Estimation of the Geomagnetically Electric Field in Japan

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This is the essence of the paper to be submitted to Earth, Planets and Space (Fujita et al., 2013)

INTRODUCTION

The geomagnetically induced current (GIC) happens to damage transformers of electrical power line systems in high-latitude countries like Canada and Sweden where the intensified geomagnetic disturbances occur frequently. Eventually, GICs sometimes cause the power line failures. It is noted that severe GICs result in natural disasters like the wide-area blackout in 1989 in Canada. Thus, there have been many researches about GICs in the high-latitude countries [i.e., Pulkkinen et al., 2005]. On the other hand, the low-latitude countries like Japan seem to be regarded to be free from dangers of the GIC disasters [Pulkkinen et al., 2008]. Indeed, Watari et al. [2009] revealed that the GICs measured at a transformer station in Hokkaido are as small as several Ampere. These values are negligibly small compared with the permissible current of a transformer.

The result by Watari et al. [2009] seems to indicate that Japan is safe from the GIC disasters. However, it should be noted that the ground resistivity structure is quite different between Hokkaido and other Japanese areas like the most industrialized and highly-populated Kanto plain. This difference invokes the following geoelectric characters in Japan; the geomagnetically induced electric field (GIE) at Kakioka in Kanto plain is sometimes about 10-times larger than that at Memambetsu in Hokkaido. This fact also suggests that information of GICs in Hokkaido may not be applied to GICs in other areas in Japan. In addition, this fact suggests significant effect of the ground resistivity structure on evaluation of the induced electric field and GICs. Concludingly, the GIC should be studied based on a realistic 3D ground resistivity model in Japan.

RESISTIVITY MODEL AND BASCI EQUATIONS

The GIC is evaluated from the GIE and the impedance of the electric power line. Unfortunately, it is difficult to obtain the impedance now. In this report, we present the GIE evaluation.

In order to calculate the GIE in Japan, we need to employ a three-dimensional model of the ground resistivity. Unfortunately, we do not have the model covering entire area of Japan based on the direct measurements based on the magnetotelluric method. From this circumstance, we cannot help using an alternate convectional model of ground resistivity. Namely, we utilize the land topography and bathymetry data disclosed at http://www.ngdc.noaa.gov/mgg/global/global.html and the sediment map at http://igppweb.ucsd.edu/~gabi/sediment.html to estimate the ground resistivity. The three-dimensional resistivity distribution will be obtained when we assume siutable values of the ground resistivity in the characteristic layers consisting of the sea-water, the sediment layer and the rock layer. In the present calculation, resistivity of the sea water, that of the sediment layer, and that of the rock layer are assumed to be 0.333Ωm, 10Ωm, and 1000Ωm, respectively.

Now we perform a numerical analysis by using the electromagnetic response equations with the resistivity estimated above. We employ the source current which is the alternate of the magnetospheric current. In the analysis we assume as the source current the periodically oscillating east-west ring current flowing in the region around r ~ 10Re in the equatorial region. Thus, the numerical analysis based on the relaxation scheme is employed.

RESULTS

The preliminary results of the GIEs are obtained through numerical analysis. As the source current is in the east-west direction, the induced electric current is basically in the east-west direction. Therefore, the enhanced GIE appears along the coastlines extending in the north-south direction. It is noteworthy that the coastline effect appears in the other region when we employ the other source current polarized in the different direction. Then, it is interesting to offer the GIE intensity for the extreme space weather event. Minamoto et al [2013] estimated the H-range of the magnetic storm and SC amplitude which may occur once a 1000 years. These extreme values are 2800nT for the H–range and 1100/sec for the SC. Then, the estimated extreme values of GIEs in Japan become 3.9V/km for the H-range and 18V/km, respectively. Note that these values are very rough estimates because the resistivity model may be considerably different from the real one and the source current is artificial. The extreme values of the GIE possibly larger than the estimated one because the employed resistivity model with 100km-mesh data fails to reproduce the fine structure of the ground resistivity. The realistic resistivity model proposed by Japanese geoscientists is highly desired.

CONCLUSION

We present the preliminary results of the GIE based on the modeled three-dimensional ground resistivity map and the source current with east-west polarized ring current flowing in the region around the altitude of 10Re in the equatorial plane. Numerical results indicate that enhanced GIEs appear in the coast line area, which are physically reasonable, but we need to justify the results with other methods.

Very rough estimates of the maximum GIEs are presented based on the space weather events expected to occur once a 1000 year.

The final goal of this research is to evaluate the extreme values of the GIC. We need collaboration with the power-line companies to perform GIC evaluation.

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