THE GROUNDING SYSTEM AT TPS

Tzong-Shyan Ueng, Jui-Chi Chang, June-Rong Chen, Yu-Chih Lin, NSRRC, Hsinchu, Taiwan

Abstract

An elaborately designed grounding system has been installed under the TPS construction site. The ground grid was installed sector by sector to comply with the building construction schedule. The ground resistance measurement of each sector was carried out right after the grid installation. The final ground resistance measurement for the whole grounding system was performed also right after its completion. The measured ground resistance of each sector was used to estimate the final ground resistance, and its result was compared to the final ground measurement result. Also, the theoretical calculation is used to justify it. The low impedance of TPS grounding system, < 0.14 ohm, is to insure the safety of TPS personnel and instrumentation, also, to reduce the noise of electronic devices.

INTRODUCTION

To cope with the need for a highly brilliant x-ray source for multidisciplinary research, the construction of a 3.0 ~ 3.3 GeV low emittance synchrotron radiation source, Taiwan Photon Source (TPS), is underway at NSRRC now. The accelerator has a circumference of 518 m and is designed to have an emittance of 1.7 nm*rad. It has a 24-cell DBA lattice and 24 straight sections for insertion devices. In order to deliver a high quality synchrotron light, a reliable electric power is important. A good electrical grounding system is thus essential, too. To fulfil this requirement the grounding system of TPS was designed to have a ground resistance less than 0.2 Ω [1]. This should be able to stabilize the voltage to earth during the normal operation and provide the fault current path at fault condition, also provide the safety environment for the personnel, protect against lightning. In addition, a good ground for the electric process control and all the electronic instruments used for the data acquisition is important in reducing the electronic noise to obtain high grade data in the accelerator laboratory. To guarantee the constructed ground grid will meet the requirement, the ground testing is also very important. Due to the limited space for the ground testing, several different methods have been used for the testing of TPS ground grid in order to guarantee it meeting the designed goal.

THE CONSTRUCTION OF GROUND GRID

The schematic layout of TPS ground grid can be seen in Fig. 1. The structure of TPS ground grid consists of 4 horizontal rings and 64 vertical electrodes. These four horizontal circular rings which are made of 250 mm^2 bare copper wires having diameters of about 200 m, 160 m, 150 m and 128 m. They are interconnected by the same type of bare copper wire in radial direction. The 64 vertical electrodes have 30 m in length each and are copper tubes having outside diameter of 54 mm and wall thickness of 1.78 mm. In order to accommodate the higher ground current RF system might produce, there were 3 vertical ground rods specially installed under the ground of RF transmitters for RF system to use. Among all these vertical electrodes, there were 12 Ionic Earthing Array (IEA) chemically charged rods which were dispersed at the designed positions. These IEA rods give chemical charge of 60% sodium chloride and 40% calcium chloride [2]. When this charges release into the surrounding soil, it will decrease the ground resistivity greatly. In order to guarantee a good mechanical strength and excellent corrosion resistance, the exothermic welding was used to join the copper conductors used in the ground grid.

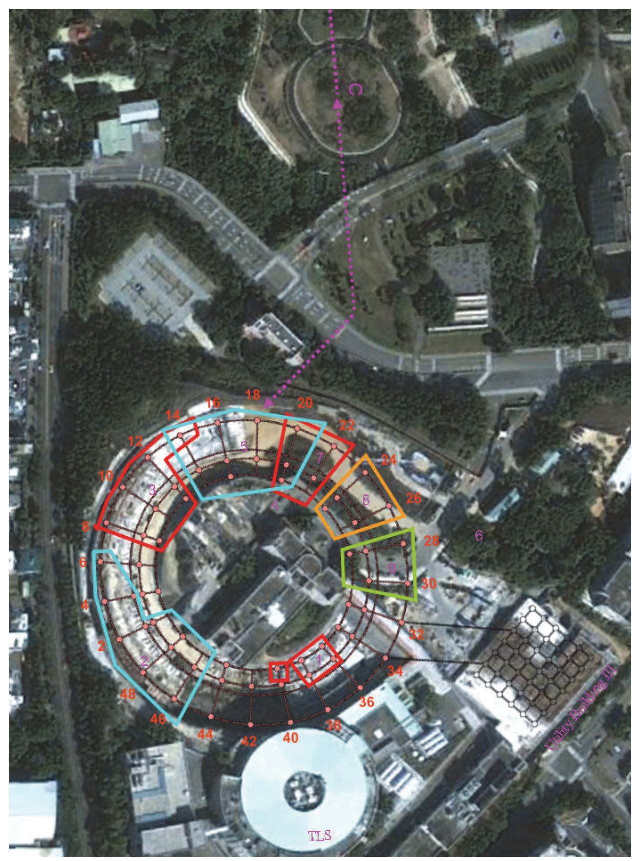

Figure 1: The TPS construction site and the layout of ground grid. The number outside the grid shows the pillar position. The blocks and the numbers inside indicate the order of ground resistance measured. The pink dash line extends to the north is the route for the final ground testing.

The Utility Building III is located away from the TPS Building about 45 m. It will provide the utility, such as the electricity and water to the TPS building, so it was constructed at the beginning of construction project in January 2010. Therefore, its ground grid was installed first. This ground grid is mainly for the local utility of the Utility Building III, thus, a conventional grid design was used. It is a 42 m x 36 m rectangular horizontal grid of wire pattern of 7 x 6 and 42 copper-clad steel vertical rods of 3 meters located under the grid. After the completion of the main ground grid of TPS, this grid was connected to the TPS ground grid with two channels. Each channel has two 250 mm^2 bare copper wires.

The construction of TPS main building in which the accelerator will be installed is divided into 6 sections. Its construction was done one after another. Thus, the excavation was done at 6 different time periods. The installation of the ground grid required the complete excavation of construction area to the elevation below the level of TPS foundation which is at sea level of 110 m. The installation of ground grid was eventually divided into 8 times. In order to match the construction schedule, the ground grid of each section was installed a few days after the excavation. So, the construction of the building foundation could be started on schedule.

The installation of horizontal ground electrode begins by digging a trench about 30 cm * 30 cm. After installing the horizontal ground wire the bentonite was added in surrounding the ground wire for further decreasing the earth resistivity. Each 30 m vertical electrode was installed in the designed position where a 4” hole was drilled by the drilling jumbo. After installing the vertical electrode, the bentonite was added into the empty space surrounding the electrode for further reducing the ground resistance, too. Eventually the ground grid was connected to the grounding box which located in the ground level of TPS. There are also connections from the reinforcing steel of the foundation of TPS building to the grounding box. This will allow one to connect the ground grid to the reinforcing steel of the TPS building if one finds it can reduce the ground resistance without producing any noise or signal interference to the experimental equipment inside TPS building later.

THE GROUND TESTING

The ground testing for each section was performed a few days after the installation of grid of that section. Because the ground grid was connected directly to the grounding box in the ground floor without connected to the reinforcing steel of the building directly, in principle, the construction of the foundation of building does not have any influence on the ground testing result. The ground tester used was Megger’s DET2/2 auto earth tester [3], which was designed to be able to operate in the most difficult and electrically noisy environment and with resolution to 0.001 Ω on reading. The test frequency used was 128 Hz. Other frequencies have been used also, they gave the same result. Other ground tester UNILAP GEO X [4] from LEM Instruments was also used side by side for comparing the measurement result. The TPS construction site is in the hillside and there are residential area and many factories nearby. The open area is in the north which is the campus of a local university, and it was just prepared as lawn recently. There are also 2 small streams pass by to the north in this area. For the previous ground testing of each section, the testing was only performed mainly within the range of NSRRC site. Due to the limited space, four ground testing methods have been studied. These methods are the fall-of-potential method, the slope method, the intersecting curves method and the test-current-reversal method [5, 6, 7]. The differences obtained with these methods were generally within 10%, which should be reasonable in the ground testing. Eventually, the slope method and intersecting curves method were selected as the major testing methods. The ground resistances of each section measured are summarized in Table 1. For the final whole ground grid of TPS, it required longer distance for the ground testing. Thus, the ground testing must be performed with the test leads extended to the campus of the local university. The longest distance which was used to locate current electrode for the ground testing is 450 m. It is just enough for the slope method and the intersecting curves method. The existence of roads and buildings also posed some difficulties during the measurements. A final ground testing for the whole grid was also performed a few days after the completion of the whole TPS ground grid. Four sets of data were taken, Fig. 2. With the slope method the ground resistance of the grid is about 0.14 Ω, and the intersecting curves method gives it between 0.14 Ω and 0.16 Ω. The slightly larger uncertainty appears in the intersecting curves method is the result of the data taken close to the road.

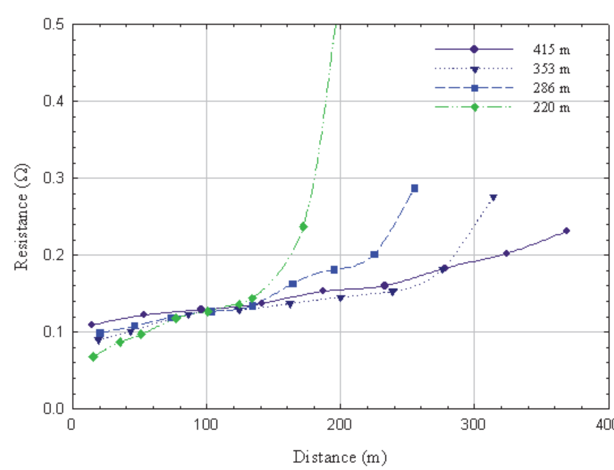

Figure 2: Four ground resistance curves for different distances of E electrode to C electrode.

COMPARISON AND ANALYSIS

Using the measured ground resistance of each section, one tried to deduce the ground resistivity at the site of each section with the computer software CYMGRD [8] to find the resistivity of that section. Since all these grids of

ISBN 978-3-95450-115-1

each section were installed within the area of diameter of 200 meters and the geological condition was not much different, the resistivity obtained from all these sections should be very close. For the foundation of TPS, the construction site was dug more than 10 m in depth from the original ground surface. During the further digging of 30 m holes for the vertical electrodes, one saw some wet soil dug out and also some groundwater coming out from some holes, especially at the southeast side. Due to the confliction with the construction schedule, the ground testing was not done completely at the southeast area. But, it should indicate the resistivity is slightly lower at this area. Taking this phenomenon into consideration the estimated resistivity of each section from each measured ground resistance is also shown in Table 1. From these estimated values of resistivity, we take 90 Ωm for the top layer of 15 m and 50 Ωm for the lower layer of 15 m to calculate the ground resistance of the grid with "two-layer" soil model. The calculated ground resistance of TPS grid is 0.13 Ω. Compare this result with the measured ground resistance of whole TPS grid, which is about 0.14 Ω. We believe that the ground resistivity of the TPS grid should be around 0.14 Ω. If we check this result with the previous geological survey [9], it suggested the resistivity of 100 Ωm for the top layer and 60 Ωm for the lower layer in this area. The smaller value obtained from the field measurement should be the result of treating the soil with the bentonite and using 12 IEA chemical rods, which can reduce the soil resistivity. After combining the ground grid of TPS building with the ground grid of Utility Building III, which has measured ground resistance of 1.19 Ω, the total ground resistance should be around 0.13 Ω. In the future if the grid for TPS is connected with the TLS ground grid, which has ground resistance about 0.2 Ω, we believe that the whole ground grid at NSRRC should be around 0.1 Ω or even smaller.

Table 1: The measured ground resistances at each section of TPS construction site. The estimated ground resistances with "two-layer" soil model analysis are show in the last two columns.

#	# of Rods	Section Ground Resistance	Top Layer (ΩM)	Bottom Layer (Ω.M)
1	4	0.56	80	28
2	11	0.23	80	26
3	9	0.30	90	30
4	1	3.22	90	64
5	10	0.40	90	45
6	1	3.30	90	66
7	5	0.57	90	41
8	5	0.63	90	47
9	5	0.58	90	42

CONCLUSION

The TPS ground grid has been constructed with a low ground resistance < 0.2 ohm in mind. Before the design stage, the geographic data of construction site has been investigated. Using the geographic information, we have designed the ground grid which best fit our purpose with self developed programs and commercial computer software. During the construction stage, the construction hardware has been carefully selected and installed. The ground testing has also been done right after the installation of grid of each sector, and also the complete final grid. The result shows that the final ground grid matches our original design goal. This will insure the safety of the personnel and guarantee the stable operation of the accelerator and the experimental electronics.

ACKNOWLEDGMENT

During the period of construction of TPS ground grid, J. P. Jen and members of E&C Engineering Corporation were the main workforce. Also, C. N. Chien of Chi Chi Electric Co., LTD was the key person for working on the ground testing. They did a great job with enthusiasm. The authors are appreciated their efforts in building the TPS ground system with low ground resistance. Many thanks are also given to the Utility Group of NSRRC for many useful discussions and assistance during the construction.

REFERENCES

[1] T. S. Ueng, Y. C. Lin, J. C. Chang, H. S. Wang, "The Conceptual Design of TPS Grounding System", PAC'09, Vancouver, May 2009.
[2] UL 467 "Grounding and Bonding Equipment" (2007).
[3] Megger, "Getting Down To Earth", (2005). http://www.BiddleMegger.com
[4] LEM Instruments.
[5] Tzong-Shyan Ueng, Yu-Chih Lin, Jui-Chi Chang, Chien-Kuang Kuan, "The Ground Testing of TPS Ground System", IPAC'11, San Sebastian, Sep. 2011.
[6] ANSI/IEEE Std 81-1983; IEEE Std 81.2-1991; IEEE Std 80-2000.
[7] MIL-HDBK-419A (1987).
[8] CYMGrd 6.3, rev. 7, CYME International T&D Inc. (2006).
[9] NSRRC and China Engineering Consultant Inc., "Technology Services of Site Geology Exploration and Micro-vibration Measurement", (Dec. 2005).