# Research on Selecting X-ray DR Radiographic Parameters to Detect Electrical Equipment

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**Abstract.** With the rapid development of China's power industry construction, operation substations, power plants and other power equipment is often some failures, affecting the stability and reliability of the power system. X-ray digital imaging technology in recent years gradually able to power failure diagnostic equipment, and achieved certain results. In the X-ray detection process, the influence between selected transillumination imaging quality parameters, the relationship between whether the defect can be clearly locate and determine its type. This paper studies the selection DR Radiographic detection parameters, to ensure that the X-ray image quality, practical engineering testing and safe and stable operation of the power grid is important.

**Keywords:** Electrical equipment, X-ray, Radiographic parameters.

## 1. Introduction

With the rapid development of society, the rapid construction of China's power industry, modern power system is moving in large power grids, large units, high pressure, high capacity direction, to safeguard the stability of power system operation and reliability; it is for electricity quality and safe operation of power equipment and put forward higher requirements.

On-site substations, power plants, etc. there is a lot of noise, and because electrical equipment is relatively large, very complex internal structure and other reasons, X-ray digital images obtained are often not very good, the image is not clear enough, electrical equipment and so give a professional image locality who brought a great impact on the judgment of defects [1-3]. Therefore, the electrical equipment of X-ray digital images a degree of processing (denoising, enhancement, stitching, etc.) is particularly important. In the field test, the technician first concern is how to shoot good quality digital images, easy to determine the position of the image and nature of the defect. In the DR test, select the perspective of each parameter determines the system detects the image quality is good or bad. To obtain high-quality images, improve the efficiency of field testing, it is necessary to select the parameter DR detection system research.

## 2. Select DR Power Equipment X-ray Detected Parameters

### 2.1. DR power equipment X-ray detection of focal length selection.

Tab. 1 Recommended scales ray detector

| Technical Level | Transillumination Distance$f$ | $U_g$ |
|---|---|---|
| A Leveal | $f\geq 7.5\ d\cdot b^{2/3}$ | $U_g \leqslant \left(\frac{2}{15}\right) b^{1/3}$ |
| AB Levea | $f\geq 10\ d\cdot b^{2/3}$ | $U_g \leqslant \left(\frac{1}{10}\right) b^{1/3}$ |
| B Levea | $f\geq 15\ d\cdot b^{2/3}$ | $U_g \leqslant \left(\frac{1}{15}\right) b^{1/3}$ |

The focal length of a straight line from the source to the X-ray imaging plate. When the focal length of the X-ray detection image geometric clarity, choose the size of the exposure parameters such as have a big impact [4].

Select the size of the focal length focal length of the first to consider the impact of geometric clarity. JB / T 4730.2-2005 standard, defines the relationship between f d and b, as shown in Table 1.

**2.2. DR power equipment X-ray detection of amount of exposure selection.**

Ray intensity of the exposure amount E i is the product of an irradiation time of the emitted X-ray source, the tube current is equal to the time t i and the lens according to the product. X-ray exposure dose is an important parameter detection transillumination, which directly affects the black level of the image, both a linear relationship in a certain range, adjust the exposure can adjust image quality. Also affects the exposure amount of the image contrast, graininess, signal to noise ratio, sensitivity[5].

**2.3. DR power equipment X-ray detection of voltage selection.**

In the X-ray inspection work, the correct choice of the X-ray tube voltage machine is crucial, which directly determines the X-ray transillumination capacity.

Ray detection sensitivity depends on the workpiece and the contrast sensitivity of the imaging plate [6]. Wherein the sensitivity of the imaging plate is determined by the detection system itself is not easy to change the contrast of the radiation through the workpiece in two different regions of the workpiece-ray intensity ratio. Mainly by the absorption coefficient of the material, the depth of the defect and the tube voltage. The following relationship exists:

$$\frac{I_A}{I_C} = e^{\mu \Delta x} \tag{1}$$

Formula $I_A$-X-ray after the beam intensity non-defective parts;

$I_C$-X-rays have been post-ray intensity defective parts; μ-absorption coefficient of the material; $\Delta x$-defect depth.

$\Delta x$ is the actual depth of the defect inspection of the workpiece is constant, the size of μ is calculated by the following formula: $\mu = K\lambda^3 Z^3$, wherein the constant value $K$ is a coefficient, λ is the wavelength of the incident radiation is determined by the ray machine parameter, $Z$ as being atomic coefficient detection workpiece material for the given value. It shows the contrast of the decision for a specific piece by ray wavelengths, is proportional to the third power-ray wavelengths. And according to the formula $\lambda_{min}=1.24/U$, ray wavelength and inversely proportional to the voltage relationship. Materials deduced absorption coefficient $\mu$ is inversely proportional to the third power with $U$. A smaller tube voltage can effectively improve the contrast of the workpiece, thus greatly improving the quality of the image. Represented by the following formula:

Half-thickness image illustrates this problem. Half of the thickness means that half of the incident ray attenuation material thickness, the presence of $d_{1/2}=0.693/\mu$. Easy to know and attenuation coefficient is inversely proportional to half the thickness, and tube voltage proportional to the third power. When a tube voltage of $U_1$ transillumination workpiece, the tube voltage is set at the thickest part of the $C$ region of the workpiece, X-rays passing through the four half of the thickness, the attenuation of the X-ray intensity to the original 1/16 thin workpiece X-rays passing through the two parts half of the thickness, a quarter of the original ray attenuation. At this time the contrast workpiece $I_A/I_C=4$. When the voltage increases to $\sqrt[3]{2}\,U_1$, half of the thickness is increased to 2 times the original, the attenuation of the thickest part of the workpiece to the original 4, the attenuation of the thin portion of the original half. At this point the contrast of the workpiece for $I_A/I_C=2$.

Tube voltage selection principle: in permitting, should try to choose a lower tube voltage and improve workpiece contrast to improve the sensitivity and image quality ray detection.

**2.4. DR power equipment X-ray detection of current selection.**

X-ray tube current is a heated filament cathode current machine, the greater the current generated by electrons more electrons hit the anode target, the more the number of X-rays generated in [7]. DR system transillumination time is generally set to 2s, collected four times a superimposed image, the focal length for the set value, usually to adjust the tube current to change the size of the exposure.

GE's DR detection system power is 900W, maximum transillumination voltage of 300kV. Initial tube current is set to 3mA convenient tube current values do not change in the choice of maximum tube voltage. The total intensity of the X-ray tube voltage is proportional to the square, the high voltage detection, it is bound to the desired exposure amount is small. Tube voltage change directly affects the image contrast and resolution. In order to improve the efficiency of radiation detection and ensure the quality of X-ray detection, you must also consider the purpose and the relationship between tube voltage and tube current, select the appropriate tube voltage and tube current.

## 3. Select the Typical Parameters of Electrical Equipment

### 3.1. DR power equipment X-ray detection of focal length selection.

Plum breaker contacts to the junction with the guide rod for example, Plum contact with the guide rod relative to the tank circuit breakers, it is rather small, and at the center position. In order to see the internal structure can be appropriately reduced focal length, which makes the overall image representing a greater proportion of the image at the center position. Combined focal length relationship with geometric clarity, first select the AB level detection level.

Ray source focal spot size $d$=1.2mm, 220kV circuit breaker tank radius $b$=600mm, and according to the formula $f \geqslant 10d \, b^{2/3}$, $F=f+b$, come to the focal length: $F \geqslant 1454$mm.

Take focal length $F$=1400mm, calculate the value of $F$=1850mm focal length is the choice of a Class B standards. Select Radiographic parameters as shown in Table 2, the circuit breaker testing.

Tab. 2 Radiographic parameters breaker

| Number | Focal length /mm | Voltage /kV | Current /mA | Exposure time /s | Collection times |
|---|---|---|---|---|---|
| 1 | 1400 | 200 | 3 | 2 | 4 |
| 2 | 1850 | 200 | 3 | 2 | 4 |

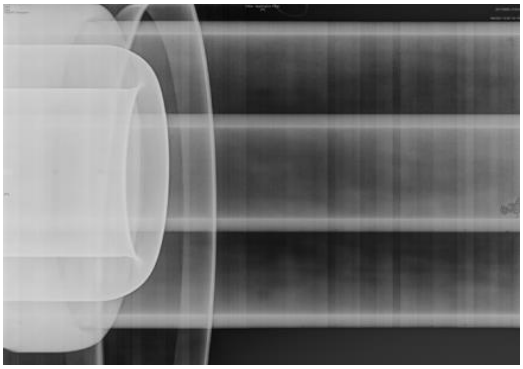

Fig. 1 Small focal length X-ray renderings

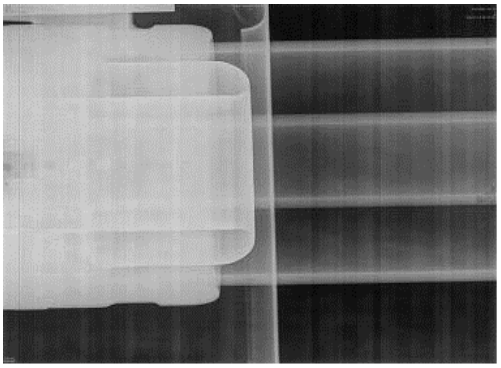

Fig. 2 Big focal length X-ray renderings

Fig 1 can accurately determine the relationship between the various components, and can accurately determine whether the internal defects or impurities have an impact. More can be seen in Fig 2 the internal structure of the contact position of the guide rod connected to the plum is not clear. Figure effect of a better connection, the overall image more clearly.

The internal structure of the physical size is relatively small in relation to the tank diameter, select AB grade-ray detection level, but has no effect on whether or not the defect detection in GIS equipment in the external tank structure imaging and defect location mainly concentrated at the center can be appropriately the decrease is calculated focal length value. This will not only meet the requirements for geometric unsharpness can also be appropriate to enlarge the internal parts of the image to be detected, more conducive to the location and type of defect judgment [8].

### 3.2. DR power equipment X-ray detection of amount of exposure selection.

220kV GIS breaker tank diameter of 1200mm [9]. First select the section of the circuit breaker according to the best transillumination focal length value. Select the focal length is 1400mm, at different voltage levels of circuit breaker transillumination test voltage selector Table 3, X-ray imaging is shown in Fig. 3 to 5.

Focal length of 1400mm, tube voltage of 200kV, tube current of 2.5mA when the image best. According to the formula: $E=it$ was $E$=0.42 mA·min, where the time $t$ is 10s. The exposure circuit

breakers, surge arresters and other equipment needed to detect when the DR can only get the best X-ray image renderings around 0.42mA·min.

Tab. 3 X-ray exposure amount of the circuit breaker under different parameters

| Number | Focal Length(mm) | Voltage (kV) | Current (mA) | Amount of exposure(mA·min) |
|---|---|---|---|---|
| 1 | 1400 | 200 | 2 | 0.34 |
| 2 | 1400 | 250 | 2.5 | 0.42 |
| 3 | 1400 | 300 | 3 | 0.51 |

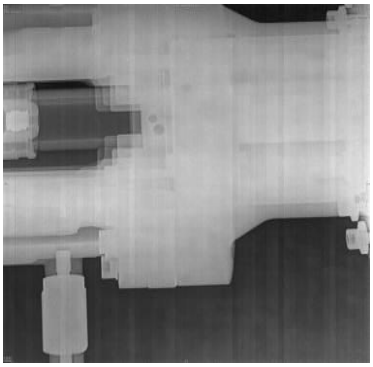

Fig. 3 Small amount of exposure

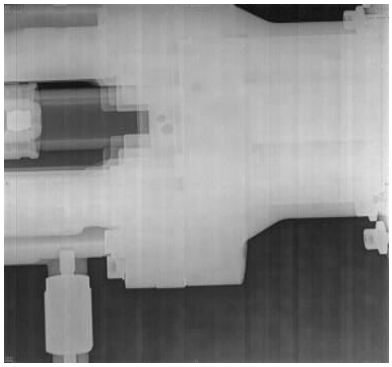

Fig. 4 Right amount of exposure

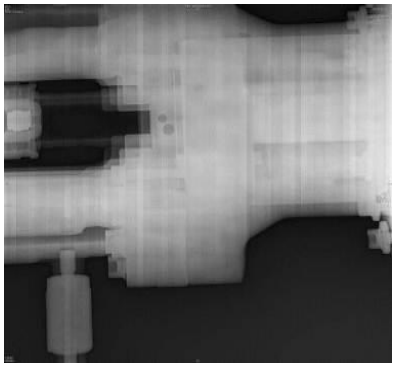

Fig. 5 Large amount of exposure

**3.3. Typical electrical equipment tube voltage and current selection.**

Select 500kV circuit breaker for the detection of static and dynamic contact at the position. According to the formula: $f \geqslant 10d\ b^{2/3}$; $f \geqslant 854$ again: $F=f+b$, have a focal length: $F \geqslant 1454$mm. Where, $d$=1.2mm for the size of the effective size of the focal point, $b=D/2$=600mm half the diameter of the tank. Choose a focal length $F$=1500mm. Select Tab 4 Radiographic parameters for static and dynamic contact breaker Department to conduct transillumination tests.

Tab. 4 Radiographic parameters breaker contact movement

| Number | Focal length(mm) | Voltage (kV) | Current (mA) | Exposure time(s) | Collection times |
|---|---|---|---|---|---|
| 1 | 1500 | 180 | 3 | 2 | 4 |
| 2 | 1500 | 220 | 3 | 2 | 4 |
| 3 | 1500 | 250 | 3 | 2 | 4 |
| 4 | 1500 | 300 | 3 | 2 | 4 |

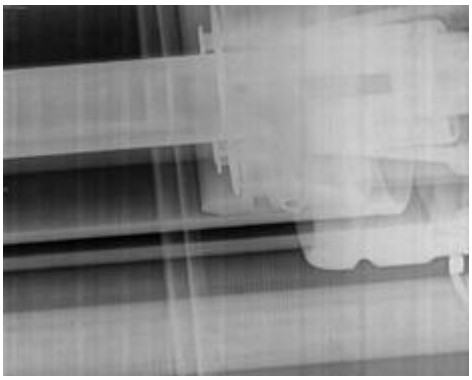

Fig. 6 X-ray detection circuit breaker renderings

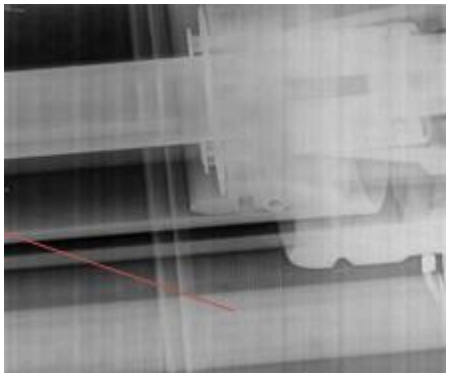

Fig. 7 X-ray detection circuit breaker renderings

Effect of Figures 6 and 7, preferably, can be seen comparing the fine structure. Figures 8 and 9 a higher voltage to be according to some structural details of the lens is not conducive to the judgment. Figure 6 and Figure 7 can be excessive X-rays, some structural isolation switch is directly illuminated through. Analysis Figures 6, 7 and 8 can be drawn: at the same voltage level, the tube current increases the contrast of the resulting image quality is better, the larger the image blackness, the sharper the image [10]. To some extent, determines the X-ray tube voltage transillumination ability to determine a tube current gradation image.

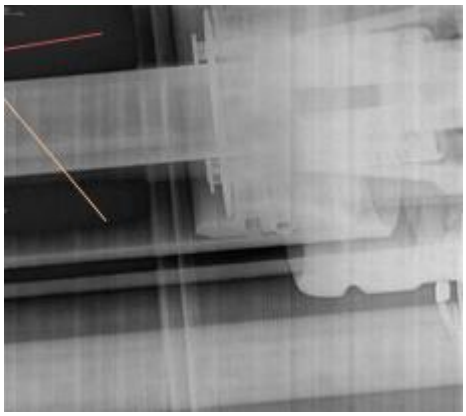

Fig. 8 X-ray detection circuit breaker renderings

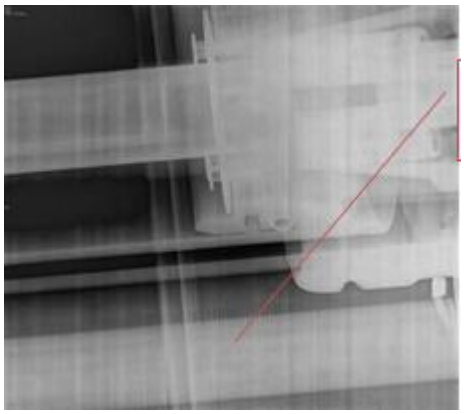

Fig. 9 X-ray detection circuit breaker renderings

## 4. Conclusion

By focal length values for the X-ray DR testing, exposure, tube current, tube voltage and other parameters of the discussion, we can draw the following conclusions: Radiographic tube voltage determines the ability of X-ray machines, equipment for the detection of transillumination first select the voltage level; tube current great impact on the overall image quality, in circumstances permit try to select a larger tube current. When the need to distinguish the subtle images, select a smaller tube current to prevent minor defect is annihilation; focal length is selected by the internal structure of seized equipment decisions. Internal structure is relatively simple device selection B grade ray detection level, the internal structure is very complex equipment will have to select the Class A ray detection level; different parts of the same device, you should choose a different Radiographic parameters according to the internal structure of specific parts; given the power much larger than the imaging plate equipment, some equipment must be selected on the need to step detecting parts of transillumination test.

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