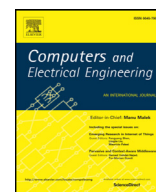




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Power quality analysis for the distribution systems with a wind power generation system [☆]

Cheng-Ting Hsu, Roman Korimara, Tsun-Jen Cheng^{*}

Department of Electrical Engineering, Southern Taiwan University of Science and Technology, Tainan, Taiwan

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ABSTRACT

This paper investigates the impacts of a large wind power generation system (WPGS) on the distribution system. The installation of various types of distributed generators (DGs) on the distribution system will significantly affect the operating, planning and maintaining strategies of the utility. In this paper, one practical distribution system of Taiwan Power Company (Taipower) is selected for study. Various power quality issues like steady state voltage variation ratio, reverse power, flicker, short-circuit current as well as harmonic are investigated and calculated by applying the computer program simulation and the simplified calculation methods suggested by the International Electrotechnical Commission (IEC). The results will be compared with the Taipower relative standards to demonstrate the feasibility of the WPGS to be installed in the distribution feeder.

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1. Introduction

The efficiency improvement of electric appliances and the development of renewable energy are considered to be the most critical issues for the sustainable environment [1]. Among various types of renewable energy sources, the wind power and solar energy have been promoted dramatically world-wide for the distributed generations (DGs) in recent years. Among the renewable energy power-generation systems in Taiwan, wind power systems offer the greatest potential in comparison to existing systems. In the end of 2013, the total installed capacity of wind power generators has achieved 610 MW and is expected to have 4200 MW by 2030.

In general, most of the DGs have smaller installation capacity and have to be connected to the distribution network for providing electric power to the utility as well as local loads. DGs may make a contribution to improve power quality and reliability, reduce peak load demand and eliminate the reserve margin [2–4]. However, it is also a challenge for utilities to execute the planning, operating and maintaining of the distribution networks when the DGs penetration is getting higher. Therefore it is necessary to have a maximum installation capacity limitation of DGs according to the values of voltage magnitude, voltage variation ratio, flicker, fault current, harmonic, unbalance, reverse power and wholesale power.

This paper is organized as follows. Section 2 presents the impacts of DGs on distribution system. In Section 3, a Taipower feeder with a WPGS is selected as a case study. And lastly, Section 4 presents the conclusion.

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^{*} Corresponding author. Tel.: +886 625331313326.

E-mail address: chengtj@mail.stust.edu.tw (T.-J. Cheng).

2. Impacts of DGs on distribution system

To maintain the quality of electricity, reliability and stability of the power supply, and safety of the public, the Taipower has the guidelines for the installation of renewable energy power generation systems. The guidelines cover various assessment items such as voltage variation ratio (VVR), flicker, fault currents and harmonic. Each assessment item was analyzed using a relatively complete power program to execute the load flow, short-circuit fault and harmonic analysis. In addition, the simplified calculation methods recommended by the International Electrotechnical Commission IEC [5] are also included and explained as follows.

2.1. Steady state VVR

The steady-state voltage fluctuations generated by wind turbines in distribution systems is expressed as

$$\Delta V(\%) = n \times \frac{S_{A \max \times 1 \min}}{S_{pcc \min}} \times \cos(\Psi_k + \phi) \quad (1)$$

where n denotes the number of wind generators, $S_{A \max \times 1 \min}$ is the maximum rated effective power in the wind field over 1 min, $S_{pcc \min}$ represents the minimum three-phase short-circuit capacity at the point of common coupling(PCC), $\Psi_k = \tan^{-1}(X_k/R_k)$ represents the grid impedance angle at bus k , and ϕ denotes the power factor angle of the wind generator.

Furthermore, the load flow simulation results can also be used to calculate the VVR by the following equation:

$$VVR_k(\%) = \frac{V_k^{DG} - V_k}{V_k} \times 100\% \quad (2)$$

where V_k and V_k^{DG} are the voltage magnitude at bus k without and with DG, respectively.

2.2. Flicker

The IEC61400-21 standard was also adopted to calculate the voltage flicker created by the wind turbines. This formula can be used to determine both the short-term voltage flicker severity index P_{st} and long-term voltage flicker severity index P_{lt} . It is expressed as

$$P_{st} = P_{lt} = c(\Psi_k, v_a) \frac{S_n}{S_{pcc \min}} \quad (3)$$

where S_n is the maximum rated effective power in the wind field over 1 min, and $c(\Psi_k, v_a)$ denotes the voltage flicker coefficient. Taipower uses ΔV_{10} to assess the voltage flicker severity, and it can be expressed approximately as

$$\Delta V_{10} \cong \frac{P_{st}}{3}. \quad (4)$$

2.3. Fault current

For wind turbines directly installed in distribution systems, the short circuit power (S_{SC}) of the wind generators can be written using the following equation:

$$S_{SC} = n \times \sqrt{3} \times V_{WT \text{ rated}} \times I_{SC} \quad (5)$$

where $V_{WT \text{ rated}}$ and I_{SC} denote the rated voltage and short circuit current of the wind generator.

For wind turbines installed in systems through static power converters (SPCs), the SPC automatically shut down when the fault currents supplied by the power generators exceed the acceptable range. In this study, the fault currents were set as two times the rated current of the SPC.

2.4. Harmonics

In the IEC61400-3-6 guidelines, the formula for calculating the harmonic currents created by wind turbines at the PCC is given as:

$$I_h = \sqrt{\beta \sum_{i=1}^{N_{WT}} \left(\frac{I_{h,i}}{n_i} \right)^2} \quad (6)$$

where I_h is the h th harmonic order at the PCC; N_{WT} is the number of wind turbines; $I_{h,i}$ is the h th harmonic order at the i th wind turbine; n_i is the transformer ratio. $\beta = 1$ when $h < 5$, $\beta = 1.4$ when $5 \leq h \leq 10$ and $\beta = 2$ when $h > 10$.

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