Earthing Grid Design and simulation of an Electric Substation (33/11KV-30MVAsc) Using an Electric Transient and Analysis Programmer

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ABSTRACT

Earthing can be defined as an earth being used as a conductor to get electrons back to the supply, consequently earthing all equipment as well as all metallic structures in substations can prevent workers and equipment from getting affected by the rise of voltages, which always cause disaster to the workers, equipment, as well as the animals which may get too close to the electric substations. Ground potential rise (GPR) is one factor that must be considered during the design. GPR increasing leads to the potential gradient getting increased, hence the value of GPR must be identified well during the design. In this paper, the earthing grid for a 33/11KV-30MVA electric substation was simulated using ETAP. In addition, the ground short circuit current is simulated. Moreover, the substation soil resistivity is measured using the Wenner 4 pins method. The main calculations for the earthing grid design are obtained. GPR, touch, and step voltages are mathematically calculated using specific formulas. Step potential, and touch potential profiles are graphically obtained by using ETAP 19.1.0. All data required for the design is attached. The absolute potential profile is graphically illustrated. The summary of the substation earthing grid design output is obtained. The layer of the soil, which is used for the design is 3 layers, and the shape, which was used for the earth grid is chosen to be a rectangular shape. The finite Element Method (FEM) in ETAP19.1.0 is used as a base for the methodology of the earthing grid design.

الملخص:

يمكن تعريف التأريض على أنه الارضية التي تستخدم كموصل لإعادة ارجاع الإلكترونات حرة الحركة إلى مصدر التغذية، وبالتالي فإن تربة جميع المعدات وكذلك جميع الهياكل المعدنية في المحطات الفرعية يمكن أن تمنع العمال والمعدات من التأثر بارتفاع الجهد، التي تتسبب دائمًا في كارثة للعمال والمعدات والحيوانات التي قد تقترب كثيرًا من المحطات الفرعية الكهربائية. الارتفاع المحتمل لجهد الارضي (GPR) هو أحد العوامل التي يجب أخذها في الاعتبار أثناء التصميم. تؤدي

زيادة GPR إلى زيادة التدرج المحتمل في الجهد الكهربي، وبالتالي يجب تحديد قيمة GPR جيدًا أثناء التصميم. في هذه الورقة، تمت محاكاة شبكة الأرض لمحطة فرعية كهربائية (33/11KV) باستخدام برنامج المحاكاة (ETAP). بالإضافة إلى ذلك، تم محاكاة تيار القصر الارضي لمحطة التحويل ببرنامج الايتاب. تم قياس مقاومة التربة في محطة التحويل باستخدام طريقة **وينر** ذو الاربع اقطاب. تم الحصول على الحسابات الرئيسية لتصميم شبكة الأرضي حيث تم حساب كلا من جهد GPR وجهد اللمس وكذلك جهد الخطوة رياضيًا باستخدام صيغ محددة. تم الحصول على منحنيات لكل من جهد الخطوة وجهد اللمس المحتملة باستخدام رنامج الايتاب. بالاضافة الي ان جميع البيانات المطلوبة للتصميم تم تدوينها واستخدامها اثناء التصميم. باستخدام برنامج المحاكاة الايتاب تم الحصول علي مقدار فرق الجهد المطلق والمطلوب مقارنته مع كلا من جهد الخطوة وجهد اللمس للحصول علي تصميم ذو كفاءة عالية. تم الحصول على ملخص مخرجات تصميم شبكة تأريض لمحطة التحويل. طبقة التربة التي تم استخدامها في التصميم هي 3 طبقات، والشكل الذي تم استخدامه للشبكة الأرضية يتم اختياره ليكون شكل مستطيل. تم استخدام طريقة العناصر المحدودة (FEM) في برنامج المحاكاة الايتاب كأساس لمنهجية تصميم شبكة الأرضي.

KEYWORDS

Earth Mat, Earthing, ground resistance, electrodes, ground short circuit, earth grid, substations, Safety, Touch and Step voltages, GPR, ETAP19.1.0, Grounding Study.

INTRODUCTION

Substation grounding is vital for providing a low-resistance path to the ground, allowing for a discharge channel in the event of a lightning strike, and protecting equipment and employees from transmitted potential. By providing a low-resistance channel to the ground, the ground potential rise (GPR) can be reduced. The voltage gradient created by an earth fault should be correctly calculated so that it does not exceed the human tolerance limit. In the event of a lightning strike or an earth fault, tremendous current flows through the substation, creating a potential difference that causes a severe electric current to pass through the human body (Mithun et al., 2013).

A good substation grounding design should have low ground resistance and a safe step and contact voltage limit. The purpose of this paper is to give a fast overview of grounding system calculations utilizing Finite Element Method (FEM) methodology by using ETAP 19.1.0. The substation's ground grid is designed to withstand the freezing and wet seasons as well (Mithun et al., 2013).

The Electrical Transient Analyzer Program is one of the best tools, that have been using to analyze electric networks. ETAP enables an engineer to do ground grid design and analysis using principles defined in IEEE-80-1986, IEEE-80-2000, and IEEE-665-1995 standards. For a more precise study, this software also includes finite element modeling (FEM) of the ground grid, which is used in this design. Basically, with this software, both technical and commercial issues can be well Analyzed (Mithun et al., 2013).

Step voltage, touch voltage, mesh voltage, metal-to-metal touch voltage, and transferred voltage are the five forms of shocks that a substation worker may be subjected to. Step and touch voltage are used to determine the safety criterion for grounding grid design. In a proper grounding system, actual mesh and step voltages should be significantly lower than tolerated touch and step voltages. The tolerable safety threshold for grounding system design is calculated using the fibrillation discharge limit of the body current. When constructing substation grounding, the most important thing to remember is that real step and mesh voltages must never exceed the authorized voltage limitations. Figure (1) shows the basic shock scenarios for a substation's ground grid (Prakash et al., 2017).

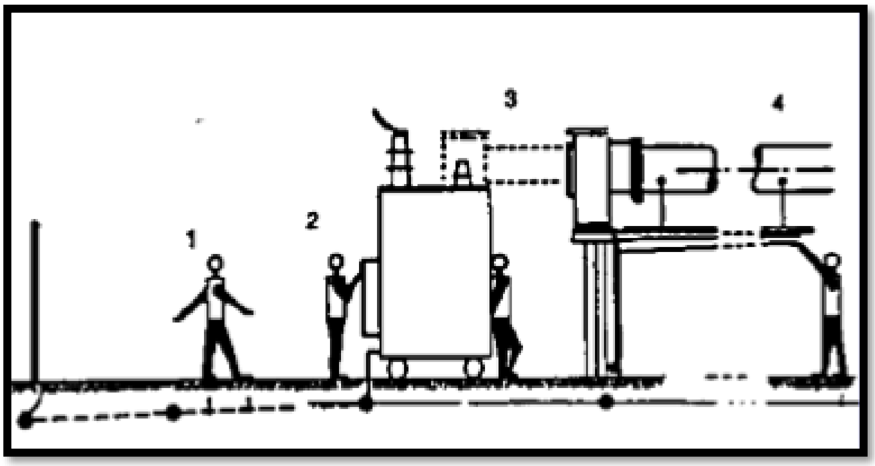

Fig.1 Basic shock situations for the substation ground grid (Prakash et al., 2017)

WENNER FOUR- PROBE TESTER

Wenner method is one of the best technical methods used for earthing resistance measurement as illustrated in figure (2) below. It consists of 4-pins which have to be pushed some distance into the ground. These pins can be effective in most places for measuring the resistance of the ground.

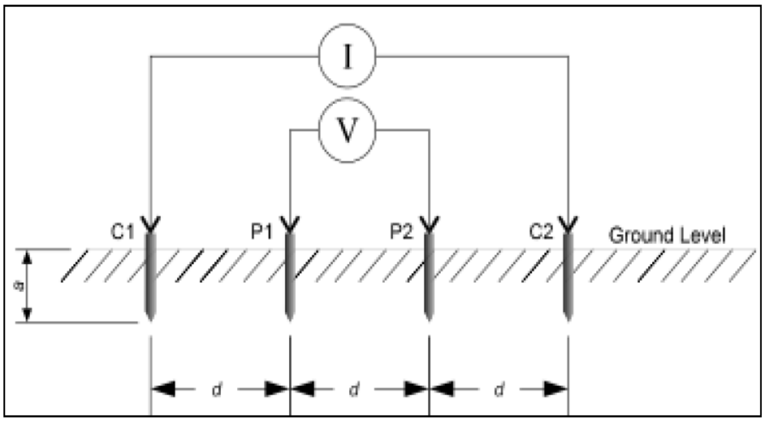

Fig.2 Wenner four-pin method configuration (Prakash et al., 2017)

Generally, for designing an earth grid network, measuring the ground resistance is the first step have to do deal with. However, the Wenner method is a very effective technique for measuring the resistance of the ground for designing an earthing grid well (Prakash et al., 2017).

GROUNDING GRID MODEL SUBSTATION

Different models of establishing networks have been utilized for electric substations in particular rectangular shape, square shape, L-shape, and T-shape. Figure (3) below illustrates the rectangular shape which is the most common shape used in designing the earthing mats (Hardi et al., 2021).

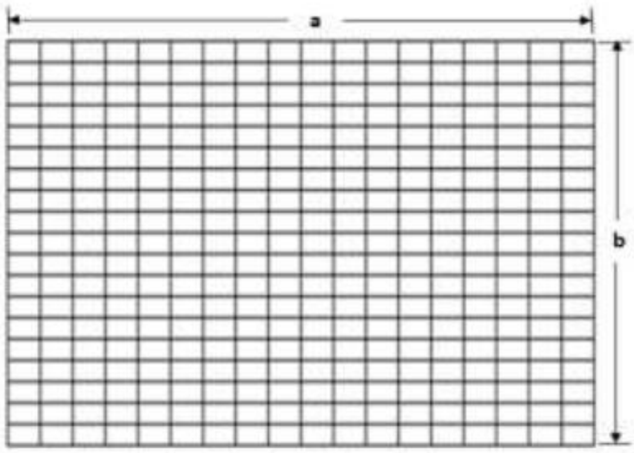

Figure.3 Rectangular shape (Hardi et al., 2021)

GROUNDING RESISTANCE

The significance of establishing obstruction is key to the establishing framework's prosperity or disappointment. On the off chance that this opposition is moderately high, the voltage charge to the ground is not released, and accordingly, its dangers are produced to get away from establishing an organization. The accompanying implications should be shown prior to tending to the significance of this obstruction (Thanoon et al., 2021).

TOUCH AND STEP POTENTIAL CALCULATIONS

Right when power is made from good ways and there are no return ways for earth faults other than the earth itself, then, there is a bet that earth inadequacies can cause unsafe voltage points in the earth around the site of the issue (called ground potential climbs). This infers that someone staying near the issue would be capable of a perilous electrical shock due to:

1. Touch voltages - there is a risky conceivable differentiation between the earth and a metallic thing that an individual is reaching.
2. Step voltages - there is a risky voltage slant between the feet of a person staying on a plant (Esobinenwu et al., 2014).

PROPOSED METHODOLOGY

The proposed system of this paper is planned as follows. Step (1): Collecting all data required to design the electric power system. Step (2): Entering all data into the components of the electric power system. Step (3) Applying the earthing grid on the substation zone. Step (4): Run the load flow analysis. Step (5): Applying the short circuit on LV side of the substation and run load flow analysis to get the value of short circuit current. This value required to complete the earthing grid design. Step (6): Finding the values of step, touch voltage, as well as absolute potential profile. Step (7): Finding the shape of step, touch voltages, as well as absolute potential profile. Step (8): Compare the results of step and touch voltages with tolerable voltage to confirm the design is correct and secured. All steps illustrated will be followed depending on the Electric transient and analysis programmer (ETAP) 19.1.0.

GROUNDING GRID MODEL DESIGN, LOAD FLOW, AND SHORT CIRCUIT ANALYSIS

According to a standard established by the finite element method (FEM) in ETAP 12.6.0, the magnitude of the mesh voltage must be less than the tolerable touch voltage, and the predicted step voltage must be less than the tolerable step voltage. Mesh voltage is a form of maximum touch voltage. Figure (4) below illustrates the load flow analysis of the network.

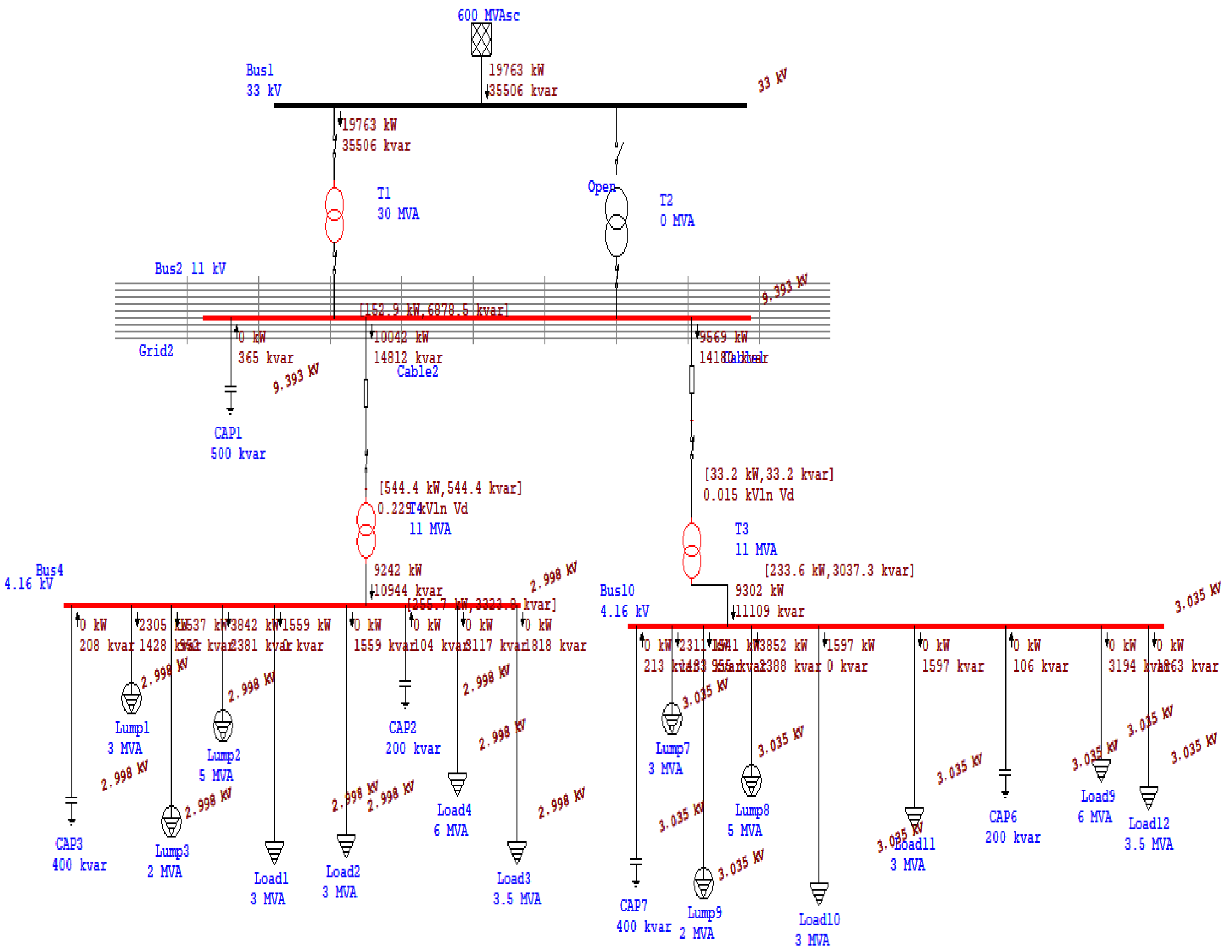

Fig.4 Load Flow Analysis for the electric network model

The results determinations contain information that must be set in ETAP 19.1.0 and according to FEM such as conductor cost per rod network design. Also, step voltages per plan, which are provided in line with the results and the earth system to promote optimization and major cost reduction. The suggested network parameters, such as the maximum flow error and network flow factors K, C_S, and D_f (Tabatabaei & Mortezaeei, 2010).

It is worth noting that the preceding investigations will be carried out for a person weighing 50 kg, at a temperature of 40°C, using the finite element method (FEM) (Tabatabaei & Mortezaeei, 2010). Moreover, the resistivity of the surface material is 2500 Ω.m level network is considered in the design, furthermore, the top layer is formed of (moist soil) resistance at 100 ohms, and the second layer is made of moist soil at 100 ohms as well. Basically, the fault is assumed to be marked on bus2, 11KV . Figure (5) below illustrates the calculated short circuit current (I_{sc}) with a value of 15.686 kA, where $t_f = t_c = t_s = 0.5$ *second* as illustrated in table (1) below.

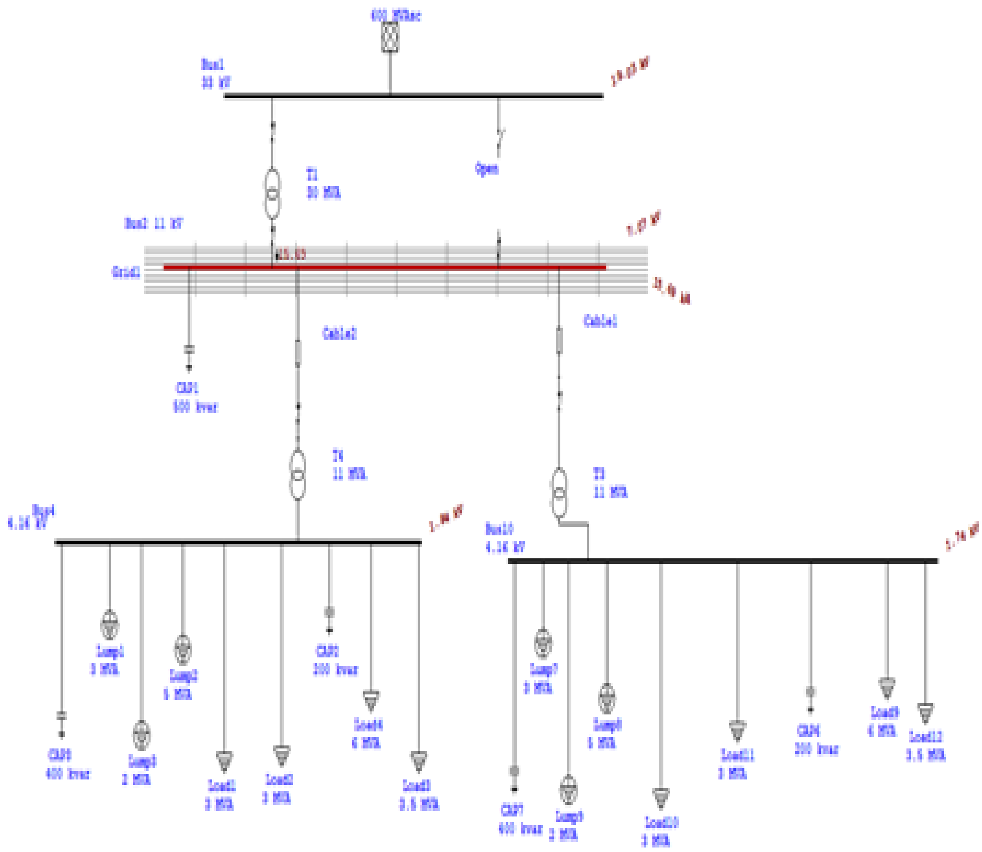

Fig.5 Ground grid short circuit results using ETAP

Earthing grid results and discussion

For earthing mat system analysis, the finite element method (FEM) is used to examine the following 3-D potential profiles. Figures (6) & (7) illustrate step and touch potential profiles respectively with overvoltage constraints. Figure (8) shows an absolute potential profile.

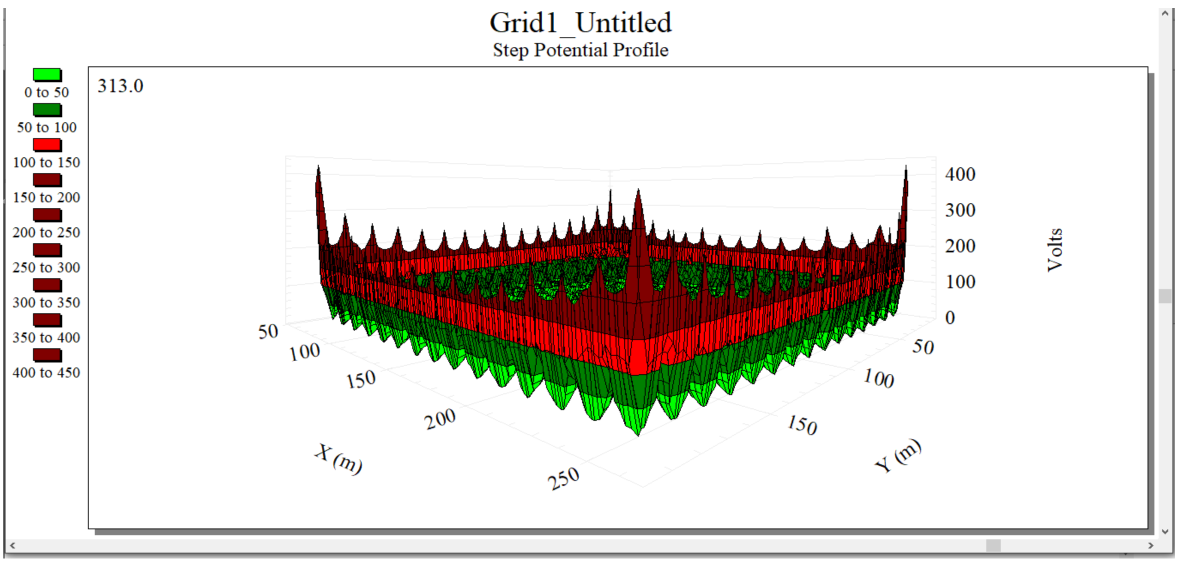

Fig.6 Grounding Grid Step Potential Profile

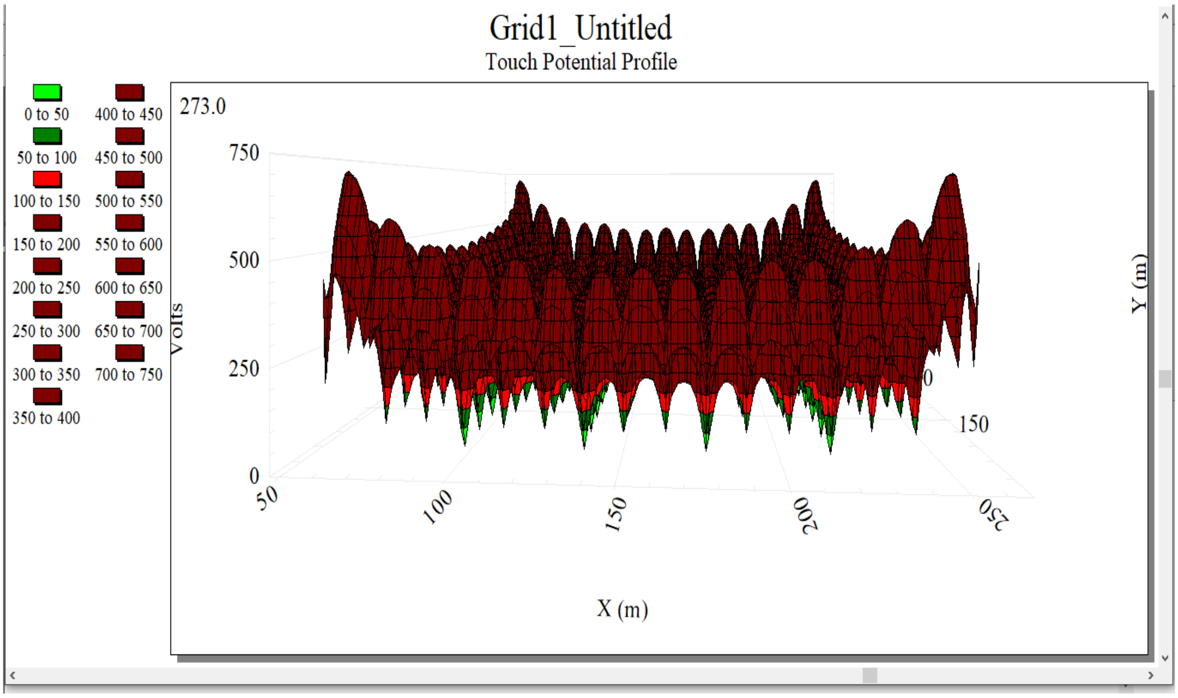

Fig.7 Grounding Grid Touch Potential Profile

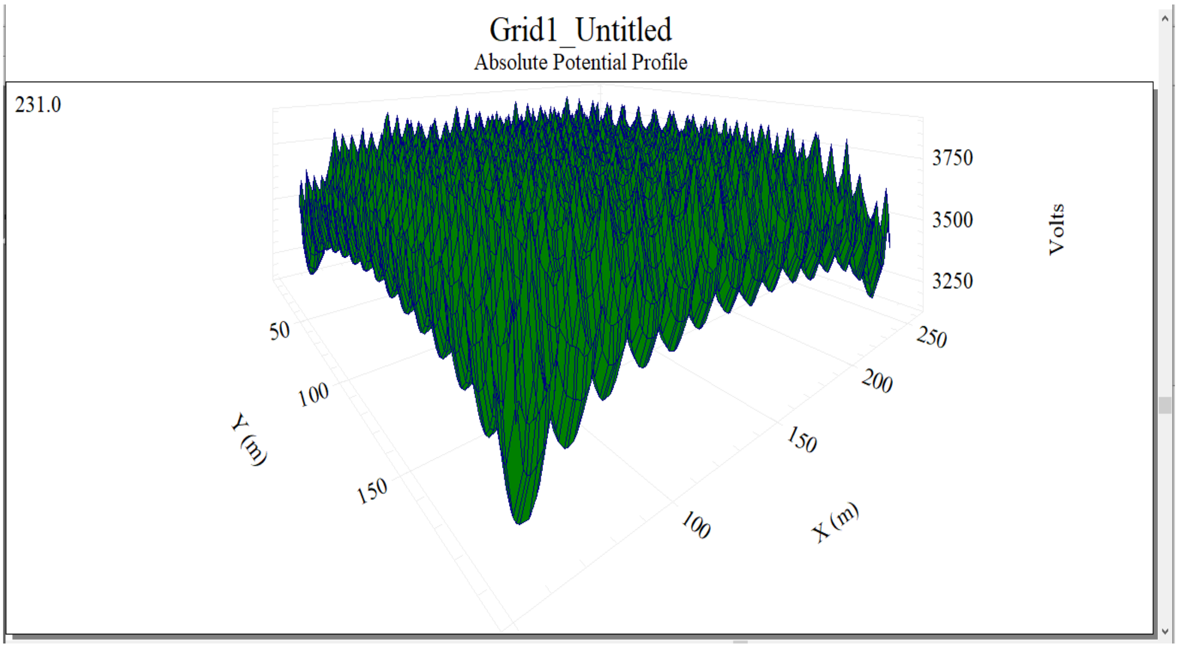

Fig.8 Ground Grid Absolute Potential Profile

Schematic Diagram of A 30KV/11KV, 600MVAsc Substation Earthing Grid Model Design Output Using ETAP19.1.0

The earthing grid of a 33KV/11KV substation was simulated with the ETAP19.1.0 and the grounding grid design was evaluated as well. Rectangular shape is used for the grid design. Except for the shape models and number of rods, the design characteristics of a grounding grid are preserved, including spacing distances, grid depth, soil and crush rock resistivity, conductor diameter, and electricity parameters. The simulation findings for touch and step tolerance for a 50kg body weight are illustrated in figure (9) below.

Based on the size of the site, we selected a rectangular grid design (other grid patterns are also possible, such as a L or T shape), with a 10-meter distance between conductors. A 0.3 m depth is where Grid is buried. Figure (9) below illustrates how the grid is set up. A total of 51 conductors and 7 rods are needed, according to estimates. The results reveal that the manual and simulated values are both satisfactory.

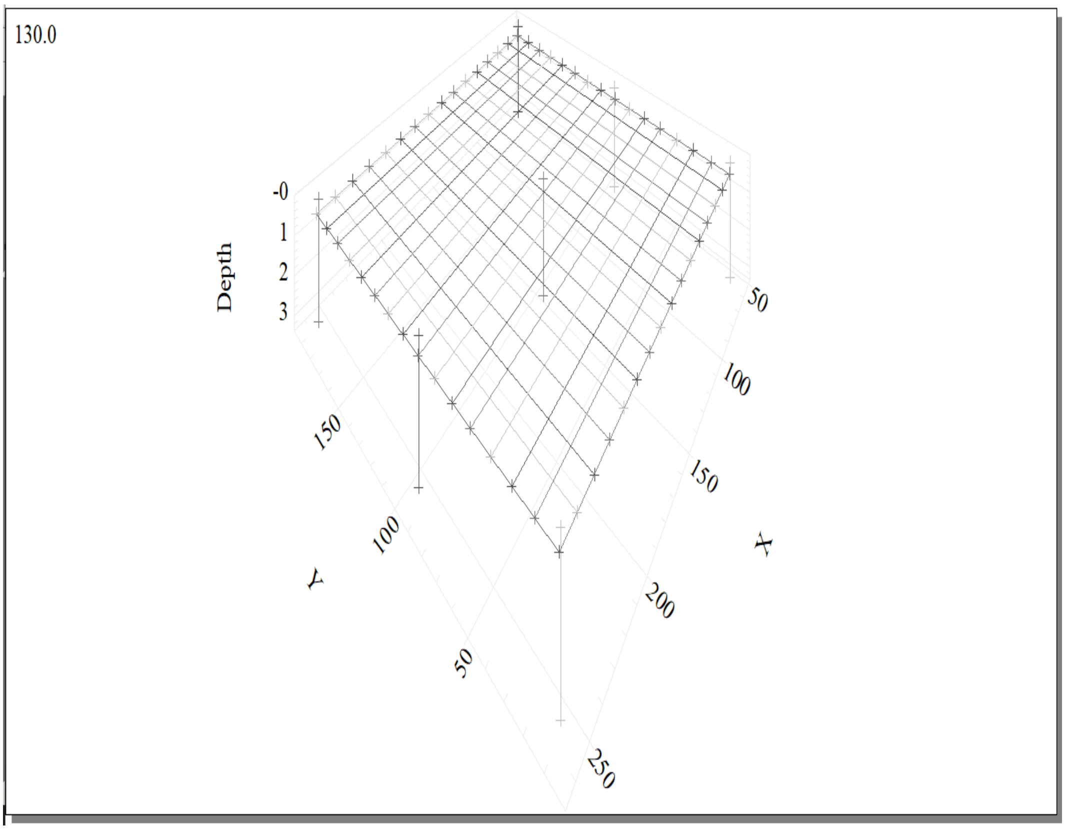

Fig.9 Rectangular-shaped earthing grid with earth electrodes

CONCLUSION

The findings for the earthing system for a 33/11KV substation were obtained using ETAP according to Finite Element Method (FEM) standard. The vertical earth electrode is made of copper, annealed soft-drawn, as is the earthing conductor. A step-by-step method was taken into account during the lengthy manual calculations. Step and touch voltages are harmful to all bodies attached to the substation. Electric shocks can occur when step and touch voltages are used. Step and touch voltages should be estimated when building high-voltage substations, and real values based on the design should be kept within acceptable ranges.

The transfer of ground potential rise (GPR) under fault conditions must be prioritized in order to avoid dangerous scenarios for humans, attached equipment, and even animals in the vicinity of substations. The step and mesh voltages for the (33kV/11KV-30MVAsc) substation are illustrated, which are within allowed limits. The resulting values for both step and touch voltages for the substation are 428.1 Volts & 714 Volts, which are inside as far as possible. Importantly, when high voltage substations are to be designed, it is important that the real values calculated for both touch & step voltages, have to be maintained under the computed tolerable values during the design of the substation.

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