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Optimum Design of Earthing System for Wind Turbine

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ABSTRACT: Wind power production is undergoing rapid growth due to the escalating interest in green energy generation. As a result, generators are now choosing to locate wind turbine generators (WTGs) in areas where there is more lightning activity, and earthing problems can be exacerbated further by the soil resistivity being higher than where turbines are usually located. In addition, the desire to capture more energy from the wind has given way to larger WTGs, further increasing the probability of lightning strikes to the structure. This heightened regularity has emphasized the need for an effective grounding system, capable of dissipating the large currents discharged by the lightning into the lightning protection system. This “effective grounding system” must offer a low impedance by limiting the ground potential rise, which is critical due to the wider frequency content of the lightning discharge currents (ranging from DC to several MHz). The design of an effective grounding system for WTGs depends on the calculation of the minimum length of the earth electrodes, soil resistivity and its frequency-dependency, and the impact of WTG foundation. The calculation of the length of earth electrodes needs an accurate measurement of soil resistivity and modelling of the measured resistivity. Hence, this research considers the measured soil resistivity values of an Australian wind farm and presents an analysis of the soil stratification to identify the optimum soil models.

KEYWORDS: Wind power, Energy, Wind turbine, DC, WTGs, Earth

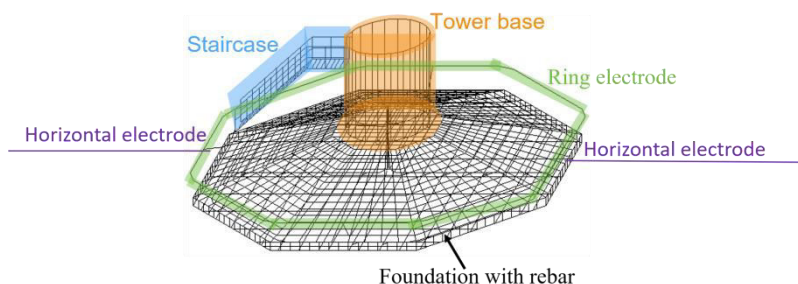
I. INTRODUCTION

Amongst all renewable energy sources, power generation from wind energy conversion systems is growing rapidly. This is partly due to the fact that wind energy has been recognized as an environmentally friendly and economically competitive means of electric power generation. Wind energy has expanded its base from high to low wind speed sites and from small scale kilowatt generation to commercial level megawatt class systems. The increase in power generation capacity of wind turbine generators (WTGs) is due to improvements in technology and the increase sizes of the WTGs. Alternative locations are on level plains where WTG are predominantly high profile structures. Moreover, WTGs are often installed at high soil resistivity sites. The future growth of wind energy may become constrained if improvements in lightning protection systems are not realised. In this paper proposed procedure of proper design of grounding systems for a wind turbine was introduced. This procedure depends on measuring of ground current of simulated wind farm under lightning taking into consideration the soil ionization. The design of a grounding system of a wind turbine is demanding and you need to take into account several factors for the proper and effective implementation. Proper design of a wind turbine grounding system is demanding and several factors for the proper and effective implementation must take into account. In this paper proposed procedure of proper design of grounding systems for a wind turbine was introduced. Aims to improve the lightning protection system of a wind turbine generator by enhancing the earthing system design. This is to be achieved by evaluating suitability of soil resistivity models, factors influencing soil parameters and an enhanced method to design earth electrodes. The earthing electrodes in combination with the rebar structure of the WTG foundation determine the earthing impedance of a wind turbine grounding system. This study computes the earthing impedance and ground potential rise of a WTG earthing system for various earthing electrodes for uniform and horizontal multi-layer soil structures to achieve a low impedance earthing system.

II. RELATED WORK

The wind turbine earthing system is designed by connecting the WTG foundation to the earth electrodes. Depicts the perspective three-dimensional (3-D) view of the wind turbine foundation and the WTG earthing system. The electrode lengths are determined by the soil resistivity of the selected WTG site. The maximum resistivity value of the soil is used for determining the electrode lengths for this analysis.[1]

Soil structure is modelled as a horizontal multi-layer with the resistivity varying vertically through the soil. The details of soil resistivity measurement and modelling are presented. A realistic evaluation of the effects of a lightning strike on a wind turbine depends on the proper representation of lightning discharge currents.[2] The frequency response of the WTG earthing system are calculated for three lightning discharge current wave shapes at two wind turbine sites. WTG-1 in this work represent the low soil resistivity wind turbine site and WTG-2 represents the higher soil resistivity site.[3] The earthing system of WTG-1 consists of a ring earth electrode, the wind turbine foundation and the other metallic components of the WTG. As the soil resistivity of all the three layers is less than $500 \Omega\text{m}$, an earth electrode length of 5 m is the required minimum electrode length adhering to the standard IEC 61400- 24. However, for WTG-2, the maximum soil resistivity is $1762 \Omega\text{m}$ for the bottom layer, hence an electrode length of 45 m has been selected. Hence, the earthing system for WTG-2 comprises of a ring earth electrode, two horizontal electrodes, the WTG foundation and other metallic components.



III. METHODOLOGY

This chapter also describes various lightning discharge current waveform models and the parameters documented in the literature. Also, an introduction to the lightning protection systems for the WTGs is presented. A discussion on the WTG grounding system is also given, along with an overview of the soil resistivity measurements and modelling required for a WTG grounding system.

1. The Blades:

New generation WTGs are equipped with 3 blades, usually made of glass fibre reinforced plastic.

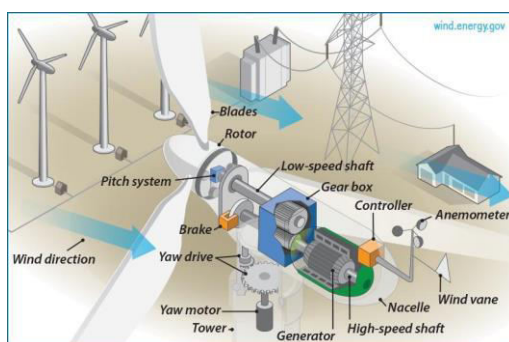


Fig 3.1: Wind turbine generator components

2. The Hub:

The major components in the hub are the pitch drives and battery boxes. Pitch drives control the blades and their angle to the wind direction to get the optimum power from the wind. Battery boxes are used to provide backup power supply to the pitch drives.

3. The Tower

The tower is the backbone of a large WTG. The tower houses the doubly-fed induction generator (DFIG) panel, power and control panels consisting of protection equipment, relays, measurement transformers, filter units, an auxiliary transformer and an uninterruptible power supply (UPS) unit.

4. The Nacelle

The nacelle is the heart of megawatt-class WTGs. Large parts of the electrical and electronic systems such as the generator, controller, and yaw drives are housed in the nacelle. The nacelle is mounted on yaw bearings which in turn are placed on the tower. The yaw system is responsible for the rotation of the nacelle to face the wind direction.

This chapter illustrates an analysis of the wind turbine earthing system for different lightning discharge current wave shapes and soil resistivity values. The grounding impedance is minimum for the first short positive stroke current parameters for all the soil resistivity values compared to the first short negative and the subsequent short current wave shapes, although the peak current magnitude is highest for this wave shape. The high frequency components have major influence on the impedance due to dominant inductive reactance. The wind turbine grounding surface is equipotential at low frequencies and has potential spikes at higher frequencies. In addition, the type B earthing system provided an equipotential surface at higher soil resistivity values. It is evident from the results that there is a strong dependency of the potential profile on the impedance.

IV. EXPERIMENTAL RESULTS

The detailed measurements and modelling of the resistivity of the soil are described. From the modelled soil structures, two wind turbine sites with low and high soil resistivity are considered for this analysis. The Wenner method is used for measuring the soil resistivity at the wind turbine sites. The measured apparent resistivity data is modelled as a horizontal three-layer model with corresponding resistivity values depicted in Table 4.1: ρ_1 , ρ_2 and ρ_3 are the top, central and bottom layer resistivity's, respectively.

Table 4.1: Soil Resistivity Values of Wind Turbine Locations

Location	ρ_1 [Ωm]	Thickness [m]	ρ_2 [Ωm]	Thickness [m]	ρ_3 [Ωm]	Thickness [m]
1	85	0.4	39	21	74	∞
2	1710	2.2	806	13	1762	∞

The frequency response of the WTG earthing system are calculated for three lightning discharge current wave shapes at two wind turbine sites. WTG-1 in this work represent the low soil resistivity wind turbine site and WTG-2 represents the higher soil resistivity site. The earthing system of WTG-1 consists of a ring earth electrode, the wind turbine foundation and the other metallic components of the WTG. As the soil resistivity of all the three layers is less than 500 Ωm , an earth electrode length of 5 m is the required minimum electrode length adhering to the standard IEC 61400- 24. However, for WTG-2, the maximum soil resistivity is 1762 Ωm for the bottom layer, hence an electrode length of 45 m has been selected. Hence, the earthing system for WTG-2 comprises of a ring earth electrode, two horizontal electrodes, the WTG foundation and other metallic components.

V. CONCLUSION

To achieve this challenging task, five objectives were defined for this re- search. The research in this thesis presents an analysis and design of improved grounding system for lightning discharge currents. It start with the analysis of soil resistivity modelling for a wind turbine grounding system considering the relevant parameters. Research into

developing a framework to assess effectiveness of WTG lightning protection system was performed. This analysis also looked into the effect of various lightning protection level and lightning discharge current parameters on WTG grounding system. In addition, a study on various electrode configurations to achieve the research objectives was performed. Finally, a method was proposed to improve the design of earth electrodes of a WTG grounding system.

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