

---

# Research on the Stability of Circuit Breaker Based on Sinusoidal Excitation

**Kun Zhang, Ying Pan**

College of Mechanical Engineering, Shanghai University of Engineering Science, Shanghai, China

**Email address:**

978538640@qq.com (Kun Zhang), ap\_xjtu@163.com (Ying Pan)

**To cite this article:**

Kun Zhang, Ying Pan. Research on the Stability of Circuit Breaker Based on Sinusoidal Excitation. *Engineering Science*.

Vol. 2, No. 3, 2017, pp. 53-57. doi: 10.11648/j.es.20170203.11

**Received:** February 28, 2017; **Accepted:** March 16, 2017; **Published:** April 7, 2017

---

**Abstract:** With the rapid development of new technology of electrical, all walks of life to the reliability of low voltage circuit breaker and other electronic products requirements are increasingly demanding, low voltage circuit breaker as the main electrical equipment in the power distribution system to connect to the circuit and disconnect plays a decisive role in the railway road, maritime transport, strong shock and vibration. Natural mechanical environment has become one of the important factors affecting the safe operation of electrical equipment is stable and reliable. The circuit breaker is generally under static conditions to study the performance index, this paper circuit breaker on-off of dynamic reliability experiment, build platform, find the circuit breaker on-off phase Should the parameters (frequency, acceleration). This paper adopts Es-60Wls3-445/LT0606/LTT1212 electric vibration system stability test sine on SIEMENS 3VL2716-1AA33-0AA0 molded case circuit breaker, and to study its stability.

**Keywords:** Low Voltage Circuit Breaker, Sinusoidal Excitation, MCCB, Stability

---

## 1. Introduction

Vibration is a mechanical system in volume (displacement, velocity or acceleration) of the oscillation phenomenon, specifically, vibration is reciprocating motion in the vicinity of the equilibrium position of the mechanical system, it is the most common form of electrical and electronic equipment. [1] The vibration may cause the structure of electrical and electronic equipment damage. Strong continuous vibration formed by alternating stress can cause the cumulative fatigue damage. The stress Changbiaoxianwei deformation structure of electronic equipment and components, mutual impact fracture ask, vibration on another important effect of electric and electronic products is due to the performance of equipment failure or performance stability loss, including the failure and performance of ultra poor vibration. Can cause a decline in product process performance, this kind of fault are common screw or loose connector and desoldering. Vibration test of electrical and electronic equipment the purpose is to evaluate the ability to withstand the vibration of the machine and parts. [2]

The vibration environment test of electronic equipment to the sine test and random vibration test test. The general

approach is to find out the structure resonance frequency or direct definition of the vibration frequency, the frequency of anti resonance tests. [3] Structures in the resonant state of local displacement will produce, caused by the local bending deformation, resulting in fatigue damage. It can quickly assess the structure strength, structural defects, and evaluation In this paper, the dynamic characteristics of the specimen are tested, and the dynamic characteristics of the low voltage circuit breaker are studied.

## 2. Sine Vibration Test

### 2.1. Sinusoidal Vibration

Sinusoidal vibration can be described as deterministic motion, motion with time according to the sine function change, also known as the harmonic vibration. Compared with random vibration test method, test method of sine wave usually requires a longer time to stimulate the failure, this is because each sweep process, time only at each resonance point is very short. [4] Although only applied a frequency at any time, if the sweep rate is full enough, can make the specific resonance peak of the sample reaches the maximum. [5] A detection that the use of vibration most often can be divided

into two kinds of sinusoidal vibration and random vibration. Sinusoidal vibration test method is often used in the laboratory, to simulate the rotation, pulsation, vibration (in ships, aircraft, vehicles, the spacecraft) caused by vibration and resonance frequency analysis and product structure the resonance point resides and is divided into the verification, sweep vibration and fixed frequency vibration of two, its severity depends on the frequency range, amplitude, duration of the test. The random vibration in seismic intensity simulation of structural integrity assessment of products and packaging in the condition of the transportation environment, its severity depends on the frequency range GR. MS, test duration and axial.

Vibration is a mechanical system in volume (displacement, velocity or acceleration) of the oscillation phenomenon, specifically, vibration is reciprocating motion in the vicinity of the equilibrium position of the mechanical system, it is the most common form of electrical and electronic equipment. The vibration may cause the structure of electrical and electronic equipment damage. Strong continuous vibration formed by alternating stress can cause the cumulative fatigue damage. [6] The stress Changbiaoxianwei deformation structure of electronic equipment and components, mutual impact fracture ask, vibration on another important effect of electric and electronic products is due to the performance of equipment failure or performance stability loss, including the failure and performance of ultra poor vibration. [7] Can cause a decline in product process performance, this kind of fault are common screw or loose connector and desoldering. Vibration test of electrical and electronic equipment the purpose is to evaluate the ability to withstand the vibration of the machine and parts.

## 2.2. Vibration Test

In the vibration test in the provisions of the "fixed frequency test" and "sweep test" of the two kinds of test methods, frequency sweep test and linear sweep and logarithmic sweep in two ways.

### A: Fixed frequency sine vibration test

Fixed frequency sine vibration test is to test various vibration parameters of different magnitude at a fixed frequency point is generally the vibration or structure of natural frequency of rotating machinery simulation. A fixed speed caused by constant frequency sinusoidal vibration is mainly used for high resonance frequency and high frequency processing a predetermined processing, resistance to the resonance frequency processing is applying a predetermined amplitude the vibration response of products found in the inspection of vibration of the obvious resonance frequency, the ability to test products resistant resonance.[8] In the known product use environmental conditions of vibration frequency, the resistance of a predetermined frequency vibration test, the purpose is to test products under vibration frequencies at a predetermined risk Capability [5].

### B: Swept sine vibration test

Sweep test is to maintain one or two parameters in the vibration test process (displacement, velocity or acceleration)

magnitude unchanged, the vibration frequency in a certain range. The changes of continuous reciprocating frequency sweep test will change according to certain rules, and the vibration level is a function of the frequency sweep in. [9] Change rate is divided into linear and logarithmic sweep sweep. Sweep frequency is divided into linear sweep and logarithmic sweep according to the rate of change:

### Inspection of vibration response of products

That is, the initial resonance check to determine the stability of the resonance point and work to find the product resonance frequency, so as to do the vibration treatment.

### Sweep frequency processing

When the product is in the use of the frequency range of non resonant point, or several obvious resonance point must be resistant to sweep, sweep approach with positioning displacement amplitude in the low frequency, high frequency logarithmic fixed acceleration amplitude continuous scanning, the sweep rate according to the general per minute per pick 'silk minute octave. The same method is used to check the reliability of the product after vibration treatment to determine the reliability of the product after vibration treatment [10].

## 3. Test Platform and Scheme

### 3.1. Platform Design

Breaker contact in ES-60WLS3-445 shaking table can not be separated, the frequency and acceleration platform under the allowable result, according to the requirements of the test, the running state of vibration and vibration laboratory work environment, the development of circuit breaker vibration test platform, shell vibration test platform design including 3D driving control system design and drawing mechanism. [11] The detection system, the main purpose of the simulation environment of circuit breaker in the real state, and test the reliability of the circuit breaker.

To determine the three-dimensional driven design drawing mechanism mainly includes the overall size and structure of each module layout, mechanism selection and optimization of each module. In the mechanical system design, consider the following points: 1) the choice of materials; 2) size of the design of the organization; 3) dynamic environment with reliability and stability; design of the UG modeling in the structure to ensure the overall three-dimensional drive test requirements of drawing mechanism [12].

The design of the control system is based on SIEMENS S7-200PLC as the controller, pulse number setting step by programming the stepper motor driver, stepper motor operation, the table by moving to the traction point, to achieve the movement of the manipulator.

In order to realize the mechanical arm stretch on the circuit breaker contact and circuit breaker vibration test, put forward the circuit breaker test platform, As shown in Figure 1, the system includes a three-dimensional drive stretching mechanism, control system design and testing system, finally realizes the manipulator in X, Y, 3D mobile Z three direction controller using SIEMENS CPU 224 XP. CN, the use of

programming software to achieve control of the motor.

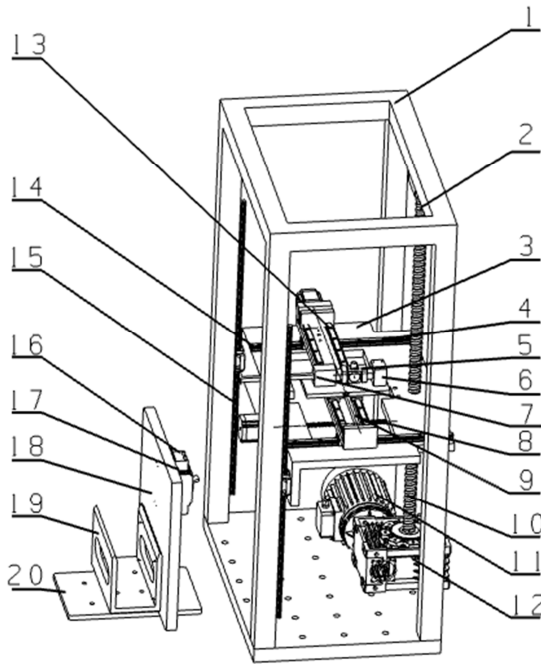


Figure 1. Experimental platform.

1- bearing frame; 2- screw; 3- platform; 4- second rail; 5- force sensor 6- sensor is fixed on the hook plate; 7- 8- second; 9- third screw; screw rod; 10- first screw; 11 step motor; 12- reducer; 8- second rail 9- stepper motor; 10- reducer 11- electrical control cabinet floor; 12- mechanical arm; 11- steel column; 13- third screw; 14- second 15- the first guide rail; 16- circuit breaker; 17- circuit breaker contact breaker mounting plate; 18- 19-; support plate; 20 floor.

### 3.2. Experimental Scheme

Assuming the breaker contact quality of M, the critical acceleration for circuit breaker tripping. The device measured the circuit breaker breaking force is  $F=16.2\text{N/kg}$ ; This experiment requires the circuit breaker to be tested in a closed state, Therefore, the circuit breaker is pushed forward to  $4.1\text{N/kg}$ , Guarantee period control force is  $\Delta F=4.1\text{N/kg}$ .

Assuming the breaker contact quality of M, the critical acceleration of circuit breaker tripping.

$$a_c = \Delta F / m.$$

## 4. Experimental Data Analysis

### Frequency Under the Frequency of 15Hz As A Study

Through the LabVIEW acquisition voltage change circuit breaker during vibration test, proper acceleration of  $0.09\text{G}$  circuit breaker has been Unicom, when the circuit breaker is disconnected when the acceleration is  $0.1\text{G}$ . Figure 2 LabVIEW voltage data acquisition program, record breaker voltage changes in the circuit breaker in the experimental process, the recording time is 20s. 3 for the circuit breaker on-off LabVIEW waveform, a figure that basically stable at around  $4.5\text{V}$ , so the vibration process has remained connected state judgment; B diagram in 7S after the voltage fluctuation

between  $0\sim 4.5\text{V}$ , so it can be judged in isolation During the process of disconnection, (a represents the test data under  $0.09\text{G}$  acceleration, B represents the test data under  $0.1\text{G}$  acceleration).

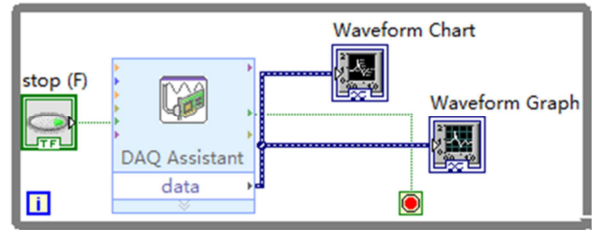
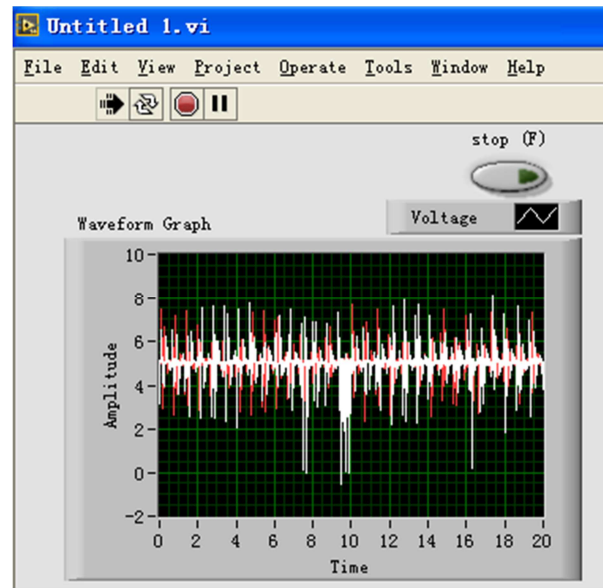
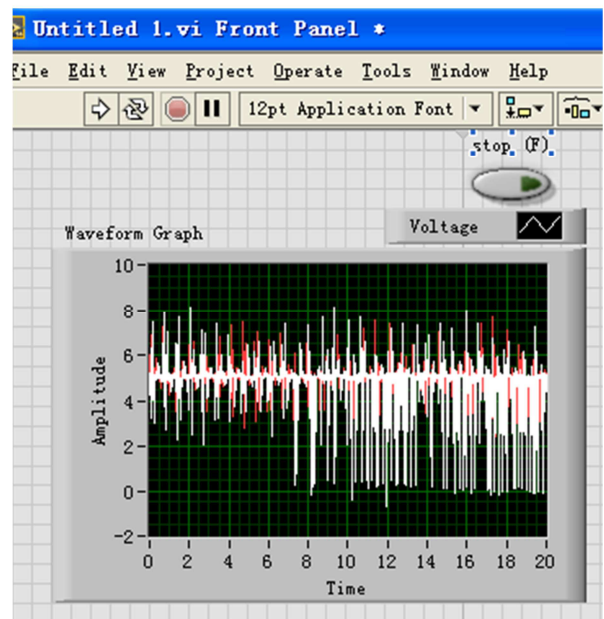


Figure 2. LabVIEW voltage data acquisition program.



a



b

Figure 3. Circuit breaker LabVIEW waveform.

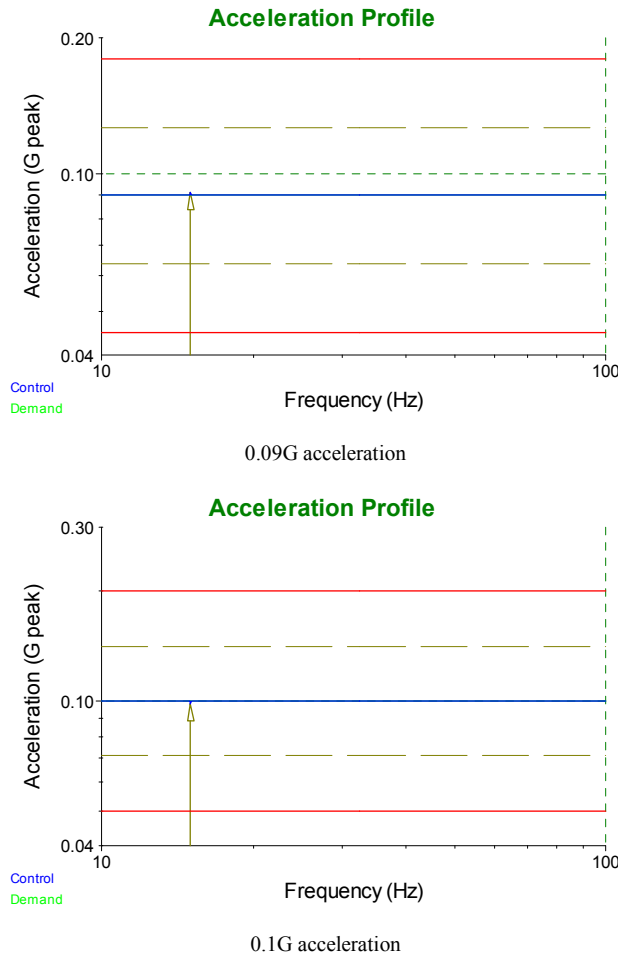


Figure 4. Critical acceleration.

Under the premise of constant frequency  $f$ , change the size of the acceleration  $a$ , through the observation of the changes in the oscilloscope, to find the circuit breaker off the critical acceleration point AC. test data measured in Table 1 and the corresponding fitting curve as shown in Figure 5.

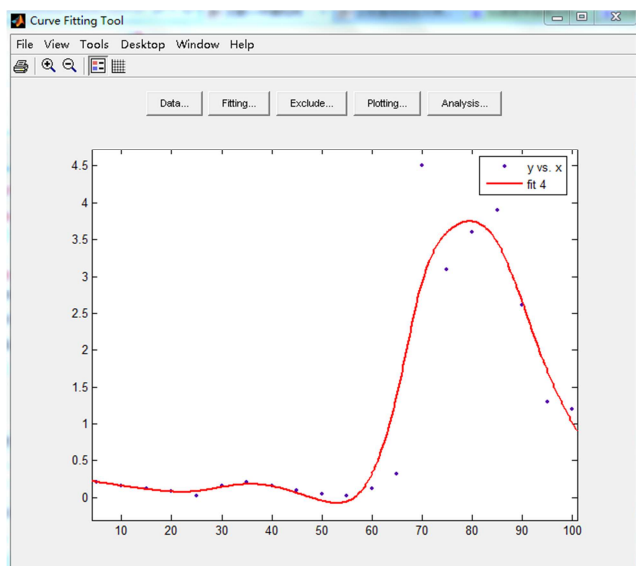


Figure 5. Fitting curve of frequency acceleration.

Table 1. Sine vibration frequency of low voltage circuit breaker.

f	5	10	15	20	25	30	35	40	45	50
$a_c$	0.21	0.16	0.12	0.08	0.02	0.16	0.21	0.16	0.1	0.04
f	55	60	65	70	75	80	85	90	95	100
$a_c$	0.02	0.12	0.32	4.5	3.1	3.6	3.9	2.6	1.3	1.2

Through the experimental data, we can see that the frequency of 1~5G in the 0~55Hz interval, the critical acceleration in the 0~0.5G interval regular fluctuations in the 55~100Hz interval, the critical acceleration in the regular fluctuations.

## 5. Conclusion

The vibration test is a test method used in the laboratory, widely used in product reliability test. Based on the experimental study on reliability of low voltage circuit breaker, further build the test platform, provides a new way for the reliability of low voltage circuit breaker. With the reliability of electronic products have become increasingly demanding, the use of reliability test sinusoidal vibration test method of low-voltage circuit breaker can be applied to more electronic products.

## Funding

This work was supported by Program of Shanghai College Construction [14110501200].

## References

- [1] Shilin Huang. Application of modal analysis to the study of automobile vibration [J]. technology and management, 1984 (2): 7-20.
- [2] Sanling Wu. Practical vibration test technology. Ordnance Industry Press, 1993.
- [3] Hu brother. Implementation of vibration test technology. Some are ready to explore environmental technology. 1994.1.
- [4] Average Control For Simusoidal-And Random-Vibration Testing, Usher. T. J. Aeoust, Soe, Amev, Vol 41 no. 4.
- [5] GB/T 2423.10: 2008 environmental testing for electric and electronic products part second: Test methods test Fc and guidance: vibration (sinusoidal).
- [6] IEC 60068-2-6: 2007 testing - Part Tests - Test Fc: Vibration (sinusoidal) 2-6: (Environmental).
- [7] Lizi Xu. Reliability analysis of substation automation system [J]. Power System Technology, 2002, 26 (8): 68-72.
- [8] Xiaofeng Wu. Hao Zhang. Development of digital processor based measuring and controlling unit for intelligent breaker [J]. Power System Technology, 2003, 27 (7): 70-74.
- [9] Nochumson C J. Discussion of "survey results of low-voltage circuit breakers as found during maintenance testing: working group report" [J]. IEEE Transaction on Industry Applications, 1997, 33 (5): 1370-1371.
- [10] Billinton R, Allan R N. Reliability Evaluation of Engineering Systems. London [M]: PITMAN B00KS LIMITED, 1983.

- [11] Daolian Wang, Guang Xu, Haoyang Zhou, et al. Analysis of fatigue life of composite cylinders under random vibration [J]. Strength and environment, 2015, 42 (1): 18–22.
- [12] Qianmin Mao, Jiayou Zhao. RongTai Jin. Asynchronous motor speed measurement and rotor fault monitoring [J]. Instrument technique and sensor, 2015 (12): 29–31.

## Biography



**Kun Zhang** was born in April 1992 in Jiangsu Province. He has got a bachelor's degree of material forming and control engineering in Changzhou Institute of Technology in 2015 and now he is a postgraduate in Shanghai University of Engineering Science.



**Ying Pan** is associate professor of Mechanical Engineering College of engineering, Dr. 2004 in June graduated from the Xi'an Jiao Tong University engineering mechanics, Shanghai University of Engineering Science in July of the same year. The structure design has been engaged in since 1998, research on structural vibration control etc.