Earthing system lightning

1. 1Introduction

Earthing system electrodes are used to divert high currents to the earth. Therefore a proper design of an earthing system is required to dissipate high currents magnitude to the earth safely regardless the fault type. Lightning and other surges subject the electrical power system to high magnitude and fast rise-time transient currents and voltages requires dissipation to earth in controlled methods. In order to minimise damage to the electrical equipments and safety measures have to be taken to protect the human beings. On high voltage transmission and distribution systems, lightning protection and insulation co-ordination schemes are employed to protect power system equipment from damage. The main factor that determines the effectiveness of these schemes is the soil resistivity properties of the earth.

In this thesis, the performance of wind turbine earthing systems subjected to power frequency and impulses is investigated by considering both their high frequency and transient behaviour.

1. 2 Earthing System Functions

Earthing systems are designed primarily for power frequency earth fault conditions. However, certain plant within substations such as surge arresters will provide a path to earth for transient currents and in such cases the standards recommend the installation of a ‘ high frequency earth electrode’, usually an earth rod [1. 1]. High frequency earth electrode means that the earth rod is to dissipate to earth all the high frequency components of the transient. In practice, all the parts of the earthing system are interconnected and may play a role in the dissipation of both power frequency faults and surges. In the case of wind turbine there will earthing termination system especially designed for lightning protection.

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1. 3 Components of earthing systems

Generally, substation earthing grids consist of a system of conductors buried in the ground occupying an area related to the dimensions of the substation. Additional components may include the metallic sheaths of cables and earth wires of tower lines and their associated tower footings. These extended earth systems emanate from the substation and are bonded solidly to the earth grid. The performance of these components is difficult to predict because soil has a non-homogeneous resistivity ranging from 10 to 10, 000 m [1. 2].

1. 4 Wind turbine earthing system

IEC 61400-24 IEC technical Report of wind turbine generation lightning protection [1. 3] states that each turbine must be equipped with its own earth termination system, even if it connected to a general wind farm earthing system. The report [1. 3] described the basic requirements for lightning protection of the windfarm. Earthing systems should be designed in accordance with ICE 61024-1 standard of lighting protection of structures [1. 4]. This standard recommends two types of earth electrode systems for wind turbines and are referred to as Type A and Type B arrangements.

1. 4. 1Type A arrangement:

This type employs of horizontal or vertical electrodes connected to each down conductor in the case of wind turbine the down conductor would be the wind turbine tower.

1. 4. 2Type B arrangement:

This type uses a ring earth electrode external to the structure soil. A wind turbine normally uses the Type B arrangement with a ring earth electrode placed around the foundation reinforced [1. 3] as can be seen in Figure 1. in the standard the ring earth requires to be in contact with the soil for at least 80% of its total length of a foundation earth electrode. The ring electrode should be buried to a depth of at least 0. 5m. However, Additional vertical and horizontal earth electrodes may be used in combination with the ring electrode. The radius of the ring electrode will therefore normally be defined by the radius of the turbine foundation and extra conductors may have to be installed as stated below.

Figure 1. Typical wind turbine earthing arrangement

Foundation reinforced bar normally bonded to lightning protection earth

Top view

Wind turbine tower

2m vertical electrodes

Transformer

If the recommended 10W resistance by [1. 4] is not achieved then an additional horizontal or f vertical electrodes may be used in combination with the ring electrode.

Also, in the standard it states that no more than 50m of the horizontal electrode can be attached to the wind turbine, may be a low resistance value achieved, but could have high transient impedance due to high series impedance of the conductor.

1. 5 Soil resistivity

Conduction properties of soil are important, particularly its specific resistivity. The soil resistivity is one of the main factors determining the resistance of any earth electrode. Most soils and rocks are poor conductors of electricity when dry. The exceptions to this are certain mineral bodies. However when soils contain water, the resistivity drops, and they may then be considered as moderate conductors, although they are very poor when compared with metals. For example, pure copper resistivity is 1. 6 cm whilst a quite normal value for soil would be 10, 000 cm. The resistivity is determined by the following factors:

a) type of soil b) chemical composition of the soil c) concentration of salts dissolved in pore water d) overall moisture content e) temperature f) grain size and the distribution of grain size [1. 2].

1. 6Tolerable voltage

During a ground fault on a transmission line, a number of towers near the fault are likely to acquire high potential. Potential gradients are also set up in the ground surface and these may present a hazard to humans and livestock. These hazard voltages are generally referred to as touch and step potentials, which are defined [1. 5] as follows:

a) The touch potential is the difference between the earth potential rise (EPR) and the surface potential at the point where a person is standing, while at the same time having his hand in contact with a ground structure [1. 5].

b) The step potential is the difference in surface potential experienced by a person bridging a distance of 1m with his feet without contacting any other grounding object [1. 5].

There are limits placed on the allowable EPR of an earthing system as stated in International Telecommunication Union ITU-T [1. 6]. These limits are as follows.

650 V for sites fed from high reliability lines where faults are rare and cleared quickly (200 ms maximum).

430 V for sites fed from lines having standard protection.

The limits of touch and step potentials are related to the current that can be withstood by a human body before there is a serious risk of fatality [1. 5, 1. 7]. A magnitude in the order of 50mA is sufficient to cause ventricular fibrillation, which will normally result in death [1. 8-1. 9].

1. 7 Standard Lightning Impulse

The lightning impulse is characterised by three parameters, the peak current magnitude, the time to peak current and time to half peak current which is the time required for the current impulse to decay to half of its peak magnitude. However, standard lightning impulse shapes are generally described by the peak current or voltage and the time to the peak T_1 and the time to the half peak T_2 and usually written as T_1/T_2 in microseconds defined as the rise-time. e. g. a 10kA, 5/20ms.

Figure 1. 2 Lightning Impulse

Lightning impulses are usually described by their peak current (or voltage) and by T_1 and T_2 written as T_1/T_2 in microseconds. e. g. a 10kA, 5/20ms impulse.

1. 7 Standards Applicable to Earthing Systems

There are UK and international standards provide guidelines to different earthing systems configurations design. These standards are concerned with power frequency earthing systems design and give limited guidance when earthing system subjected to transient conditions. These standards are:

Engineering Association Technical Specification 41-24 (EA TS 41-24), ‘ Guidelines for the Design, Testing and Maintenance of Main Earthing Systems in Substations’ (UK) [1. 1]. This standard recognises that ‘ *equipment such as surge arresters and CVTs are more likely to pass high frequency current due to the low impedance they present to steep fronted surges* ‘. This standard suggests that unless a low impedance earth connection is provided, the effectiveness of a surge arrester may be compromised. It is therefore recommended that the connection from the equipment to earth should be “ *as short, and as free from changes in* *direction, as is practicable* “. Another guideline in the same standard states that the effectiveness of a surge arrester can be improved by placing a ‘ *high frequency earth electrode* ‘ in its immediate vicinity. The standard does not specify any quantitative limits such as over all earthing impedance limit.

ANSI/IEEE standard 80 [1. 5] ‘ Guide for safety in AC substation grounding’ widely used throughout the world. This standard does not provide detailed guidance for designing for earthing systems subjected to transient conditions. However, it considers that an earthing system that is designed to be safe for power frequency faults should also be safe for transient faults. This is based on the assumption that the human body can withstand higher currents for very short duration. It also considers the safety issues and defines the touch and step potential and provides equation which can be calculated.

CENLEC HD 637 SI, ‘ Power Installation Exceeding 1kV ac or 1. 5kV dc’ [1. 10]. The standard provides measures to reduce the amount of interference created when surges are dissipated to earth. These measures include reducing the inductance of the current path by significantly meshed the earthing system. Moreover, the connection to the earthing system should be as short as possible.

– BS 6651 [3] Protection of structures against lightning the standard recommends that the earthing system designed for lightning protection should have an earth resistance of less than 10W. The same requirement appears in BS 61400-24: 2002 Wind turbine generator system __ Lightning protection with some details regarding earthing system arrangements as mentioned previously.

1. 9 Aims of the research

Wind turbines become the largest growing electrical energy in the world.

Wind farms, however, have particular requirements for earthing compared with conventional electrical installations. They are often very extensive, stretching over several kilometres and subject to frequent lightning strikes due to the height of the structures and their location on high rocky terrain with associated high earth resistivity. Consequence of these developments, there is an increase in fault current associated with windfarms and an increase in the probability of a lightning strike a wind turbine. Therefore, the protection of human beings and livestock becomes more important due to the trend towards large scale high capacity wind farms.

The aims and the objectives of this work therefore can be summarised by the following:

To review the methods that representing the wind turbine earthing system and their limitations

To develop models that produce more accurate results.

To use computer simulation to overcome problems in modelling of the wind turbines earthing system

To carry out computer simulations in order to investigate the importance of the wind turbine steel tower in modelling of wind turbine earthing system.

Design mitigation techniques for fast surge injections.

To carry out soil resistivity using a 2-D technique in order to obtain a soil model to be used for Wind Turbine earthing simulations.

To carry out dc, ac and impulse measurement of resistance/ impedance of an isolated wind turbine.

To carry out dc, ac and impulse measurement of resistance/ impedance of the wind farm interconnected at the location of wind turbine used in point above.

To carry out measurement of safety voltages (step and touch voltages) around an isolated wind turbine.

To carry out measurement of safety voltages (step and touch voltages) around the same wind turbine when its earthing system is bonded / connected to the wind farm earthing network.

To obtain details of the design and construction of the test wind turbine (s) for CDEGS simulation purposes.

To draw conclusions and suggest recommendations for a better estimation of Wind farm earthing systems and related safety precautions.

1. 10 References:

[1. 1] Technical Specification 41-24, Guidelines for the Design, Testing and

Maintenance of Main Earthing Systems in Substations, Electricity

Association, 1992.

[1. 2] Tagg, G. F.: ‘ Earth Resistance.’ Gorge Newnes Limited. (London), 1964.

[1. 3] IEC Technical Report, Wind Turbine Generation System -24: Lightning

Protection, TR61400-24, 2002.

[1. 4] IEC International Stand Protection of Strictures against Lightning IEC61024

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[1. 5] IEEE guide for safety in AC substation grounding, ANS/IEEE standard 80,

2000.

[1. 6] ITU-T (International Telecommunication Union): ‘ Calculating Induced Voltage and Currents in Practical Cases.’ Volume II, 1999

[1. 7] International Electrotechnical Commission IEC Report 479-1: ‘ Effects of current passing through the human body’, IEC, 1984.

[1. 8] Electricity Association: ‘ Engineering Recommendation S. 34: A guide for assessing the rise of earth potential at substation sites.’ Engineering

Management Conference, May 1986.

[1. 9] IEEE: ‘ IEEE Std 81. 2-1991, IEEE Guide for measurement of Impedance and Safety Characteristics of Large, Extended of Interconnected Grounding

Systems’, The Institute of Electrical and Electronic Engineers, New York, 1991.

[1. 10] HD 637S1, ‘ Power Installations Exceeding 1kV AC’, European Committee

for Electrotechnical Standardisation (CENELEC) 1999.

[1. 11] BS 6651, Code of Practice for Protection of Structures Against Lightning,

British Standards Institution, 1992.