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Earthing Parameters of the Hybrid Power Stations: Design and Determination

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***Abstract*— Renewable energy markets have grown predominantly due to strong, consistent international incentives and policies. Earthing the hybrid power systems is the key of power station safety; this paper considers the effective earthing parameters of the hybrid power station. The earthing resistance depends on three different factors; sun states, soil types, and the used electrodes. The effect of these factors together on the earthing resistance are in particularly evaluated. Characterization the resistivity of the frosty soil based on measured data is demonstrated and discussed. The earthing resistance calculators are carried out using Simulink Matlab package. On one side, stony and rocky soil with a very shiny sun state, yields the higher earthing resistances. On the other side, the lower earthing resistances can be obtained with boggy soil at night. These show the dangerous of neglecting any of the whole environmental climates during soil resistivity determination for the earthing purposes. Moreover, higher protection of the hybrid power systems can be achieved by integrating these systems grounds.**

Keywords*— *Hybrid Power System, Earthing, Grid, Renewable Energy

I. Introduction

Electrical grounding or “Grounding” originally began as a safety measure used to help prevent people from accidentally coming in contact with electrical hazards. Objective of any power system grounding is to provide a low impedance path for current to drain into the ground at the point of fault with the least clearing time. However, there could be situations where obtaining a low impedance path would not be an economical solution. Hence we have to modify our grounding design to best fit the situation. A poor grounding system leads to instrumentation errors and harmonic distortions in any electrical system. Therefore, a good grounding system is very important not only for safety reasons but also for preventing damages to industrial plants and equipment. The design of a good grounding system depends on many factors such as the weather, characteristics of the soil, the surrounding environment of the power plant, the arrangement of the grounding electrodes, etc. After looking into the importance of a good grounding system design, many researchers have carried out extensive studies in this area. [1-3]. The earthing in electric powered strength facilities is to ensure powerful protection of people and animals from accidents outdoor and within the substation [4-7]. The renewable energy enterprise has the crucial characteristic in normal boom in the global financial gadget within the closing too many years, renewable power property, i.e., power generated from sun, wind, biomass, Biomass assets have an amazing functionality in sustainable energy selling [8-12]. The increased penetration of wind power will increase the impact of wind power on the grid and thereby increase the importance of a clear guidance concerning the requirements on the protection system of the wind power units [13]. Photovoltaic (PV) power systems are capable of producing hazardous voltages and currents for decades. To ensure the safety of the public for these extended periods of time, PV systems must be properly designed and installed using the highest standards of workmanship. Proper grounding of a photovoltaic (PV) power system is critical to ensuring the safety of the public during the installation’s decades-long life. Although all components of a PV system may not be fully functional for this period of time, the basic PV module can produce potentially dangerous currents and voltages for the life of the system. Effective, code-compliant, properly maintained grounding helps ensure the overall safety of the system, even if it is no longer producing usable power. Grounding resistance must be estimated in an early layout segment, its most authorized value of soil resistance varies from 0.1 Ω to 10 Ω [14-15]. Electric parameters of the earthing GADGET depend upon soil resistance and earth electrode geometry. Resistance of soil is characterized by way of earth resistivity, which changes over an extensive variety from some Ω.m up to 3 thousand Ω.m, relying on the sort of soil chemical composition. The relationships describing earthing resistance are derived with take into consideration that the soil has a homogeneous shape and regular resistivity [16-20].

II. Effective Parameters of the Earthing Resistance

Good earthing as mentioned before depends on several factors, such as soil types, sun statuses, and both rod type and dimensions. Soil can be classified into stony, rocky, sandy and boggy soil. The sun statuses are very shiny, shiny, low shiny, disable sun effect and no shine or winter. they have different effects on the earthing resistance. The soil resistivity is varying with the changes of the environmental climate. One can determine the soil resistivity using equation (1),

$$\rho = 2 * \pi * A * \left(\frac{I}{V}\right) \quad (1)$$

where ρ: is the resistivity in ohm-meter of the soil, A is the distance in meter between probes, I is the current source value in ampere and V is the measured voltage in volt. Some of measured resistivity ranges are listed in table. 1.

Table.1. RESISTIVITY OF DIFFERENT SOIL TYPES

Soil type	Resistivity (ohm-meter)	
	Range	Average
Boggy soil	2-50	30
Adobe clay	2-200	40
Silt, sand and humus	20-260	100
Sand and sandy soil	50-3000	200
Peat	>1200	200
Stony and rocky soil	100-8000	400

III. FROSTY SOIL RESISTIVITY BEHAVIOUR

The hybrid renewable energy sources with public grid power stations are distributed on different soil types as well as different whether climates. Furthermore, the wind energy generators may be located in a moisture soil. In case of lower environmental temperature, the soil resistivity can dramatically be changed (increasing or decreasing) according to the moisture state. Increasing the temperature degrees in the range down the 15 C^0 yields a lower soil resistivity due to the moisture unfreezing, while the increasing in the range above the 30C^0 gradually results in a higher soil resistivity due to the moisture drying as shown in Fig.1.

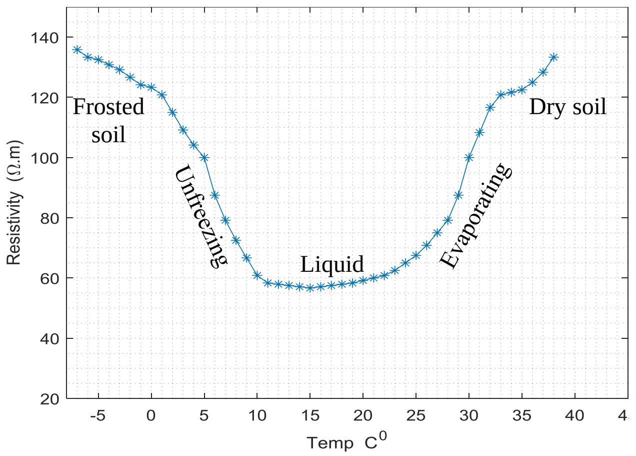

Fig.1. *Moisture sandy soil resistivity versus temperature*

On the other hand, decreasing the temperature degrees in the range down the 35 C^0 yields a lower soil resistivity due to the moisture presence (liquid state), while the decreasing in the range down the 5C^0 gradually results in a higher soil resistivity due to the moisture freezing. Soil resistivity along one frosty month are measured and displayed in Fig.2. However, relating the moisture amount in the soil to the soil resistivity can be empirically estimated. Considering the seasonal climates one can expect a higher immunity prospective to earthing the hybrid power systems. These different parameters can provide an interpretation for different values of the soil resistivity.

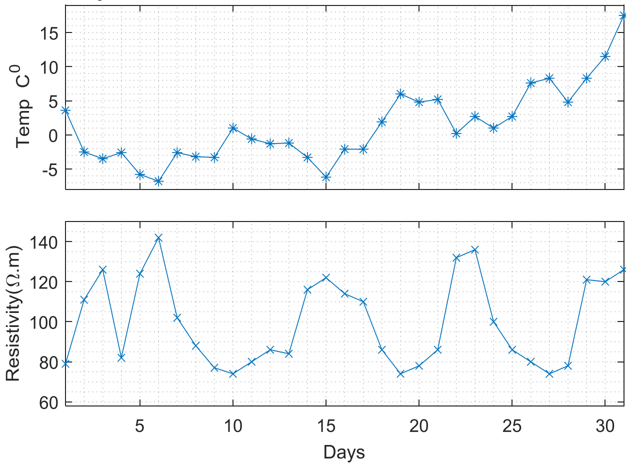

Fig.2. *Measured frosty soil resistivity versus temperature*

IV. EARTHING RESISTANCE CALCULATION

The earthing system often includes single rod, multi rods as well as lattice grid, the challenges of successful system protection are the soil type and the rod type and dimensions. In the next sections, two different alternatives of the earthing parameters will be elaborated.

A. Single rod earthing system

The earth resistance in term of the soil resistivity and the rod dimensions is given by eqn.2,

$$R = \frac{\rho}{2\pi L}\left[ln\left(\frac{8L}{d}\right) - 1\right] \quad (2)$$

where R is total earth resistance, L, d are the rod length and diameter respectively, and ρ is the soil resistivity.

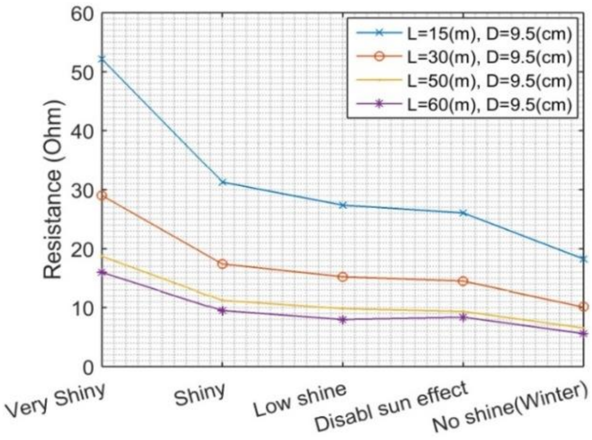

Fig.3. *Rod lengths versus sun statuses*

In Fig.3, a 9.5cm rod diameter in a rocky soil type yield a range of the earthing resistance from 52.5Ω to about 5Ω corresponding to a range of rod lengths from 15m to 60m respectively. The same rod dimensions with a boggy soil provides an acceptable and recommended earthing resistance in the range of 0.5Ω up to about 5.0Ω as shown in Fig.3. A limited improvement can be obtained by the earthing resistance reduction via the rod diameter increasing as shown in Fig.4. however, the single rod is one of the earthing techniques, lower safety due to the unacceptable earthing resistance can be instigated.

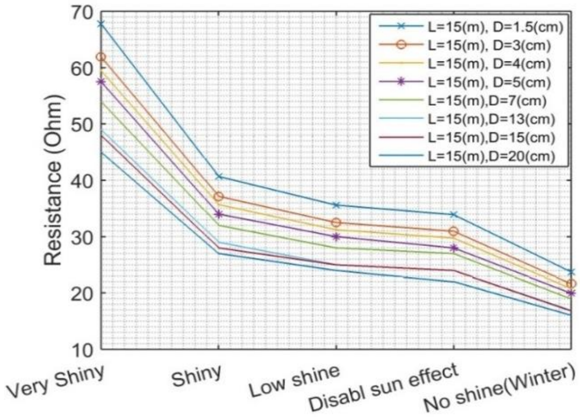

Fig.4. *Rod lengths versus sun statuses*

Multi rod can therefore, be considered for higher safety of the hybrid power station. The single rod earthing scheme has a limited reduction range of the earthing resistance that in case of stony and rocky soil types. The grid earthing scheme provides a quite acceptable reduction range of the earthing resistance. Calculation of grid parameters will be discussed in the next section.

B. *Lattice (grid) earthing system*

In order to carry out these computations, Simulink model and Matlab computer program has been developed. Fig.5 illustrates an L_X*L_Y square meters (m^2) grid; it consists of N regular squares of d_X*d_Y (m^2).

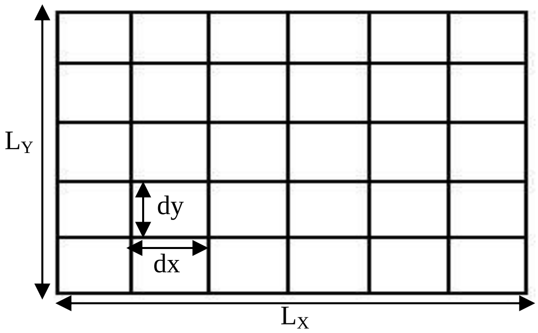

Fig.5. *Earthing grid*

The soil is assumed to be homogenous with a 300Ω.m resistivity. Soil resistance can be calculated by using the equation (5).

$$R_g = \rho\left[\frac{1}{L_T} + \frac{1}{\sqrt{20A}}\left(1 + \frac{1}{1 + h\sqrt{20/A}}\right)\right] \quad (5)$$

Where R_g is the grounding resistance (Ω), ρ is the soil resistivity (Ω.m), L_T is the total length (m), A is the area of lattice (m^2) and *h* is the depth of lattice (m). In the following section results of different grid earthing schemes will be elaborated. Indeed, the lattice (grid) can be found in a square, rectangular, L, or T shapes. However, these lattice shapes are available, the shape effect is considerably limited or can be neglected. The dominant effective grid parameters are the total rod length of the grid, square dimensions (rod spaces), soil type and the sun states.

1. *Lattice dimensions*

A lattices of 70mx70m, and 0.5m depth, the earthing resistance of different rod spaces as well as the different sun statues are depicted in Fig.6. The freezing effect are neglected in these results due to the consideration of the tropical environment.

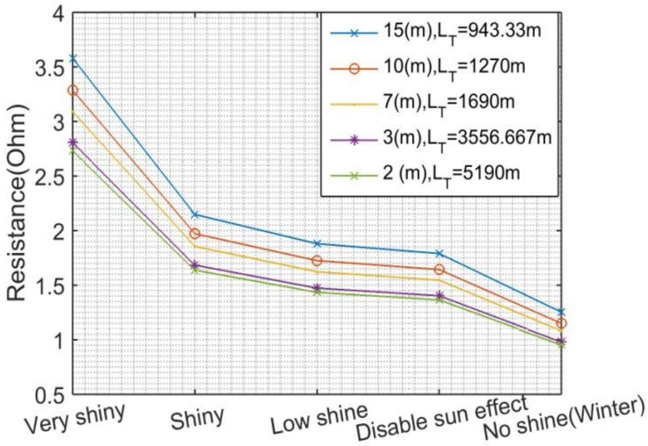

Fig.6. *Total length and spaces versus sun statuses*

The influence of the total rod length and the rod spaces of the grid is shown where increasing about five times of the length yields in about 21% reduction of the earthing resistance. As mentioned before, the effect of the grid shape can be neglected as shown in Fig.7.

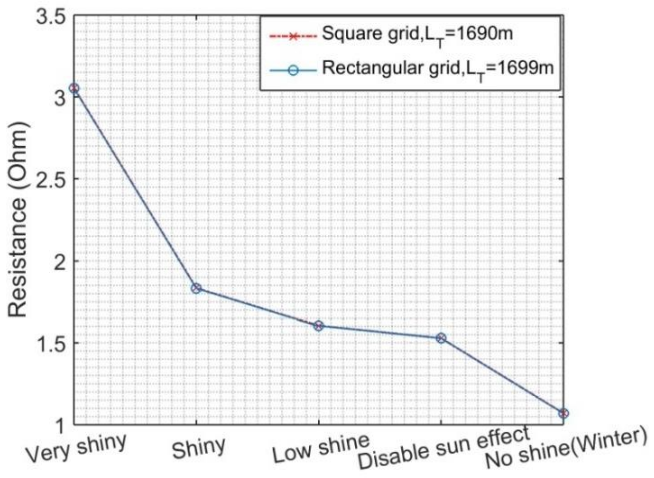

Fig.7. *Grid shape versus sun statuses*

2. Soil types

The grid earthing resistances of the same 70mx70m lattice, 2m space, about 5040m length and 0.5m depth are calculated for different soil types at different sun states. The calculated resistances are depicted in Fig.8. in this figure, moisture effect at different sun states is clearly displayed in case of both wetted and dry concretes.

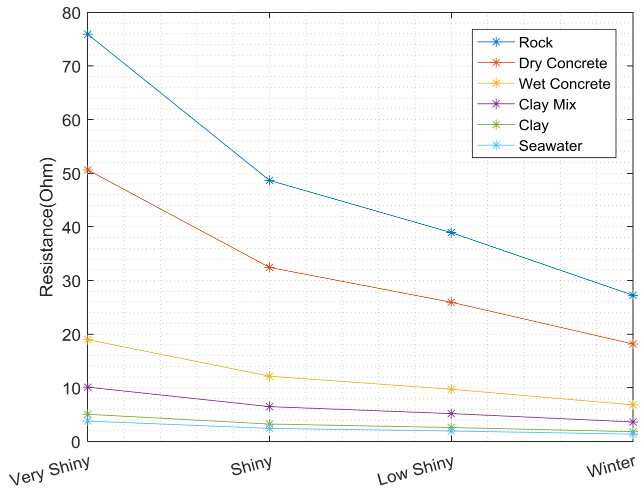

Fig.8. *Grid resistance for different soil types and sun states*

Broadly, soil hybridization with another soil type, salts treatment, or grid design considering the environmental climate are the most suitable alternatives of earthing the hybrid power stations.

V. Conclusions

The effect of the soil types, electrode dimension, and the sun states on earthing resistance in has been discussed and presented. Behavior of the frosty soil resistivity based on measured data has been described. Safe earthing of the hybrid power station should consider effect of the temperature and the moisture in addition to traditional earthing parameters. The single rod earthing scheme has a limited range of the resistance reduction. This technique may satisfy the recommended earthing resistance in case of considering soil hybridization concept. The grid earthing scheme offered further reduction of the earthing resistance that is almost linearly proportional to total grid (rod) length. The results show that both the grid shape and the rod dimeters have limited effect on the earthing resistance reduction.

VI. References and Further Readings

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