Application of nano material for shielding power-frequency electromagnetic field

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Abstract. Only limited data are available on shielding electromagnetic field exposure in professional work. In our paper, we studied the electromagnetic field intensity in 500 kV substations, and explored influence of nano material in high voltage laboratory simulation. Moreover, the results of nano-fabrics material for shielding power frequency electromagnetic field indicated that, both shielding fabrics can almost completely shield the electric field, but have weak shielding effectiveness against magnetic field.

1. Introduction

Increasing exposure to power frequency electromagnetic fields (EMF, 50 Hz), generated by power lines and electric appliances, raises concern about potential adverse health effects of EMF. Early epidemiological studies indicated a correlation between EMF exposure and the development of childhood leukemia [1, 2], which has been confirmed in other studies [3-5]. The power worker are interested in knowing the sources of professional magnetic and electric fields to help determine whether exposure to these fields causes ill health and in particular [6-8], to provide a measure for reducing the health risk of the electromagnetic fields.

In professional environments, there are various publications that report on measurements of electromagnetic fields inside high voltage substations (110 kV, 220 kV, or 500 kV), and some researcher [9, 10], including us [11] claimed weak relation between electromagnetic and health. While, so far, less information is available on the measure, especially shielding the electromagnetic fields. In the measures of reducing potential health effects of electromagnetic fields, shielding persists as the principal challenge. In this paper, a variety of experiments have been used to assess the nano material for shielding EMFs.

2. Materials and methods

2.1. Experimental measurements

One representative open type air substation (500 kV) belonging to the Guangdong Power Grid Corporation (CSG) were selected for achieving the real exposure data. The electrical equipments were
installed in outdoor. Circuit-breaker, switch mechanism, current transformer (CT), potential transformer (PT), transformer and others were installed independently. All measuring spots were set near the electric equipments mention above. The measurements were performed using PMM 8053A electromagnetic radiation analyzer meter with the isotropic EPH-50B probe ((PMM, Italy) [11].

2.2. Electromagnetic shielding experiment
The nano silver fiber woven fabric and nano alloy coated fabric (Kangyi, Shenzhen) were selected as the shielding textile fabric. The electromagnetic shielding experiment was tested in high voltage laboratory simulating the real electromagnetic field. The characteristics of two kinds of textile fabric are depicted in table 1.

| Material                     | Structure                  | Character                                      | Usage                                      |
|------------------------------|----------------------------|-----------------------------------------------|--------------------------------------------|
| Nano alloy coated fabric     | Firm, hard film            | The permeability and antioxidant capability are good | the lining or pockets in protective radiation suit |
| Nano silver fiber woven fabric | Firm, hard, antioxidant film | The product has functions of wearing close to the skin | antibiotic and deodorize.                  |

The following formula can be used to compute the shielding effectiveness (SE).

\[
SE_{E(H)} = 20 \log \left( \frac{E_0(H_0)}{E_s(H_s)} \right)
\]  

(1)

Where E0 (H0) and Es(Hs) are the inducing electric (magnetic) field intensity and the shielding electromagnetic field intensity in fabric.

2.3. Exposure limits to electromagnetic fields
Both the testing and evaluating directives have been transposed in the Chinese national standard. The testing method is the measurement of physical agents in workplace part 3: power frequency electric field (GBZ/T 189.3-2007). The values of electromagnetic field intensity were evaluated according to the occupational exposure limits for hazardous agents in the workplace part 2: physical agents (GBZ 2.2-2007) and the labour environment monitoring technological specification of electric power industry part 7: monitoring of power frequency electromagnetic fields (DL/T 799.7-2010). Considering the 50 Hz power frequency, the professional exposure to the electric field is limited to 5 kV/m, and the professional exposure to the magnetic field is limited to 500 μT, which is more rigorous than the guidelines for limiting exposure of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [10].

3. Results and discussion

3.1. Electromagnetic field distribution in open type air substations
The electromagnetic field distribution was tested in 500 kV substations. As can be seen in table 2, there are 2 measuring spots in which the electric field intensity were more than 5 kV/m. there are all below the busbar. In relative high voltage regions (500 kV regions), the nearest distance measuring spots is 22 m, which largely due to the higher voltage.

Furthermore, there are also 2 measuring spots in which the magnetic field intensity exceed the professional exposure limit 500 μT. The maximum value of magnetic fields intensity in shunt reactor regions is 1490 μT. The 35 kV region contains a variety of devices (such as a capacitor, reactor), higher currents can induce high magnetic field intensity.
Table 2. The electromagnetic field distribution of open type air 500kV substation.

| location                                         | Distance (m) | Electric fields V/m | Magnetic fields μT |
|--------------------------------------------------|--------------|---------------------|-------------------|
| high voltage wire of 1# transformer A phase      | below        | 268                 | 22.3              |
| low voltage wire of 1# transformer A phase       | below        | 1269                | 49.4              |
| high voltage wire of 2# transformer A phase      | below        | 274                 | 24                |
| low voltage wire of 3# transformer A phase       | below        | 1738                | 65.2              |
| 500kV 1# busbar A phase                         | below        | 7424.0              | 3.6               |
| 500kV 1# busbar B phase                         | below        | 3389.0              | 2.4               |
| 500kV 2# busbar A phase                         | below        | 5988.0              | 15.0              |
| 2579 circuit breaker of Transmission Lines       | below        | 269.0               | 22.3              |
| 35 kV #3 shunt reactor #7 A phase                | 1            | 493.0               | 1233.0            |
| 35 kV #3 shunt reactor #7 A phase                | 3.5          | 797.5               | 489.7             |
| 35 kV #3 shunt reactor #4 C phase                | 1            | 263.2               | 1490.0            |
| 50227 circuit breaker of 2M busbar              | 2            | 4701                | 3.604             |
| 35 kV 4M busbar A phase                         | below        | 966.3               | 52.65             |
| 35 kV 2M busbar C phase                         | below        | 1266                | 25.28             |
| 35 kV #3 shunt reactor C phase                   | 2            | 1963                | 427.6             |

3.2. The effect of shielding material

It has been very clearly asserted that the electric and magnetic fields may cause physiological effects due to the currents induced into the human tissues exceeding certain levels [12, 13]. Nowadays, many positively techniques have conducted in order to face the requirements of the governmental documents regarding the professional and residential exposure to the electromagnetic fields. Wearing protective clothing and expanding working distance were the main two ways to reduce the adverse effect of electromagnetic fields.

Two shielding textile fabric were selected to test in a power frequency electric field environment. Figure 1 shows the effect of two shielding fabrics on the electric field. In table 3, the comparison of the shielding effectiveness is shown.

As the test voltage increasing, the electric field intensity were from 2.069 kV/m to 14.59 kV/m, the magnetic field intensity were from 44 μT to 115 μT. After coated nano alloy coated fabric, the electric field intensity was not higher than 6 V/m, and the shielding effectiveness was 66.28 dB–70.69 dB.

![Figure 1. The effect of two shielding fabrics on the electric field.](image-url)
Table 3. Comparison of the shielding effectiveness using the two shielding fabrics.

| electric field intensity (V/m) | experimental value | shielding effectiveness (dB) |
|-------------------------------|--------------------|-------------------------------|
|                               | nano silver fiber woven fabric | Nano alloy coated fabric |
| 2069                          | 70.58              | 84.45                         |
| 4191                          | 67.07              | 90.94                         |
| 6117                          | 69.5               | 94.08                         |
| 8186                          | 67.64              | 96.25                         |
| 10130                         | 68.94              | 97.97                         |
| 12090                         | 66.28              | 98.18                         |
| 14590                         | 70.69              | 101.99                        |

accordingly, the electric field intensity after coated the nano silver fiber woven fabric were not higher than 1 V/m, and the shielding effectiveness was 84.45 dB~101.99 dB, by which the shielding effect is better. The effects of both were higher than the previous literature [14]. That is to say the nano silver fiber woven fabric and nano alloy coated fabric can effectively shield the power frequency electric field.

However, we found that both materials can hardly shield the power frequency magnetic field in the shielding experiments. The the power frequency magnetic field intensity were nearly the same to magnetic field intensity applied [15, 16].

Nano alloy coated fabrics has good function of anti-static, anti-ultraviolet radiation and so on, but the other function of bad softness and easy breakage meant it was not suitable for the shielding cloth. On the contrary, with the characteristic of anti-bacterial, deodorant, anti-static, good absorption and permeability, the nano silver fiber woven fabric can be used for personal wearing and have good application prospects.

4. Conclusions

The electromagnetic field distribution of an open type air 500 kV substation was measured. Two kinds of shielding material were studied for their shielding effectiveness. The results showed that the power frequency electric field intensity exceed the professional limits in the spots of below busbar. It should be noted that the power frequency magnetic field were low except 35 kV reactor regions. The maximum magnetic fields intensity is 1490 μT. On the other hand, the results of shielding experiment showed that two kinds of material can effectively reduce the external power frequency electric field intensity. The shielding effectiveness were 66.28 dB~70.69 dB and 84.45 dB~101.99 dB, respectively. However both materials had no serious effect on the shielding power frequency magnetic field.

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