

# The Research on Intelligent Component Immunity Testing Method of Intelligent Substation

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## Abstract

*Intelligent substation as smart grid important core link, which based on the characteristics of Smart Substation Intelligent components have higher requirements on precision electromagnetic environment and data. This paper analyzes the distribution characteristics of interference sources and the intelligent substation of intelligent component performance requirements of electromagnetic compatibility, and has carried on the intelligent substation electromagnetic compatibility testing technology related research.*

**Keywords:** *intelligent substation, intelligent components, electromagnetic compatibility*

## 1. Introduction

Smart grid has become the new trend in the world today the development of the electric power system reform. Smart grid is considered the development trend of major scientific and technological innovation of the twenty-first Century power system. As an important basis for the smart grid, intelligent substation providing standard, reliable node support for smart grid, and it is the most important aspects of the core of smart grid [1].

There is a great source of electromagnetic interference in power system; power system will produce all kinds of electromagnetic interference. For the smart substation become from digital substation, its various intelligent components have higher request for electromagnetic environment and data precision. Therefore, under the background of present Intelligent substation in our country on the basis of the microelectronics technology of automation equipment intelligent and functional integration, and analyze the intelligent substation electromagnetic compatibility test method research has important application value and practical significance.

## 2. Research Status

With the development of computer and electronic technology and the wide application, electromagnetic compatibility between electronic equipment gradually gets scientific research institutions and enterprises attention. Intelligent substation has higher requirements of digitization, intelligent and high reliability to electric power equipment.

Smart components basically locate in various places of the transformer substation contacting closely with the high voltage substation primary equipments in the substation. At the same time they will transmit all kinds of information of high voltage primary equipments to secondary control system so that these smart components must be faced with a variety of complex electromagnetic interference inside the substation. These interference characteristics are wide frequency range, large electromagnetic disturbance intensity and multi-way coupling of electromagnetic disturbance.

While the phenomenon of electromagnetic interference in power system will not only

affect the normal work of the system but also will have harmful effects on human health, and restricted the further development of electric power system. The current is a preliminary research for intelligent substation electromagnetic compatibility [2].

Electromagnetic compatibility (EMC) refers to the system and subsystems, each interval and the circuit in the specific working environment, not because of the electromagnetic interference (EMI) and failure or performance deterioration and can work according to ability. Some scholars in the study of existing defined it as "the system of the equipment can work normally in the electromagnetic environment and not cause unable to bear the wrong things in the environment where electromagnetic interference ability", and the national standard GB/T 4365-1995 also made similar definition [3]. Although the definition emphasis is different, but we often think of electromagnetic compatibility includes two levels of electromagnetic interference and electromagnetic sensitivity, current research on the electromagnetic compatibility of the academic circles have electromagnetic compatibility electromagnetic compatibility design, spectral and electromagnetic compatibility standards and norms.

Research on interference of power system at home and abroad have done a lot of work, developed a series of standards, such as " power station, station automatic control equipment Immunity requirements ", " power station, station Electromagnetic Compatibility Guide" etc.

### **3. The Electromagnetic Compatibility Problems of Intelligent Substation**

Smart components are the important secondary equipments of power systems and they are in serious electromagnetic interference of smart substations. There are electric and magnetic connection between intelligent substation primary circuit and secondary circuit. Any transient occurs in primary circuit that will be transferred to secondary circuit through different coupling ways forming transient disturbances. Transient disturbances may cause two kinds of consequences on the secondary circuit. One is damaging secondary equipment insulation, even burning integrated chip, forming a permanent damage; the other is interfering the normal work to make it false action resulting in primary equipment failure and causing serious damage.

There are two trends making the problems of electromagnetic compatibility more prominent in modern power system. One is the improvement of the transmission voltage, when the switching operation or failure a stronger electromagnetic field will be resulted in. And the use of gas SF<sub>6</sub> insulation switch will make a high frequency fast transient overvoltage on bus when the switching operation happens because of the peculiarity of gas SF<sub>6</sub>. This will radiate pulsed electromagnetic with a very steep rising edge into space and form a strong interferer with wide band. The other widespread use of smart components, these electronic devices based on microelectronic technology have more pronounced sensitivity and vulnerability to transient disturbances. Substation automation system always uses hierarchical distributed architecture at present. The protection devices are installed in the high voltage switchgear or near ultrahigh voltage switching field which makes electromagnetic compatibility problems more prominent.

### **4. Research on Electromagnetic Compatibility of Test Method**

Electromagnetic environment evaluation is an important part of EMC technology, and it is the foundation of the intelligent substation electromagnetic compatibility testing technology research. In this paper, this part research the distribution characteristics of electromagnetic interference source and intelligent component requirements of intelligent substation electromagnetic compatibility and intelligent substation electromagnetic compatibility testing technology.

#### **4.1. Study on the Distribution Characteristics of the Electromagnetic Interference Source**

Interference sources in intelligent substation operation process can be divided into the normal operation and fault condition, the distribution features of the specific as follows:

- (1) The distribution characteristics of the interference source during normal operation;
  - (a) The power frequency electric and magnetic fields generated by the transformer and other equipment;
  - (b) Radiated interference generated when the transmission of electric energy in the high voltage transmission line;
  - (c) The power frequency magnetic field interference generated in high voltage transmission line and bus bar normal operation;
  - (d) The conducted interference of low voltage power supply system transmission and automation equipment, and the disturbance of radio equipment of high-frequency conduction and radiation;
  - (e) Natural interference phenomena such as lightning strike, electrostatic discharge, geomagnetic disturbance and nuclear electromagnetic pulse.
- (2) The specific distribution of fault state interference source;
  - (a) The operating measures of when the electric power system fault generating transient interference sources and transient overvoltage (Including isolating switch, breaker, primary side equipment etc.);
  - (b) High voltage bus bar single-phase earth fault in the secondary loop generating common-mode interference voltage;
  - (c) Changes in the load of power grid and the running fault generate some interference of interrupt, imbalance, harmonic and frequency changes.

#### **4.2. The Design on Electromagnetic Compatibility Technology of Smart Component in Smart Substation**

The basic anti-jamming measures of smart components are to prevent interference into the weaknesses of the system. One is to increase its anti-jamming capability through improved device hardware design; the other is to achieve it through a variety of shielding measures to cut off the interference transmissions. The design on electromagnetic compatibility technology should be based on three basic elements of electromagnetic compatibility.

#### **4.3. The Analysis of Intelligent Requirements of Electromagnetic Compatibility of the Component of Intelligent Substation**

Intelligent components of intelligent substation include electronic transformer, merging unit and intelligent terminal. The specific requirements of electromagnetic compatibility are as follows:

- (1) The requirements of electromagnetic compatibility of the electronic instrument transformer;

Electronic transformer with electronic components in the condition of high voltage circuit directly access or embedded in a host device, the electromagnetic interference signals operating environment is far more than the general EMC test standards, especially in some electromagnetic transient process, high pressure caused by high frequency electric magnetic wave, high frequency current and potential rise higher problem will seriously affect the normal work of electronic components in the electronic transformer,

which may cause the false positives, crash and even damage the device, thus affecting the substation safe operation.

(2) The performance requirements of electromagnetic compatibility of merging unit;

Merge cells produce electronic instrument transformer with the system, along with the application of the intelligent substation is widely used. The internal logic is relatively fixed, but the reliability, real-time, highly consistency requirements, its importance should device and relay protection quite. Because of the equipment has electromagnetic interference, noise and so serious, so that reliable signal conversion and transmission are faced with great problems.

(3) The requirements of electromagnetic compatibility of the intelligent terminal;

Intelligent terminal of intelligent substation's anti electromagnetic interference ability to meet the requirements of IEC61850-3 standard, GB/T17626 system standard, and provide the test report. [4-5] anti jamming performance requirements and tests are shown in Table 1.

**Table 1. Anti-jamming Performance Test and Requirements of Intelligent Substation's Intelligent Terminal**

Serial number	Test	Reference standard	Level requirements
one	Electrostatic discharge immunity	GB/T 17626.2	The IV level
two	RF electromagnetic field immunity	GB/T 17626.3	The III level
three	Electrical fast transient burst immunity	GB/T 17626.4	The IV level
four	Surge (impact) immunity	GB/T 17626.5	The IV level
five	Rf induced conduction harassment immunity	GB/T 17626.6	The III level
six	Power frequency magnetic field immunity	GB/T 17626.8	The V level
seven	The pulse magnetic field immunity	GB/T 17626.9	The V level
eight	Damped oscillatory magnetic field immunity	GB/T 17626.10	The III level
nine	Oscillatory waves immunity	GB/T 17626.12	The III level

Note: the above evaluation tests were adopted A level quasi.

#### 4.4. The Testing Technology of Intelligent Substation Electromagnetic Compatibility

In view of the importance and complexity of the electromagnetic compatibility problem, theoretical calculation results and actual results usually exists a big difference, so the electromagnetic compatibility test is importance [6].

Electromagnetic compatibility test is usually refers to the equipment or system meets the requirements in the electromagnetic environment is not for any equipment in the environment's ability to produce can't afford to electromagnetic interference, including radiation shielding effectiveness radiation test, sensitivity test and emission test, test method based on all kinds of standards, measuring instrument based on the frequency domain. China's national standard GB/T6113 1-1995"the radio disturbance and noise immunity measuring equipment "not only to the instrument, but also to measurement method in detail and strict rules.

##### 4.4.1. Surge Immunity Test

Lightning strikes in the power system can be induced a lot of interference in the

secondary cable, at the same time switch operation may also produce a transient overvoltage. Surge immunity test (impact) is the inspection equipment ability under the interference of anti-interference. Surge interference harm is serious, often cause breakdown, such as burning unrecoverable fault. The main principle of lightning surge voltage of is as follows:

- (1) Direct lightning strikes in the external circuit, the injection of large current flows through the ground resistance or external circuit impedance and then generating voltage;
- (2) The indirect lightning induced voltage and current in the building or the outer conductor;
- (3) The common ground path direct lightning discharge to ground of the current coupled to the equipment grounding system.

When the lightning current or fault current flows into the substation grounding grid, grounding grid is composed by steel unequal potential, especially in the vicinity of direct lightning arrester protective chamber, in two protective chamber independently online may cause transient large potential difference, the potential difference is likely to pass the two ground coupling two equipment protecting chamber to the two device, thereby causing electromagnetic interference to the two equipment; In order to prevent the protection of small indoor two interfered, and puts forward some requirements for shielding performance of the protective chamber; The anti-jamming performance of automation, national power company in Nanjing Automation Research Institute building electromagnetic compatibility laboratory automation equipment for anti interference performance of automation equipment, and automation equipment will be put into operation for electromagnetic compatibility performance appraisal.

After the lightning substation, by the large current through the ground discharged into ground, the ground potential rise greatly. If the secondary loop ground near the lightning current into the site, the secondary loop ground potential will then rise, will form the common-mode interference in the secondary loop, form the overvoltage, serious can cause secondary equipment insulation breakdown. For secondary cable due to cable connected to the grounding network on both ends of the skin, when there is lightning current flows through the ground, can produce potential difference on both ends of the cable, current will flow through the secondary cable sheath, and on the secondary cable conductor induction electric potential, superimposed on the signal interference. When the power cable, outdoor lightning current secondary cable, communication power supply into the RTU (Remote Terminal Unit) device, the RTU between the shell and the earth produced a transient reach a few kV high voltage, the high voltage will directly endanger the safety operation of the RTU device, even lead to equipment damage.

Surge detection methods used in this paper is as follows: It add the surge disturbance in the form of differential mode in the protection equipment of switch signal input port, switch input port with optical isolation and signal conversion, optical isolation protection realization itself is not a hit from surge.

#### **4.4.2. Electrical Fast Transient Burst Immunity Detection**

The reason of electrical fast transient (EFT) pulse interference is disconnect inductive load (or through to the perceptual load), because the perceptual load to store energy cannot be released, so it formed resonant with distributed capacitance. Resonance produced by high voltage constant break down circuit breaker of contact between the air gaps and produce arc discharge, until the action contact between the air gaps is too widen to breakdown. In the process, it can produce a series of sharp bursts. Electrical transient bursts immunity detection refers to observe whether equipment is affected by the electrical transient bursts.

Electrical transient bursts immunity test is to analyze ability of anti-interference of the electronic equipment of lightning, grounding switch failure or transient process

(switching inductive load, relay contact bounce, high voltage switch, *etc.*) caused by transient disturbance. In the transient electromagnetic interference of substation, interference sources is caused by a switch operation system of the transient current and transient voltage, sensitive object is mainly refers to the secondary equipment such as protection, control and communications.

The switching operation in the primary circuit is the main equipment interference source of substation secondary side equipment and mainly is the action of power plant substation circuit breaker and isolating switch. Especially when isolating switch suit no-load bus bar, due to the arc reigniting between the isolation switch contacts, produce a series of high frequency oscillation in the loop, the equipment caused a great disturbance in the secondary loop. Due to the high voltage substation often need of operation or maintenance of a variety of switching operation, the resulting form the interference of electromagnetic transient process. In the actual operation in our country, because the operation produces transient electromagnetic interference in monitoring equipment can no work normally happens.

In EFT immunity tests, we easy to ignore the understanding of the nature of the pulse interference, testing of electromagnetic compatibility can effectively eliminate the electromagnetic interference, and improve the performance and reliability of the system fundamentally. Due to pulse interference is the nature of the common mode, therefore, in the test with reference to the floor should be considered, and in order to ensure the pulse noise immunity test of repeatability and comparability, we should be carefully read the related standard and the standard method of use, so that make reference to the floor to play a proper role.

The electrical fast transient pulse testing method of immunity is the bus below ground as the measuring point; the specific operation is to disconnect a short bus. The specific operation is disconnected for a short bus, transient electromagnetic field on the transient current of 115, 230 and 500kV outdoor substation by switching operation transient generated through bus to the surrounding radiation detection.

## 5. The Test Program of 220KV Smart Substation Transient Electromagnetic Disturbance

### 5.1. Measurement Items

The specific action items and measurement object of the program are shown in Table 2.

**Table 2. The Operating and Measuring Harassment of 220kv Smart Substation**

Operation equipments	Action items	Measurement object
Breaker or disconnected switch	1. Invest 220kV main transformer	1. Space transient magnetic field; 2. Transient potential rise of GIS shell; 3. Harassment voltage of 110V DC power in station; 4. Common mode and different mode harassment of 220V AC power in station;
	2. Invest 110kV bus	
	3. Cut 110kV sense wire	
	4. Invest / cut 35kV capacitor	

## 5.2. Operate Test

### 5.2.1. Invest 220kV Main Transformer

This operation is mainly monitoring the transient magnetic field level of 220kV GIS space and the transient potential rise of 220kV GIS shell when the main transformer is invested. At the same time, the 220V AC power port inside HSBC switch cabinet in 220kV GIS is being monitored. So does the transient harassment level of 110V DC power port. The main wiring diagram is as shown in Figure 1.

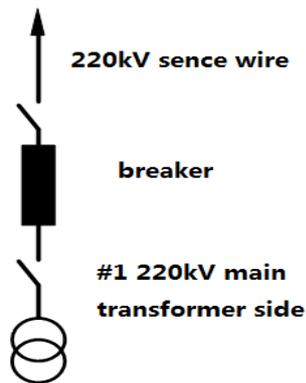


Figure 1. The Main Wiring Diagram

The measuring access ports are below:

- (1) Space magnetic field antenna is put nearby the GIS;
- (2) Ground potential rise: 220kV GIS shell – the ground copper bar;
- (3) Harassment of AC power: A phase port - the ground copper bar, common port - the ground copper bar;
- (4) Harassment of DC power: Positive port – negative port.

### 5.2.2. Invest 110kV Bus

This operation is mainly monitoring the transient magnetic field level of 110kV GIS space and the transient potential rise of 110kV GIS shell when the 110kV bus is charged. At the same time, the 220V AC power port inside HSBC switch cabinet of 110kV voltage change / lightning arrester in 110kV GIS is being monitored. So does the transient harassment level of 110V DC power port, the main wiring diagram is as shown in Figure 2.

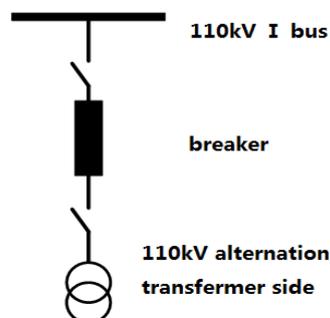


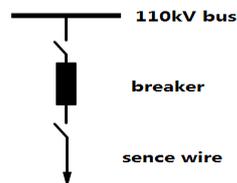
Figure 2. The Main Wiring Diagram

The measuring access ports are below

- (1) Space magnetic field antenna is put nearby the GIS;
- (2) Ground potential rise: 220kV GIS shell – the ground copper bar;
- (3) Harassment of AC power: A phase port - the ground copper bar, common port - the ground copper bar;
- (4) Harassment of DC power: Positive port – negative port.

### 5.2.3. Cut 110kV Sense Wire

This operation is mainly monitoring the transient magnetic field level of 110kV GIS space and the transient potential rise of 110kV GIS shell when the 110kV sense wire is changed from operation into cold standby including breaker and bus isolation knife switching. At the same time, the 220V AC power port inside line protection cabinet of 110kV voltage change / lightning arrester in 110kV GIS is being monitored. So does the transient harassment level of 110V DC power port. The main wiring diagram is as shown in Figure 3.



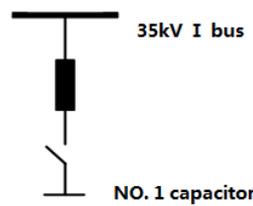
**Figure 3. The Main Wiring Diagram**

The measuring access ports are below:

- (1) Space magnetic field antenna is put nearby the GIS;
- (2) Ground potential rise: 220kV GIS shell – the ground copper bar;
- (3) Harassment of AC power: A phase port - the ground copper bar, common port - the ground copper bar;
- (4) Harassment of DC power: Positive port – negative port.

### 5.2.4. Investment / Cut 35kV Capacitor

This operation is mainly monitoring the 220V AC power port inside 35kV capacitor cabinet in 35kV distribution equipment room when 35kV capacitor invested or cut. So does the transient harassment level of 110V DC power port, the main wiring diagram is as shown in Figure 4.



**Figure 4. The Main Wiring Diagram**

The measuring access ports are below:

- (1) Harassment of AC power: A phase port - the ground copper bar, common port - the ground copper bar;
- (2) Harassment of DC power: Positive port – negative port.

## 6. Summary

In recent years the development of smart substation, on the basis of the microelectronics technology and computer technology new technology has been widely applied in practice, relay protection and automatic device, remote and communication device in an important position in the power system, such as their high sensitivity, large volume, wide distribution and vulnerable to interference. In the power system in our country, due to interference of switching operation, lightning caused by other reasons have repeatedly occurred. Therefore, properly solve the problem of electromagnetic compatibility of intelligent substation is to determine the smart substation can be an important part of the healthy and rapid development. So the study of intelligent substation electromagnetic compatibility problems becomes increasingly important.

In the first part of this paper, which analyses and studies the importance of research on the electromagnetic compatibility test method of intelligent substation under the background of intelligent substation automation equipment in our country based on micro electronics technology is intelligent and function integration; In the second part, discusses the research status in this field; In the third part from the distribution characteristics of interference sources, intelligent component performance requirements of electromagnetic compatibility of intelligent substation, electromagnetic compatibility testing technology of intelligent substation three angles has carried on the related research.

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