ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

STUDY ON ELECTROMAGNETIC SHIELDING OF THE TRANSMISSION LINES OF A MAGLEV TRAIN

Peng Li*, Hongping Tao , Xiaoqing Zhang
* Department of Electronic and Information Engineering, Tongjizhejiang College, Jiaxing, China

DOI: 10.5281/zenodo.1135428

ABSTRACT

Analyzed on all kinds of electromagnetic interference may occurred based on normal conducting magnetic levitation technology used in PUDONG magnetic train line of Shanghai in China, such as: DC magnetic field generated by the levitating magnet which is supported of DC ; A radio-frequency electromagnetic field generated in the transmission of wireless information between station and the train. An alternating magnetic field generated by the guide rail synchronous long stator linear motor to the power supply cable; The ultra-low frequency induced electromagnetic fields produced by substation and along high-voltage transmission lines and so on. Study the impact of ultra-low frequency induced electro-magnetic, which is generated by the existing high voltage, large current of largest free power supply section. Studied on the shielding method, shielding material and dimensions of shielding material about ultra-low frequency induced electromagnetic, Experiment on the ultra-low frequency electromagnetic field shielding based on the magnetic levitation experiment pus down experimental apparatus and high-power three-phase motor model. For such shielding materials as acrylic, aluminum, galvanized steel, carbon steel, 304 stainless steel and others , Experiments show that the ultra-low bcarbon steel can effectively shield low frequency electromagnetic fields generated by magnetic levitation without considering the thickness of the case.

KEYWORDS: Electromagnetic shielding, Magnetic field analysis, Magnetic levitation train

INTRODUCTION

Pudong magnetic train line of Shanghai in China is using normal conducting magnetic levitation technology, the frequency of the AC power supply is 5 ~ 300HZ, the main power station is 110kv, along the supply is 35kv, and the supply current of is up to 1600A. It can be seen from magnetic train works that [1], electromagnetic interference may arise mainly from: DC- magnetic field generated by the DC supported levitating magnet; The radio frequency electromagnetic fields generated by Transmission of wireless information between the station and train; An alternating magnetic field generated by guide rail synchronous long stator linear motor to supply cables; Frequency induced electromagnetic field generated in the high-voltage substation and transmission lines along, and other aspects. The literature [2] studied the types of electromagnetic fields may be produced by normal conducting magnetic levitating technology in details, and the calculation on these electromagnetic fields. Through analysis, we found that electromagnetic radiation generated by magnetic levitation train is small, it is considered smaller than household appliances. The literature [2] also analyzed induced electromagnetic may generated in idle power supply segment which is existing high voltage and high current ,it belongs to ultra-low frequency ranging from AC power (SLF), induced electromagnetic field energy is concentrated on the magnetic field component. So for the design of magnetic electromagnetic shielding, the main goal is to shield the magnetic field components in low-frequency induced electromagnetic. The report is studied for the normal conducting electromagnetic shielding magnetic train of Shanghai.

GENERATION AND ANALYSIS OF ELECTROMAGNETIC INTER INTERFERENCE

Pudong magnetic train line of Shanghai in China is using normal conducting magnetic levitation technology, the frequency of the AC power supply is 5 ~ 300HZ, the main power station is 110kv, along the supply is 35kv, and the supply current of is up to 1600A. It can be seen from magnetic train works that [1], electromagnetic interference may arise mainly from: DC- magnetic field generated by the DC supported levitating magnet; The radio frequency electromagnetic fields generated by Transmission of wireless information between the station and train; An alternating magnetic field generated by guide rail synchronous long stator linear motor to supply cables; Frequency induced electromagnetic field generated in the high-voltage substation and transmission lines along, and other aspects.

It can be seen from magnetic train works that, electromagnetic interference may arise mainly from: DC-magnetic field generated by the DC supported levitating magnet; The radio frequency electromagnetic fields generated by Transmission of wireless information between the station and train; An alternating magnetic field generated by guide rail synchronous long stator linear motor to supply cables; Frequency induced electromagnetic field generated in the high-voltage substation and transmission lines along ,and other aspects.
DC electromagnetic field: For the minimum interaction of DC and AC electromagnetic field electromagnetic, magnetic levitation use EFE pure iron type for shielding materials, strictly shielded so that magnetic flux leakage is minimized, The data in literature [1] (Analysis of electromagnetic environment based on the low-speed maglev trains ,locomotive, sep.10, 2012) display that, the density of DC magnetic fluxed does not exceed the maximum leakage 70T near the train running guide rails, the external leakage magnetic at a 3mm distance of rail field is substantially equal to the electromagnetic field, it is far generally lower than the magnetic field generated by household appliances.

The effect which is generated during the transmission of wireless information: frequency for the communication between station and magnetic train mainly used 37.5-39.5GHZ. In this band, the electromagnetic wave is mainly strong directional spatial straight line. The data in literature [2] (Test and Research on the interference of magnetic electromagnetic, Railway Signal & Communication Engineering and Technology, 2008, 02) display that, the distribution of frequency range for radio noise of magnetic train generated at 18GHZ is in the 80 ~87 MHZ and 880 ~ 930MHZ. Secondly, radio noise of the train generated at the frequency range of 80 ~87MHZ is not dependent on train speed, and therefore the radio frequency electromagnetic field is negligible, which is generated by wireless information transmission between the station and train.

Affect generated by the main substation and frequency alternating current in high-voltage : Voltage used in main substation is 110kv, voltage along the line used 35kv, according to << Radio Interference Limits on the transmission lines of AC high-voltage overhead >> GB15707-1995, <<High-voltage overhead transmission line and measurement method of radio interference in the substation >> GB / T7349-2002, << Electromagnetic environment requirements of shortwave radio direction finding station >> GB13614-92, and<< Electromagnetic environment requirements of remote radio navigation station in the sea >> GB13613-92, and other national standards, Protecting line space of 110kv high voltage overhead transmission is generally not less than 1000m, The protecting distance of 35kv high voltage overhead line is at least 600m , to the protecting space of the VHF band and other testing stations can be appropriately reduced. Normal conducting magnetic railway of Shanghai PUDONG magnetic line uses German international technology, operational security has more than a decade, through the above analysis, train inspection station and radio communications stations constructed for the magnetic, in accordance with national standards generally do not have large influences.

An effect on alternating magnetic field produced by guide rail synchronous long stator linear motor and power supply cables: the sides both at bottom of magnetic levitation train and the guide rails on the ground are made of alternating, the vast majority of the alternating magnetic field is in the frequency range 5-300HZ, calculation of the wavelength is 60000km -1000km, the division in accordance with provisions of wave, belonging to ultra-low frequency (SLF) long wave. Low frequency radio should not produce wave radiation. According to <<Radio Rules>> published by the ITU in 1998 and the final document adopted by the World Radio communication Conference in 2000, and << Radio Frequency Allocation Provisions of People's Republic of China >>, the 9khz and below were not planned on. It is also possible that there is substantial absence of electromagnetic radiation, or electromagnetic radiation may be severe enough to interfere with normal operation problem of other radio communication device.

Low-frequency induced electromagnetic: at very low frequency, the magnetic component is much larger than electric field component of the induced the electromagnetic field, therefore, the object of shielding induced electromagnetic field is magnetic component of electromagnetic field generated by induced magnetic train.
DC magnetic field: When the low-frequency electromagnetic field is reduced to 0Hz, the low-frequency electromagnetic field is into a DC magnetic field. DC magnetic field shielding is more difficult than low frequency electromagnetic shielding. Usual selection tried to avoid the interference of DC magnetic field sources. Under conditions permitting, you can surround the interfered source of DC magnetic field with

magnetic material, so the magnetic field lines emanating from it can form a closed loop within the permeable material, and it can reduce its outside interference.

As it can be seen from the operating mechanism of the magnetic train, a DC magnetic field only present when the bottom of the train and the ground coil work simultaneously, the magnetic circuit in part of magnetic levitation train through the good electromagnetic shielding design is closed, therefore, the influence of DC magnetic field can' t be considered. High-frequency induced electromagnetic field (usually from 1000Hz to 1MHz), high-frequency electromagnetic field (1MHz above), with increasing frequency, the energy of the induced electromagnetic field gradually incline to the electric field component, taking account into the frequency 5 ~ 300HZ of the alternating current levitating magnetic, shielding in this regard is not researched.

In summary, object studied of Magnetic electromagnetic shielding is focus on how to shield the low frequency component of induced filed on the segment of idle power. As magnetic train works and the analysis on the principle of the electromagnetic shielding, it is known that, low-frequency electromagnetic energy is concentrated in the induced electric fields, the energy of electromagnetic radiation is negligible, according to analysis of near field according with Poynting's theory. Therefore, the purpose of the experiment is also shield the strength aspect on low-frequency induced field electromagnetic.

In principle, the power section of normal conducting magnetic levitation is very similar with linear motors supplied. And the linear motor is from a radial cut of rotary motor. For power supplied section of normal conducting magnetic levitation, the track is the stator coils of three-phase power supply (primary part) and the rotor (secondary section) mounted on magnetic levitation trains. The rotor of magnetic levitation train and the stator form a closed loop, since the retardation of the three-phase power, move forward or backward. As power supply of magnetic levitation is similar with linear motor and three-phase asynchronous motors, so choose the three-phase induction motor as a shield test model. Select phase induction motor for teaching laboratory, 380V, 0.39A, 1500r / min.

As the estimated analysis of materials and methods for the low-frequency electromagnetic shielding in The literature [4], it can be seen that, for the low-frequency induced electromagnetic, since the vast majority of energy concentrate on the magnetic field components, the material which is high permeability and not easy saturated should be selected in order to shield the magnetic energy of induced electromagnetic. When the magnetic field you want to shield is weak, one layer of shielding can meet the requirements. When the magnetic field you want to shield is strong, the shielding layer may not meet the requirements, you can use a multi-layer shielding. Multi-layer shielding principle is that decay magnetic field to a certain extent using a low magnetic permeability material which is not easily saturated at first, then do further attenuation using a high permeability material (usually prone to saturation).

As the magnetic field of three-phase motor source is weak which is selected for experiment, the only one layer shielding is used. If the levitating magnetic will be studied, it is expected to adopt a multi-layer shielding based on the actual situation. Also due to the weak magnetic field of experimental source, low carbon steel can be firstly chose for shielding experiment which is under the premise of affordable without taking the thickness of the low carbon steel into account. If the electromagnetic field of levitating magnetic will be studied, you might consider silicon steel plate, permalloy and the like. Experimental material is finally selected as the following: 2mm / 3mm mild steel sheet, 2mm thickness of the acrylic plate, 2 mm thickness of 304 stainless steel plate, 2mm thickness aluminum, 3mm thickness galvanized iron.

SHIELDING EXPERIMENT FOR LOW FREQUENCY INDUCING ELECTROMAGNETIC FIELD OF MAGLEV

- The experiment mainly research on change of motor magnetic field strength shielded by various materials at different heights, different distances.
- In order to verify the shielding effect on the magnetic field using material of low magnetic even non-magnetic, add acrylic and aluminum plates as well as pure austenitic stainless steel 304.
- The selection of aluminum and galvanized steel sheet is based on it that they always used for highway sound barrier as the material, to verify that if magnetic shielding material be used for high-speed sound barrier, since the galvanized steel DX51D + Z does not arrive, only test the aluminum.

- Main purpose under using galvanized iron is to test the shielding effect of magnetic field based on magnetic material which is galvanized at the outer.
- The experiment also tested the shielding effect using shielding material to completely surround the source shielding or only shield one side.
- In addition, also do experiments on 2mm mild steel plates inclined at different angles ,in order to test how the high degree of shielding material impact on different heights and distances.

The experiment and the results are as follows：

1) Test of unshielded electromagnetic field is detailed in Table 1:

Table 1 Test of unshielded electromagnetic field

D H	0(CM)	10(CM)	20(CM)	30(CM)
0(CM)	28.4(μT)	22.4(μT)	17.2(μT)	14.5(μT)
10(CM)	4.4(μT)	4.1(μT)	2.3(μT)	1.7(μT)
20(CM)	1.35(μT)	1.2(μT)	1.0(μT)	1.0(μT)
30(CM)	0.24(μT)	0.23(μT)	0.21(μT)	0.21(μT)

Note: D is the horizontal distance, from test to the three-phase motor terminal box; H is the vertical distance, from test to the three-phase motor terminal box.

PS: For frequency electromagnetic fields, Sweden and other European countries generally consider that indoor is namely harmless to human health, and the measurement is prevail to 0.2 μT.

2) The shielding effect on 2 MM Aluminum, size of aluminum is 40×50 (MM×MM)

Table 2 Electromagnetic detection at each position shielded by aluminum

D H	0(CM)	10(CM)	20(CM)	30(CM)
0(CM)	28.5(μT)	22.3(μT)	17.4(μT)	14.1(μT)
10(CM)	4.5(μT)	4.2(μT)	2.5(μT)	1.8(μT)
20(CM)	1.43(μT)	1.23(μT)	1.1(μT)	1.27(μT)
30(CM)	0.26(μT)	0.26(μT)	0.23(μT)	0.23(μT)

3) The shielding effect on 3mm thickness low carbon steel galvanized iron, size of galvanized sheet is the same.

Table 3 Electromagnetic detection at each position shielded by galvanized iron

D H	0(CM)	10(CM)	20(CM)	30(CM)
0(CM)	19.6(μT)	16.4(μT)	12.4(μT)	9.2(μT)
10(CM)	2.9(μT)	2.9(μT)	2.3(μT)	1.7(μT)
20(CM)	0.85(μT)	0.82(μT)	0.7(μT)	0.65(μT)
30(CM)	0.23(μT)	0.27(μT)	0.21(μT)	0.19(μT)

4) The shielding effect on 2mm thickness stainless steel plate (304), size of steel plate is the same.

Table 4 Electromagnetic detection at each position shielded by stainless steel plate

D H	0(CM)	10(CM)	20(CM)	30(CM)
0(CM)	28.42(μT)	22.46(μT)	17.4(μT)	14.7(μT)
10(CM)	4.41(μT)	4.3(μT)	2.34(μT)	1.74(μT)
20(CM)	1.24(μT)	1.24(μT)	0.98(μT)	0.98(μT)
30(CM)	0.26(μT)	0.26(μT)	0.23(μT)	0.24(μT)

5) The shielding effect on 5.2mm thickness of the acrylic plate, size of acrylic plate is the same.

Table 5 Electromagnetic detection at each position shielded by acrylic plate

D H	0(CM)	10(CM)	20(CM)	30(CM)
0(CM)	28.5(μT)	22.3(μT)	17.4(μT)	14.1(μT)
10(CM)	4.5(μT)	4.2(μT)	2.5(μT)	1.8(μT)
20(CM)	1.43(μT)	1.53(μT)	0.94(μT)	0.93(μT)
30(CM)	0.26(μT)	0.26(μT)	0.23(μT)	0.23(μT)

6) The shielding effect on 2mm mild steel sheet veneer, size of carbon steel plate is the same.

Table 6 Electromagnetic detection at each position shielded by mild steel sheet veneer

D H	0(CM)	10(CM)	20(CM)	30(CM)
0(CM)	19.5(μT)	16.3(μT)	12.4(μT)	9.1(μT)
10(CM)	3(μT)	2.8(μT)	1.8(μT)	1.6(μT)
20(CM)	1.1(μT)	0.9(μT)	0.8(μT)	0.6(μT)
30(CM)	0.27(μT)	0.25(μT)	0.21(μT)	0.22(μT)

7) The full shielding effect on 2mm low carbon steel, size of full Shield is 30×40×50 (MM×MM×MM).

Table 7 Electromagnetic detection at each position full shielded by low carbon steel

D H	0(CM)	10(CM)	20(CM)	30(CM)
0(CM)	19.4(μT)	16.2(μT)	12.2(μT)	8.9(μT)
10(CM)	2.9(μT)	2.7(μT)	1.7(μT)	1.5(μT)
20(CM)	0.85(μT)	0.8(μT)	0.65(μT)	0.6(μT)
30(CM)	0.21(μT)	0.25(μT)	0.21(μT)	0.23(μT)

8) The shielding effect on 3mm mild steel sheet veneer, size of mild steel sheet veneer is 40×50 (MM×MM).

Table 8 Electromagnetic detection at each position shielded by mild steel sheet veneer

D H	0(CM)	10(CM)	20(CM)	30(CM)
0(CM)	14.4(μT)	11.2(μT)	8.6(μT)	7.5(μT)
10(CM)	2.2(μT)	2.1(μT)	1.2(μT)	0.9(μT)
20(CM)	0.7(μT)	0.6(μT)	0.5(μT)	0.5(μT)
30(CM)	0.24(μT)	0.23(μT)	0.21(μT)	0.21(μT)

9) Shielding Experiment on 2mm mild steel plates, size of low-carbon steel plate is 40×50 (MM×MM).

Table 9 Electromagnetic detection at each position full shielding by mild steel plates

D α	0^0	30^0	45^0	60^0
0(CM)	19.5(μT)	16.3(μT)	12.4(μT)	9.1(μT)
10(CM)	4(μT)	2.8(μT)	1.7(μT)	1.6(μT)
20(CM)	1.1(μT)	0.9(μT)	0.65(μT)	1.2(μT)
30(CM)	0.27(μT)	0.25(μT)	0.21(μT)	0.3(μT)

Note: α is the angle to the vertical direction.

CONCLUSION AND DISCUSSION

- Table 1.2.4.5 taking human error and measurement error of test equipment into account, it is believed, acrylic shield material, 304 stainless steel and aluminum all did not effect on shielding low frequency magnetic field, it is consistent with the analysis in Annex 3.
- Table 3 shows: there is not very different effect between galvanized iron and low carbon steel shielding.
  although the zinc plating layer of iron, and zinc is non-magnetic, because of the thickness, galvanized sheet will still be magnetic, and the eddy current shield effect did not differ much. Table 3 also taking it into account that the low-carbon steel is resistant to corrode, so we may consider the usage of galvanized iron material in future studies.
- Table 6.7 shows that the effect difference between low-carbon steel shielding, fully shielded and shielded veneer unilateral is 10% to 15%. It can completely reach the purpose of shielding without taking the thickness of the low-carbon steel into account.
- Table 6.8 shows that, shielding effect on reserved field strength of 2mm mild steel sheet should reach 65% to 70%. It reached 47% to 52% in fact. After being half shielded by 3mm mild steel, refer to the Mask data in Appendix 4. Field strength under 2mm should be maintained between 45% to 50%, while

under 3mm it should be kept about 35% .The reason for this may be due to different materials, may also be due to design of the shielding sheet size (Due to own usage of cutting machine, so only for the convenience of cutting, there is no strict cut accordance with shield size in Annex 4.) Furthermore, in reality, each shield welding between the blocks also reduce permeability and so on, experimental data is differ in theory. Test data indicate that can effectively shield low frequency magnetic fields without considering the thickness of mild steel. According to Annex 4, the magnetic field can be reduced to 10% of the original using 8mm thickness .The thickness and size can be specifically designed according to the actual requirements of the field strength and related specifications.

- Table 9 shows that the height of shielding size is related with distance of measuring point. That is, the test points of electromagnetic source must be less than or equal to the height of the shield at the same level of sensitivity. That is, if you want the test source at distance 20 cm to enjoy the shielding effect at the same height, the size of the shield must not be less than 20 cm.
- Taking characteristics into account that the low- carbon steel is resistant to corrode and easy to rust, how anti-corrode, take anti-corrosion paint smear? Oxidation? Plating coating? Nano coating? Cathodic protection? Will the shielding effect change after the processing, this will possibly continue to be experimented in future. This fragment should obviously state the foremost conclusions of the exploration and give a coherent explanation of their significance and consequence.

REFERENCES

[1] Meins J, Miller L, Mayer WJ(1998)The high speed MAGLEV transportation system transrapid. IEEE Transactions on Magn 24(2): 808-811.
[2] Lee HW,K KC, Lee J(2006)Review of MGALEV train technologies. IEEE Trans Magn 42(7):1917-1925.
[3] Shen Z(2001)Dynamic interaction of high speed MAGLEV train on girders and its comparison with the case in ordinary high speed railways. J Traffic Transport 1 (1):1-6 (in Chinese).
[4] Raghuathan S, Kim HD, Setoguchi T(2002)Aerodynamics of high speed railway train. Prog Aerosp Sci 38(6): 469-514.
[5] Shen Z(2005)On developing high-speed evacuated tube transportation in china. J Southwest Jiaotong Univ 40(2): 133-137 (in Chinese).
[6] Cai YG, Chen SS (1997) Dynamic characteristics of magnetically levitated vehicle system. Apple Mesh Rev, ASME 50(11): 647-670.
[7] Xu W, Liao H, Wang W(1998)Study on numerical simulation of aerodynamic drag of train in tunnel, J China Railw Soc 20(2):93-98 (in Chinese).
[8] Zhou X, Zhang D, Zhang Y(2008)Numerical simulation of blockage rate and aerodynamic drag of the high speed train in evacuated tube transportation. Chin J Vacuum Sci Technol 12(28):535-538 (in Chinese).