THE GROUND TESTING OF TPS GROUND SYSTEM

Tzong-Shyan Ueng, Yu-Chih Lin, Jui-Chi Chang, Chien-Kuang Kuan, NSRRC, Hsinchu, Taiwan

Abstract

A ground grid of 4 rings and 62 vertical electrodes has been constructed for the TPS storage ring. The ground resistance was designed to be smaller than 0.2 ohms in order to give a good protection of the TPS electrical facility and personnel. In order to match the building construction schedule the TPS ground grid has been installed about 1/6 segment of the construction project each period. The ground impedance of each segment was measured right after the installation. The ground grid with the diameter of 200 m of outside ring and its low impedance value, also the limit testing space, challenged the measurement of ground resistance. Several different methods of ground testing have been used and the measured results are compared with each other. These methods include the fall-of-potential method, the slope method, the intersecting curves method and the test-current-reversal method. The final TPS ground impedance will be measured and compared with the calculation from combining the previous several segment measurements. The actual TPS ground resistance should have a smaller value than expected.

INTRODUCTION

A new synchrotron facility, TPS, is under construction since February 2010. It is a 518-meter low-emittance synchrotron storage ring with the electron energy of 3.3 GeV. In order to make TPS a cutting-edge synchrotron facility, a lot of delicate, computer-controlled and automated high precision equipment will be used. Hence the grounding system should have the function of ensuring the correct operation of electrical and electronic devices and reducing the interference of electrical noise, besides providing the safety for the personnel and the equipment during normal and fault conditions. In order to meet this requirement, the ground grid of TPS has been designed to be smaller then 0.2 ohms.

THE TPS GROUND GRID

The ground grid of TPS is constructed under the TPS foundation. It consists of 4 circular horizontal ground-electrodes of 250 mm^2 bare copper wire and 62 vertical copper rods of 30 m, see Fig. 1 [1]. Among them, 12 rods are IEA chemical rods. The diameter of outside ring is about 200 m and the inside ring is about 128 m. Bentonite is also used to lower the soil resistivity. Because the construction site is in the hillside, more than 2/3 of the original surface needed to be excavated to the elevation below 110 m. The schedule of excavation and the construction of TPS building was divided into 6 sections. One section would be excavated only after the foundation of the previous section was completed. Thus, the installation of ground grid was divided into 6 sections, too. After the excavation of one section, the ground grid needed to be installed within few days, and the measurement of the ground resistance of each section must be completed in about 1 week. The ground grid is connected to the grounding box directly without connected to the steel bar of the building foundation. The measurement of the ground resistance will be done section by section at first stage. After the completion of the whole grid, the total ground resistance will be measured. There is also a ground grid under the new Utility Building III. 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 m under the grid.

Figure 1: The TPS construction site and the layout of the ground grid. The blocks and numbers in the graph indicate the order of ground resistance measured, Table 1.

MEASUREMENT OF GROUND RESISTANCE

To measure the ground impedance the fall-of-potential method is used frequently. There are several methods for arranging the test electrodes. Figure 2 shows the two arrangements for the potential electrode used in our ground test measurements. During the measurements, the distance between the ground E and current electrode C was divided as 10 segments and 9 resistances were taken with the measured potential data.

The Fall-of-Potential Method

There are some challenges when the fall-of-potential method is used in a large ground system. In general, this method needs about 5 times of the dimension of the grid to set the test probes. If the ground resistance of TPS ground grid would be measured as a whole, it might need more than 1000 m for the current test probe. In Fig. 1, one can see that about 2/3 of the neighbouring area are surrounded by residential buildings and factories for producing delicate electronics. The only open area is in the north, which is the campus of two local universities. But its elevation is much lower and there are 2 streams pass by. After studying, the longest distance can be used to place the current electrode will not exceed 350 m. Even if the ground resistance of the ground grid of each sector is measured separately, the longest distance can be used to place the C electrode is about 250 m. It is still not long enough for a ground grid having diagonal about 90 m. Thus, using the fall-of-potential method to measure the ground resistance at the TPS construction site becomes unfeasible. After many field surveys, the fall-of-potential method used only in the ground grid of Utility Building III and one small sector of the first construction section.

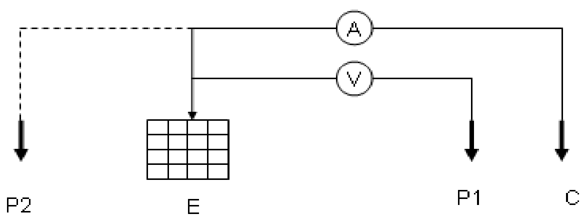

Figure 2: Layout of electrodes and meters for the fall-of-potential method, where E is for the ground grid, C is for the current electrode, P is for the potential electrode, A and V are for the current and the voltage measured by the ground test meter.

In Fig. 3, the result of resistance vs. position of P measured at one of the TPS construction site is shown. The distance between E and C electrode has about 3 times of the diagonal of the grid, thus, the central part of the curve does not show horizontal, and it is difficult for one to obtain the ground resistance directly from the curve.

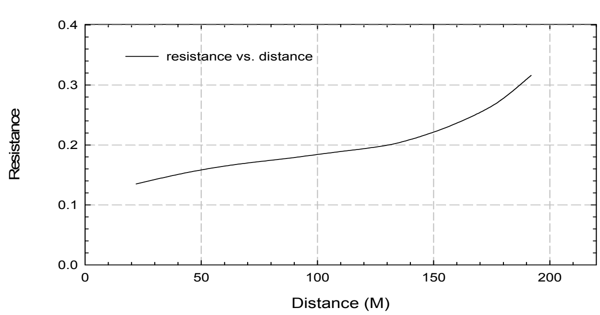

Figure 3: A ground resistance curve measured at region 2 of TPS construction site.

The Slope Method

Since the maximum distance to set the current probe is only about 3 times the distance of diagonal of measured grid and the fall-of-potential method would not give us correct ground resistance, the slope method was used. This method uses the similar measurement method as the fall-of-potential method, but it allows smaller E electrode to C electrode distance. In this method, the resistances at 20%, 40% and 60% of E to C distance are obtained first. Using these three resistances one can obtain the slope coefficient; then, with a predefined procedure the ground resistance can be obtained [2, 3, 4]. Even this method is simple but we find it is very sensitive to the localized effects of ground. It affects the measured value of potential and, thus, the calculated local resistance. If the measured resistance at the measurement point changes a little, the slope coefficient could change a lot. Hence, the slope coefficient might not be obtained accurately and the final calculated resistance will have a large error. In order to obtain a correct ground resistance with this method, many repeat measurements must be done in different directions and at different C positions, and the obtained ground resistances from all these measurements should be compared with each other.

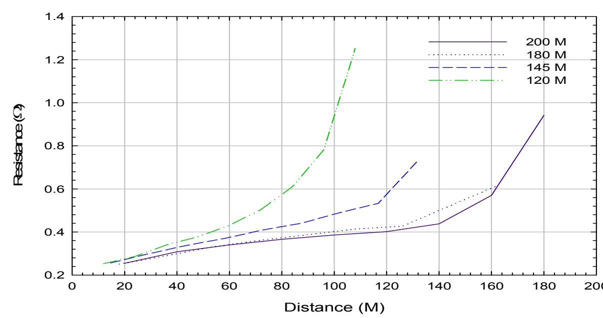

Figure 4: Four ground resistance curves for different distances of E electrode to C electrode measured at the region 5 of TPS construction site.

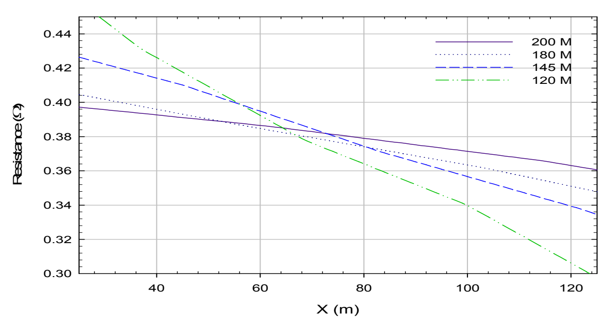

Figure 5: Intersection curves for Fig. 4. The center of the triangle formed by the intersection gives the ground resistance 0.38 Ω.

The Intersecting Curves Method

The intersecting curves method [3, 4] was adopted to measure the ground resistance of TPS grounding system, too. The same measurement method as the fall-of-potential method is used but with different calculation approach. In this method the distance between E electrode and C electrode is much shorter which is about from 1 to 2 times of the side of measured grid, if it is square. At least three measured datasets with different distances between E and C are needed to determine the intersected position of the curves in the final plot. This method seems to give a more reliable result when used to measure the ground resistance which has lower value. To use this method some calculation is needed to convert the measured resistance curves, Fig. 4, to another intersection curves, Fig. 5, for one to find the intersecting region in order to determine the ground resistance of grid. Before the computer was popular, this method seemed to be hard to use, especially in the field. The function of today's handheld computing devices or laptop computers give this method an edge. The calculation procedure can be programmed easily before the field measurement. During the ground test the computing device can be carried to the field and the measured data can be input into the computing device immediately after the measurement. The calculated result can be obtained and plotted right away, Fig. 4 and Fig. 5. Thus, the measured ground resistance is obtained. If the final resistance curve does not show reasonable smooth, the measured data could be suspect of error. In this situation, a re-measure of that data can be done right away. In other methods the measured errors in general can not be discovered easily except the errors are large.

The intersecting method is particular useful for the large ground grid which has hard time to find the enough distance to place the test probes. It is also useful when the electrical center of grid may not be known or may be inaccessible. In this method the lead is normally connected at the side of grid, which is at a distance x from the grid center.

The Test-Current-Reversal Method

The test-current-reversal method measures the ground resistance by injecting test currents taken from the power system low voltage network. This method has been performed twice at TPS construction site when other ground resistance measurements were performed in order to compare the measured ground resistances. A simple block diagram of the equipment setup is shown in Fig. 6. The detailed analysis method and formulism can be seen in Ref. 2. This method has the function of cancelling out the level of all background frequencies appearing in the measured voltage and current. In our measurement the current was increased from a low current of 1 A to 16 A. The results agree with those obtained with other ground resistance measurement methods.

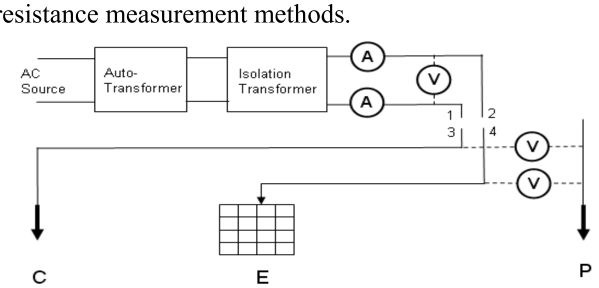

Figure 6: Block diagram for setting up the instruments used in the test-current-reversal method.

CONCLUSION

The installation of TPS ground grid was originally planned to be completed by the end of July 2011. Due to the delay of construction project, until August only 2/3 of the ground grid has been installed. The others should be completed by the end of the year. Thus, only the ground resistances of 2/3 of the ground grid have been measured. During the measurements, many ground test methods have been used in order to find the correct ground resistance. The measured ground resistances of the grid of each section are shown in Table 1. From these results, the resistivity of TPS construction site can be estimated with computer software CYMGRD [5]. Using the two-layer model, the resistivity of the top layer (15 m) is estimated about 90 Ω·m and the lower layer is 45 Ω·m. With these resistivities the ground resistance of whole TPS ground grid is estimated about 0.12 Ω. In the next few months, the construction of TPS ground grid will continue, so does the measurement of ground resistance of each new grid section and the ground resistance of whole ground grid of TPS. We believe that after the completion of the ground grid of TPS, the ground resistance should meet our goal of smaller than 0.2 Ω. This will provide a base for the stable operation of electrical and electronic devices.

Table 1: Measured Ground Resistances of Each Section at TPS with Different Ground Test Methods

Region	# of Rod	Fall-of-Potential (Ω)	Slope (Ω)	Intersecting curves (Ω)	Test-current-reversal (Ω)
1	4	0.56			
2	11		0.23	0.23	
3	9		0.31	0.293	
4	1	3.22			
5	10		0.41	0.38	
6	1	3.7			2.8
7	5	0.61	0.57	0.525	0.50

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