IEEE Std 1547.2TM-2008