Mitigating the Low Frequency Magnetic Field Generated by Substations on Electric Railways

Gaku MORITA
Researcher, Power Supply Systems, Power Supply Technology Division

Among many environmental issues, electric and magnetic fields (EMF) generated by power facilities have attracted some concern in society. The World Health Organization (WHO) has carried out an assessment of the effects on a human body of exposure to EMF, and in response to this, the ICNIRP (International Commission on Non-Ionizing Radiation Protection) and the IEEE have established international EMF exposure guidelines/standards. We are carrying out four operations (Simulation, Measurement, Mitigation measures, and Participation in the development of international standards) related to low frequency EMF generated by railway substations, as illustrated in Fig. 1. In the low frequency area, investigation of a magnetic field is particularly important, and our specific research work will be introduced in the following part of this article.

We have examined the characteristics of the magnetic field generated by the substation based on theoretical analysis and measurement/investigation in actual substations, and this enabled us to clarify that a cable through which a large current flows is a main source of magnetic field. As part of this process, we have developed software to simulate the magnetic field generated by a substation, something which was considered to be difficult, and we have confirmed the validity of the calculation method based on comparison/verification with measurements in actual substations. Thanks to simulation, it is possible to investigate the amount of magnetic fields generated at the design phase of the substation. Figure 2 shows an example (the strength of the magnetic field is illustrated with colours in the figure) of the result of a simulation of an AC magnetic field emitted from a DC electrified railway substation.

As well as conducting the simulations, we have carried out many measurements of EMF in actual substations. The objectives are to verify the result of the simulation, to continue environmental research related to power facilities, and to assess compliance with the above-mentioned guidelines, etc. The magnetic field generated by a railway substation includes, in addition to a commercial frequency component, particular frequency components such as a DC component, and the level of the field also changes significantly over time according to variations in the load. Therefore, while using a suitable measurement instrument in accordance with a target frequency domain, we also measure currents of power circuits related to the magnetic field together with measurement of the actual magnetic field. Figure 3 shows a picture of the magnetic field measurement in the vicinity of a rectifier in a DC electrified railway substation. With regard to procedures for measuring magnetic fields in a railway environment, while the European Standard EN 50500 has been issued and development of an IEC standard based on this is now underway, this matter is also important for Japanese railways. For this reason, we are playing a positive role in the development work.

It is possible to mitigate the emissions from a magnetic field by optimizing the arrangement of the power cabling, including overhead lines, bus bars etc., in the substation. Using different examples, we have computed the optimal cabling applicable to the power cables of a railway substation, and proposed examples of a design for a substation which includes measures to mitigate the magnetic field. By combining this with the above-mentioned simulation technology, it is possible to carry out verification with respect to measures and effects in the design phase. Figure 4 shows an example of the mitigation measure in DC bus lines of a DC electrified railway substation, and by changing the normal cabling (left-hand side) to an optimum cabling (right-hand side) in which the return cables are sandwiched between two positive cables, it is possible to reduce considerably the amount of EMF generated (illustrated with colours in the figure). Optimising the arrangement of the cables is particularly effective as it has a low cost and is simple to implement. We have already started to introduce this arrangement in several new substations.

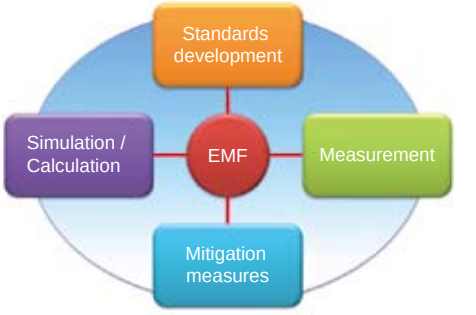

Fig. 1 Areas for investigation at the power supply systems laboratory concerning the problems of EMF generated by railway substations

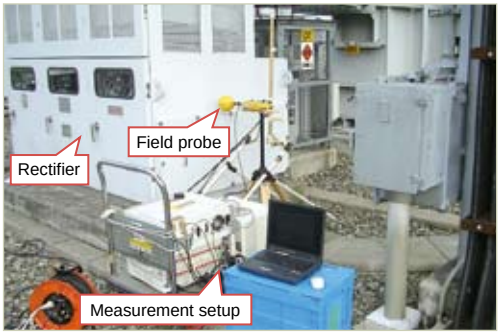

Fig. 3 A picture of magnetic field measurement in progress at an operational substation

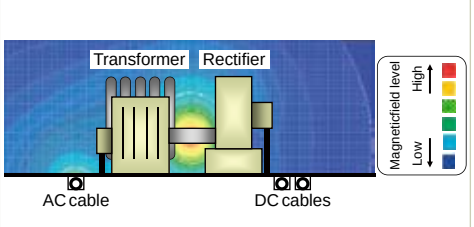

Fig. 2 The result of a simulation of an AC magnetic field emitted from a DC electrified railway substation

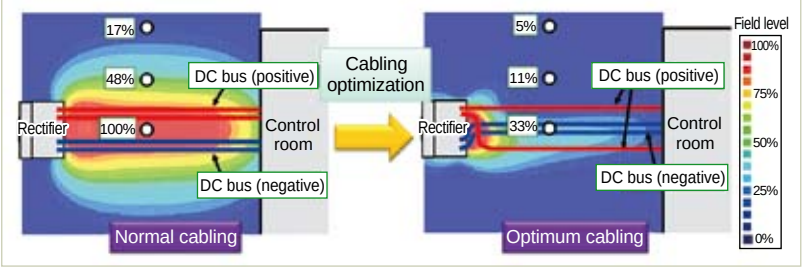

Fig. 4 A magnetic field mitigation measure using cabling optimization for a DC bus