THE CONCEPTUAL DESIGN OF TPS GROUNDING SYSTEM

T. S. Ueng, Y. C. Lin, J. C. Chang, H. S. Wang, NSRRC, Taiwan

Abstract

The TPS (Taiwan Photon Source) of NSRRC is in the design stage now. The grounding system is crucial to the safety issues, the electrical reference level, the electrical noise and the EMI problems. In order to provide a high quality electrical environment, the grounding system should be designed carefully. The soil resistivity of the construction site was investigated first. Many different configurations of the ground grid layouts were simulated and compared. Beside the horizontal ground-conductors, the vertical ground-electrodes of 30 m are considered to be installed below the ground and they will reach the ground water level in hopes of minimizing the resistance of ground grid. The main goal is to obtain a ground grid with resistance lower than 0.2 ohm. A rectangular ground grid will also be installed under the new utility building. It will be connected to the ground grid of TPS to further reduce the resistance of whole grounding system, and also to eliminate the potential difference between them.

INTRODUCTION

Taiwan Light Source (TLS) is an accelerator facility which provides high quality synchrotron radiation for the academic and scientific sectors to pursue excellent researches. After several years of service, the space of TLS has saturated with equipments. In order to provide the scientists with more space and better facilities to perform more advanced researches, a project has been made to construct a new storage ring of higher electron energy, 3.0 GeV, with more advanced features. The new storage ring will be constructed near the original 1.3 GeV storage ring. There are some overlaps in the buildings between the present TLS facility and the new TPS building due to the limitation of the construction site. But, the whole idea is to make the construction of new TPS building without severe interfere with the operation of TLS. At the beginning of the construction of new TPS building, the installation of ground grid should be done first, since it will be installed under the new building. The design and installation of ground grid for the conventional building is much easier. For the accelerator facility, in addition to providing the safety for the personnel and the equipments, the disturbance of fault current or electromagnetic wave to the equipments should also be minimized. This will require stringent rules to the design. Thus, the ground grid of TPS is designed very carefully. Our goal is to build a ground grid with ground resistance lower than 0.2 Ω, and also provide functions to minimize the noisy signals, beside the safety issue.

GEOLOGICAL CHARACTERISTICS

For the construction of TPS, NSRRC has twice requested engineering consultant companies to carry out the geological boring investigations of construction site [1]. The information of strata and related geological characteristics are also used to analyze the soil resistivity of construction site. During two field-boring investigations, there were more than 20 vertical bored holes investigated. Among them there were 11 holes having depth more than 30 m down from the earth surface. Fig. 1 shows the soil boring log from one of the boring investigations. Fig. 2 shows one of the site strata profiles. From the boring investigations and soil test the strata distribution of construction site shows that the strata are generally uniform in the horizontal direction. From the result of field survey, within 30 m under the earth surface the strata can be roughly divided into 3 layers. They are: (1) the top layer is mainly silt clay and sand mixed with gravel. It is about 5 m depth under the surface; (2) the second layer is mainly gravel mixed with sand and is distributed under first layer to approximately 28 m below the ground; (3) the third layer is rock bed, which is mainly silt stone and weathering sand, and is distributed about 23 m below the ground. The natural water content for these 3 layers are roughly 8% to 30% for the first layer, 10% to 25% for the second layer and 14% to 19% for the third layer.

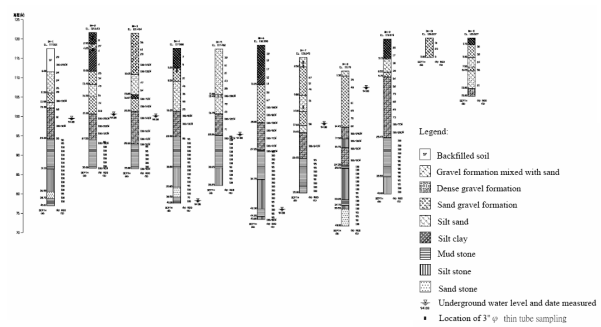

Figure 1: Soil boring log at TPS construction site [1].

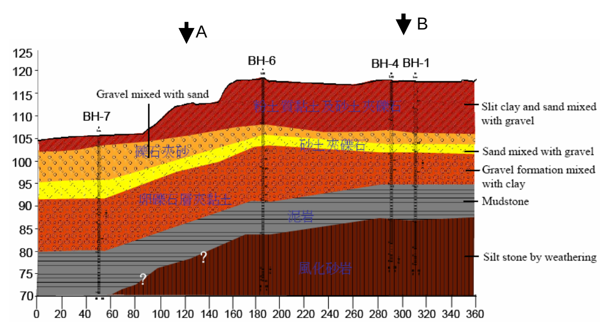

Figure 2: Site strata profile [1]; A, B mark approximately the boundary of TPS building.

The underground water may have important effect on the soil resistivity. According to the boring investigation, the underground water level is at about 95 m above the sea level, which is about 15 m below the TPS designed floor level. The corresponding pH value is about 7.1 and the chloride ion density is about 2.2 ~ 15.3 mg/L. It should not have erosive and worsening effects on the electrodes.

DESIGN OF GROUND GRID

Estimation of Soil Resistivity

In order to calculate the resistance of ground grid, the soil resistivity at the construction site is essential. The soil resistivity can not be determined easily due to the complexity of the formation of earth strata. The soil boring log at the construction site from the previous geological exploration, Fig. 2, can be used to estimate the soil resistivity. At the same time, the resistivity image profiling of direct current electrical resistance has been done at the construction site, Fig. 3. After carefully investigating the data, we estimate that 15 m under the surface the resistivity is mostly at between 100 Ω·m and 300 Ω·m, with some local areas having higher resistivity up to 500 Ω·m. The resistivity at depth between 15 m and 30 m below the TPS floor is estimated between 50 Ω·m and 100 Ω·m. Since there is underground water 15 m below the TPS floor, we would estimate the soil resistivity is around 70 Ω·m or lower.

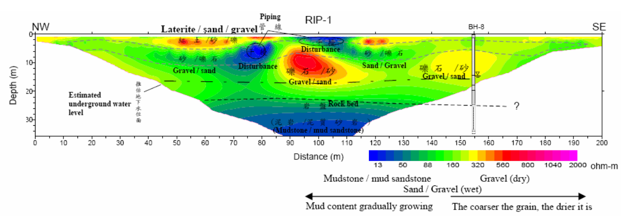

Figure 3: The profile of electrical stratum at construction site [1].

Calculation of Ground Resistances

While there are many researchers have tried to obtain the analytical solutions for various types of ground grids, due to the complexity of ground structure and different layouts of ground grids which might be used, the analytical equations we can use today are still limited to some simple grid layouts. In our study of the TPS ground grid, the commercial computer program CYMGRD [2] is used to assist us to calculate the parameters of ground grid. We would use it to study the equivalent resistance of ground grid, the ground-electrode sizing, the potential rise, the mesh and step voltage.

The layout of TPS ground grid has been modified many times according to the necessity. The latest update was following the last major change in the equipment arrangement in the TPS building. The present design of ground grid for the TPS consists of 4 circular horizontal ground-electrodes, which are about 2 m below the floor, and 62 vertical ground-electrodes, Fig. 4. There are 24 vertical rods under the first and third ring and 12 vertical rods under the inner ring. In the present design, all of the vertical rods are 30 m long. There is possibility to use 15 m vertical rods under the third ring. As for the second ring, beside 2 vertical rods for the extracting and injecting kickers, there is no other vertical ground electrode. The electrodes in the outside ring are mainly for the equipments in the beam-lines and laboratories. The second ring is for the equipments in the accelerator tunnel. The third ring is for the control and instrumentation areas, and the inner ring is for other equipments which are used to accelerate the electron beam inside the accelerator. There will be also a ground grid under the new utility building. The design of its ground grid is a simple rectangular horizontal type (7×6) with 3 m vertical rods under the horizontal grid.

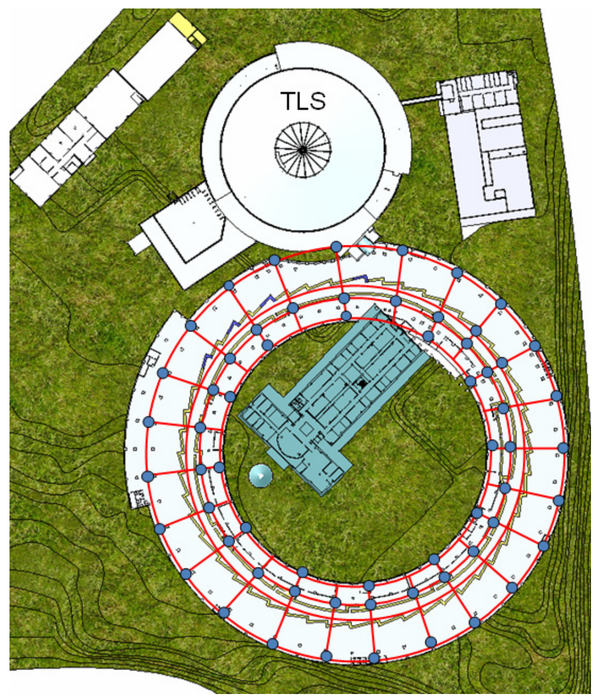

Figure 4: The layout of TPS ground grid. The red lines indicate the horizontal grid conductors and the blue dots indicate the vertical ground rods.

During our calculation of the ground resistance two-layer soil model is used due to the capability of computer software CYMGRD. CYMGRD supports at most only "two-layer" soil model analysis. From the geology exploration result, the strata distribution of the construction site shows uniform. A "two-layer" soil model analysis seems to be sufficient for us to design a safe grounding system.

During the designing process, many pairs of top and lower layer soil resistivities have been used to calculate the ground resistance and the associated parameters. The typical soil resistivity used is 200 Ω·m for the top layer and 80 Ω·m for the bottom layer. With these resistivities the new utility building will give us ground resistance about 1.2 Ω. The ground resistance of TPS ground grid is about 0.21 Ω. These two ground grid will be combined together to give a total ground resistance about 0.19 Ω, Fig. 5a and 5b. This result will meet our designed goal. From the geological consideration, the underground water may further reduce the lower level resistivity to lower than 80 Ω. In this situation, we will expect that the value of ground resistance becomes even lower. Besides obtaining a lower than 0.2 Ω ground resistance, the guide line described in the “IEEE Std 80-2000” [3] are followed in the design of the TPS ground grid.

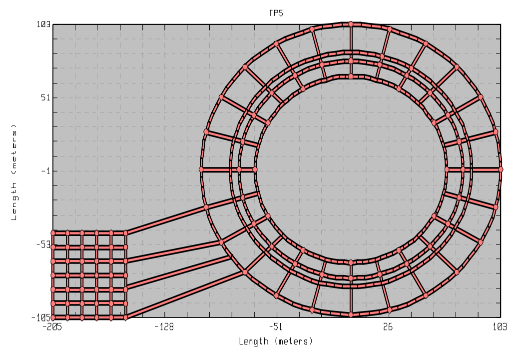

Figure 5a: The TPS ground grid design used in the computer simulation. The rectangular grid is for the new utility building and the circular one is for the TPS building.

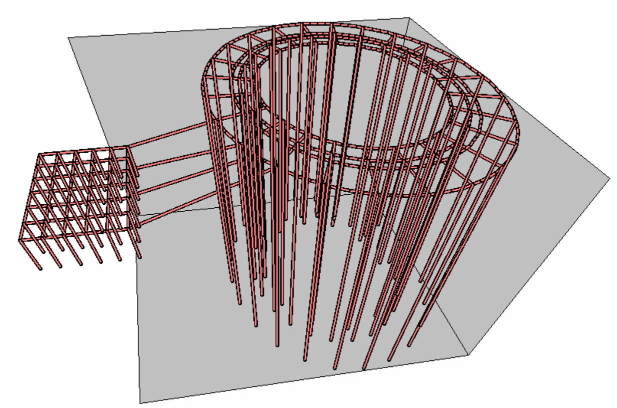

Figure 5b: The TPS ground grid design used in the computer simulation, a 3-D view.

Further Improvements

The ground resistance reduction agents have been proven to be able to decrease the ground resistance. It has the function to increase the diameter of electrode by modifying the soil surrounding the electrode. In 2002 the improvement of ground grid of TLS was to add nine 30 m vertical electrodes around the TLS building and add bentonite as ground enhancement material. It decreases the TLS ground resistance to about 0.2 Ω. During the installation of TPS ground grid, we also intend to add ground enhancement material with resistivity lower than 0.2 Ω·m to further reduce the ground resistance. Also, at least 12 chemical ground electrodes with length 30 m will be used for the vertical electrodes to improve the performance of TPS ground grid.

CONCLUSION

The TPS grounding system is being designed to have a ground resistance lower than 0.2 Ω. Our design principle is to follow the guidelines described in “IEEE Std 80-2000”. Beside the general function of providing the safety to the personnel during normal and fault conditions, it assures correct operation of electrical and electronic devices and also to prevent their damages. Some other effects which relate to the electromagnetic interference are also been studied in hopes of minimizing this type of problems.

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[2] CYMGrd 6.3, rev. 7, CYME International T&D Inc. (2006) .
[3] IEEE Std 80-2000.