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Preventive simulation studies based on single-phase test of 750kV Magnetic Controllable Reactor

by

GuXin bo, QuTong , XieZhixun, ZhouWen, LiuBufeng

TBEA ShenYang Transformer Co., Ltd.

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SUMMARY

The article introduces the principle of Magnetic Controllable Reactor(MCR) in power system applications, the author used the PSCAD / EMTDC software to conduced the 750Kv/330Mvar MCR simulation study, the simulation contains: 1, Three phases MCR excitation and harmonic characteristics, 2, Single phase MCR excitation characteristics and harmonic characteristics。The author compares the PSCAD simulation results to the data of the dynamic simulation test and 500kV MCR filed data , the results is reasonable, effective, and can be used for factory test. The article describes content of the MCR factory tests ,as well as the factory test conditions and on-site (with a transmission line) test conditions in different place ,the author also pointed out that the MCR is the world's first voltage level of the highest and largest capacity ,so the single-phase factory test present a number of difficulties and the risks ,which should be avoided s, therefore it is necessary to carry out the factory test environment preventive simulation ontology the particularity (UHV / high-capacity) to solve: 1,The harmonics will produce along with the excitation characteristics test, the author gives the methods to solute . 2, The use of the existing equipment to build small power load case temperature rise test conditions, given a three-winding single-phase controllable reactor (high voltage winding / control winding / compensation winding) current accounting standards. The above factory test difficulty risks live small capacity / low voltage test data and waveforms to verify the accuracy of the simulation trends, and ultimately the use of effective preventive simulation in PSCAD / EMTDC guidance field tests.

KEYWORDS

MCR Nonlinear PSCAD Temperature-Rise Test

* China Liaoning Province Shenyang Kaifa Road No.32
Fax: + 86 024-25699002 e-mail: haijuntidu@163.com

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1. Introduction

Magnetic Controllable Reactor(The paper referred to as "MCR") is the power equipment, which is suitable for super / ultra-high voltage power system suppression over-voltage and reactive power compensation , it can also solute frequency overvoltage under the long-term no-load operation mode and transmission network losses under overload issues. The MCR is not only as reliable as the transformers maintenance, but also has low grid losses, low cost, small harmonics.MCR can be directly linked to the high voltage line and bus .Therefore, MCR technology research for safe and stable operation of power grid has very important significance.

1.1 The Electric Circuit of MCR

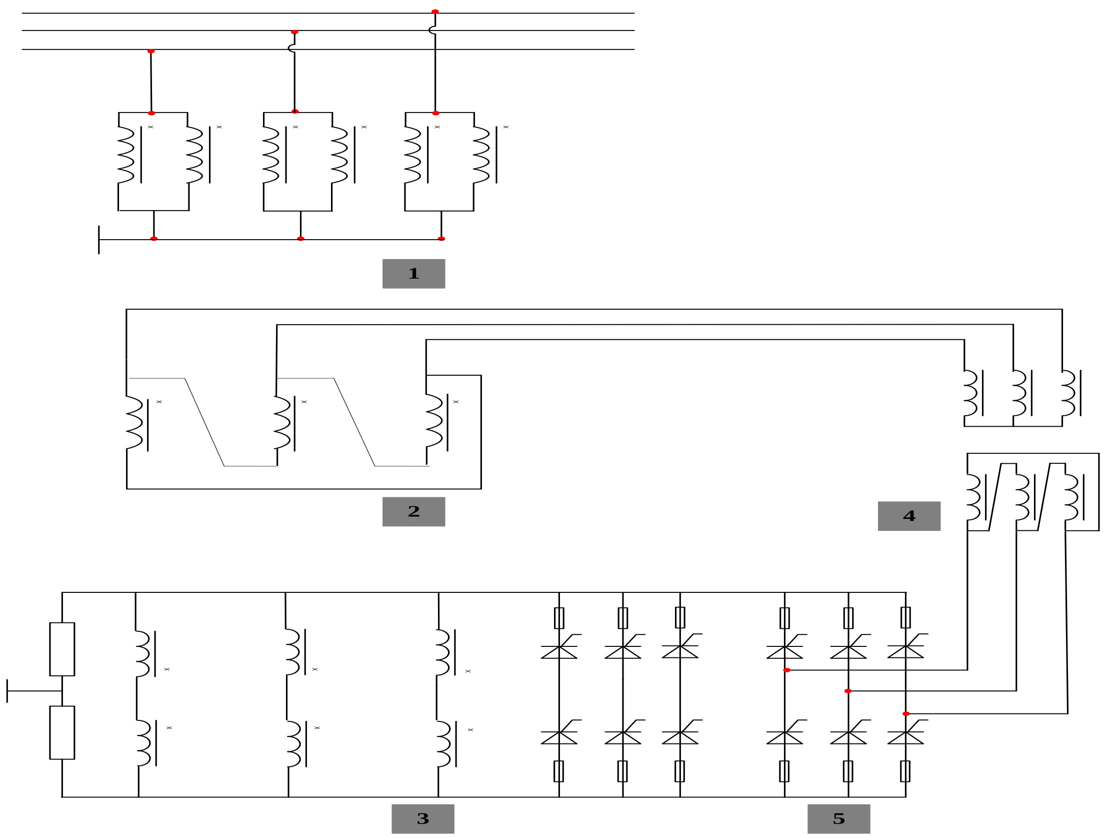


Figure 1 Three-phases MCR wiring diagram

AS shown in Figure 1,the numbers is expressed as follows:

1. MCR high voltage winding, Wye connection, single-phase has two windings in parallel with the grid, the other end to the earth, rated voltage is 800kV.

2. MCR compensation winding, delta connection, supply energy to the rectifier, rated voltage is 40.5kV.

3. MCR control winding, which has two windings .The two windings has dotted terminal, rated voltage is 41.85kv.

4.The excitation transformer, as viewed from the compensation winding ,is a step-down transformer winding end, the capacity is 1MVA, a voltage is 40.5kv, secondary voltage 0.2kv, Y / ∆ connection

5. DC output control and protection system

1.2 The Work Principle of MCR

MCR is based on the three-winding transformer structure design, which is using the direct current to control core saturation, therefore the inductive impedance will change. As follows, after the high voltage winding is energized, the compensation winding will induce a corresponding voltage and supply the rectifier device power. When the current flows out from the three-phase bridge rectifier, a DC current flow into the control winding, by changing the saturation of the core thereby changing the controllable reactor side of the net impedance.

2.Introduction of Factory Test And Test Problem

Our Company is developing the 750kV MCR. Besides the routine tests, the single-phase MCR type tests is needed. Since the routine tests are no different with the traditional transformer, the paper will not repeat again. The focus here is about the temperature-rise test(1), because the assessment of temperature rise test is MCR during normal working hours average winding temperature rise (measured by resistance method) and top oil temperature rise, as these two temperature measured values does not exceed the standards set forth in the allowable temperature rise limits. Then it is considered the MCR pass the temperature rise test.

2.1 Introduction of the test line

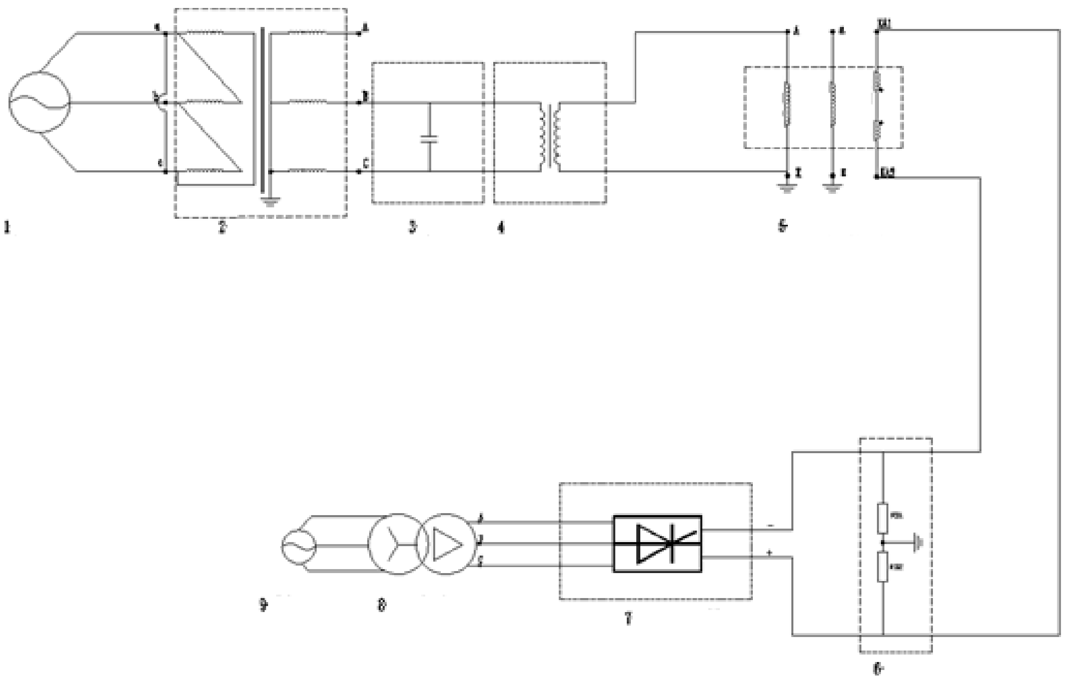


Figure 2 750kV single phase MCR temperature-rise test wiring diagram

Figure 2 is a 750kV single phase MCR temperature rise test wiring diagrams, in which:

1. Plant generators with a capacity of 60MVA, because then single-phase controlled reactor temperature rise test conducted, so the generator needs to change the single-phase method.

2. Intermediate transformer to step-up transformer (from the generator side looking into), the ratio is: 12kV / 88.334kV.

3. Capacitor towers, uncharged switching mode, in accordance with the demand of reactive power capacity of linear compensation, but not supply real-time compensation.

4. Step-up transformer capacity of 63MVA,the ratio is: (1700 /√3)kV/132kV.

5. Single-phase MCR.

6. Clamp resistor, which is used to clamp the potential.

7. DC control and protection system, which controls the DC output and protect the control circuit.

8. Excitation transformer, the ratio is: 6kV/0.535kV.

9. Excitation generator, the capacity is 6MVA.

2.2The Impact of MCR's Characteristics On the Temperature-Rise Test

Through the introduction 2.1 shown the test circuit can be equivalent to a single large load of small power supply systems. Because there is no FACTS devices, the real time reactive power balance could not be adjusted, can only rely on a fixed capacitor tower linear compensation, but when MCR temperature-rise test carry out, the impedance of MCR will change nonlinear, when MCR high voltage winding current from no load to rated current state changes , the reactive power which capacitor tower supply would not accurately follow the nonlinear changes impedance of MCR, if we rise generator export voltage to MCR rated voltage may cause capacitive reactive power to the generator, the resulting over-voltage may damage insulation of MCR. Also, because when the control winding together with the rated excitation current, it will lead to single-phase controllable reactor two core columns saturation inconsistent, because there is no control of the three-phase windings connected in parallel with the high voltage winding will result in both sides of the control winding inducing overvoltage. So if we want to complete temperature-rise test, we need to solve the following problems:

1.Make sure the high voltage winding current from the load current to the rated state, capacitor impedance changes do not cause capacitive reactive send down cause overvoltage.

2. Under MCR temperature-rise test conditions, the effect of the control winding voltage and harmonic voltage to the rectifier

As the test circuit parameters above is clear, before making the temperature rise test can take advantage of the power system simulation software. Pieces of this test circuit modeling, and taking into account the temperature rise test method simulation, in which the author uses the power system widely used PSCAD-EMTDC.

3.PSCAD Simulation For 500kV MCR and Accuracy Verification

As 750kV MCR is currently largest capacity and the highest voltage level in the world, and the test circuit external parameters is clear, the simulation accuracy is determined by the modeling of MCR, Particularly based on the accuracy of excitation characteristics, namely high voltage winding current and the DC excitation current relationship. With the right relationship, we can deduce the impedance value form excitation current, so as to properly calculate the capacitance of the tower should cast the capacity to ensure that no power will not send down. The author use the existing 500kV Jing Zhou substation MCR site running excitation characteristics data, simulate the 500kV MCR model. Since the body structure or from the voltage / capacity levels are comparable to 750kV MCR, if the deviation is not less than + -5% considered feasible simulation model, we can achieve the temperature rise test the feasibility of the method validation.

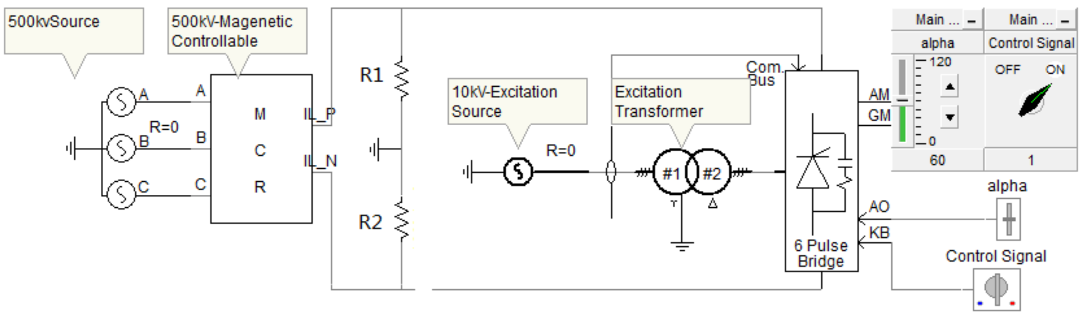


Figure 3 500kV MCR simulation graphics

Table 1-500kV single-phase MCR rated parameters

Rated capacity (Mvar)	Rated voltage (kV)	Rated short-circuit impedance	control winding voltage (kV)	Rated current (A)	Control winding rated current (A)
40	550kV/√3	63%	38.5	127	1180

Table 2 500kV MCR the measured excitation characteristics data

Capacity	Excitation current (A)	Rated current (A)	Impedance (Ω))
5%	45.5	7.31	43440.76
25%	240	32.4	9800.987
53%	468	66.5	4775.217
72%	702	90.2	3520.532
100%	1180	127	2500.409

Table 3 Simulation data and measured data Impedance deviation

Capacity	Excitation Current (A)	High Voltage Winding Current (A)	High Voltage Winding Impedance (Ω)	Impedance Deviation
5%	45.5	7.31	43440.76	0.00%
25%	240	33.6	9450.951	-3.57%
53%	468	63.7	4985.117	4.40%
72%	703	88.3	3596.285	2.15%
100%	1182	126	2520.254	0.79%

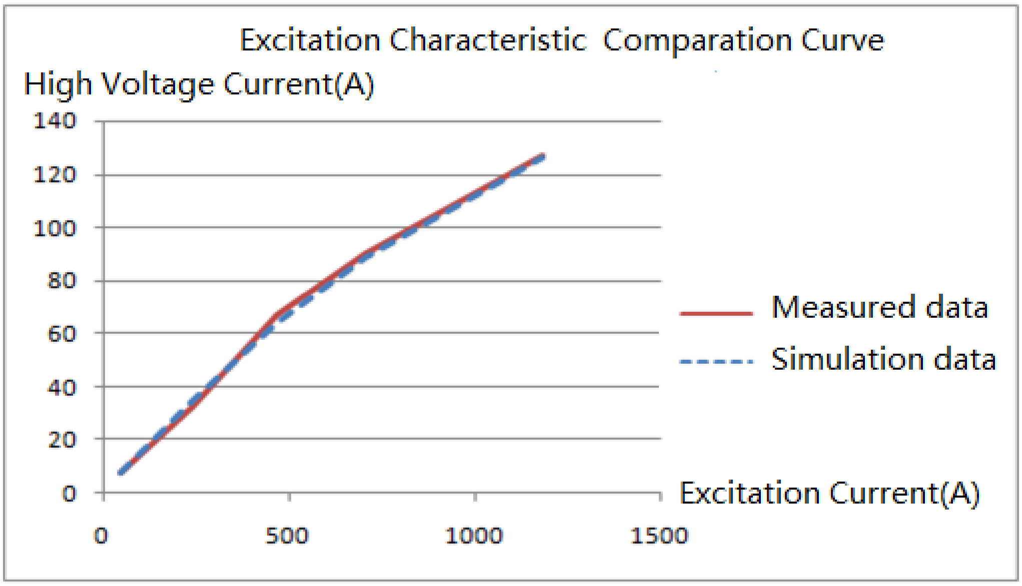


Figure 4 500kV MCR excitation characteristic comparison chart

Through figure 4, the largest Impedance deviation is 4.40%, it can be considered for the MCR simulation modeling reasonable, effective. The PSCAD simulation model could be used for temperature -rise test.

4.750kV single-phase MCR Temperature Rise Test Method Validation

Based on the IEC standards, there is no MCR temperature-rise standard definition. But from the IEC60076-2 standard oil type transformer temperature- rise test for significance: to ensure the transformer / reactor operates at a nominal state oil average winding temperature and the temperature does not exceed the IEC standard requirements, means the power equipment pass the test.

It should be introduced that MCR temperature -rise test on single-phase power-up sequence: the high voltage winding load, applied control winding to excitation current ,when the rated excitation current reached, the high voltage winding applied to voltage, when the rated current reach ,stop the high voltage winding voltage and start the temperature- rise test timing.

However, as described in Article 2.2, with the high voltage winding voltage of the application process, the impedance is changing, and this has led to a fixed-capacity capacitor could not follow MCR impedance change process.

The MCR nonlinear impedance limit the temperature-rise test. If we can guarantee MCR impedance range is limited, the inductive reactive power should be always higher than the capacitive reactive power, can make the temperature-rise test carried out smoothly. Therefore, I consider to increase in the compensation side suitable impedance, this method can not only protect the MCR's core saturation impedance will not change dramatically, but also can ensure the compensation winding be assessment by the temperature-rise test. Based on this approach, the author uses the PSCAD simulation, simulation results are as follows:

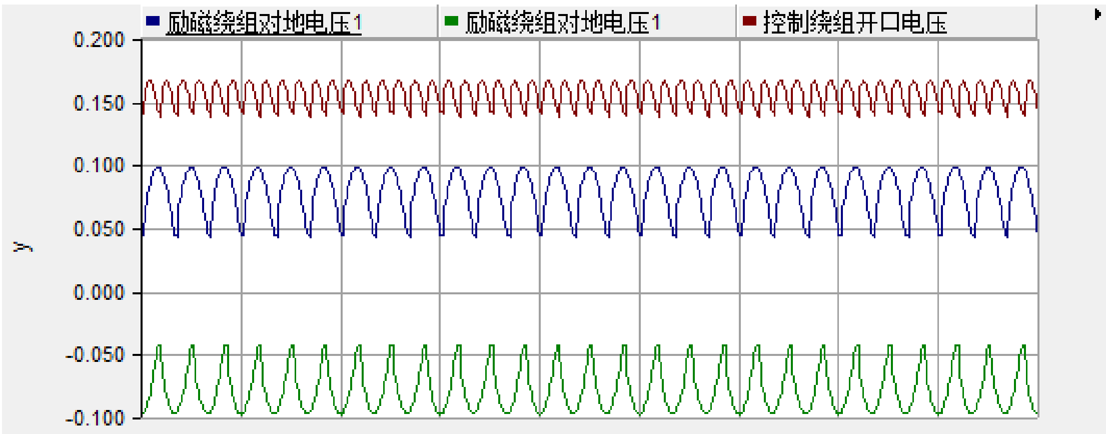


Figure 5 Control winding voltage and voltage to earth

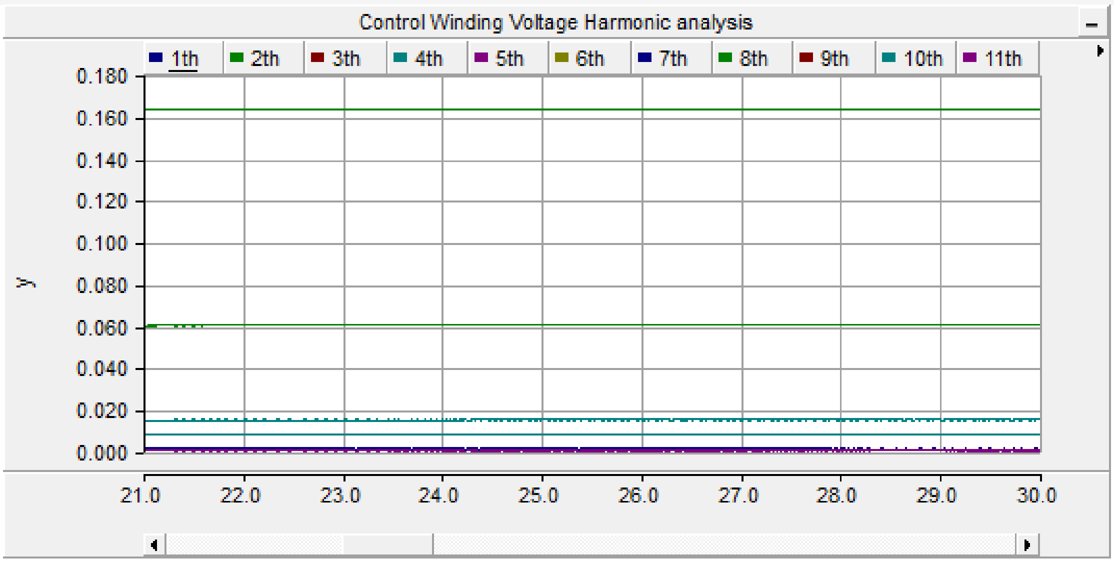


Figure 6 Control winding voltage harmonic analysis

Figure 5 and Figure 6 is the data, which the author use PSCAD to simulate. The high voltage reaches the rated current work status, the status satisfied to the temperature-rise test. The control winding voltage amplitude and harmonics of voltage wouldn't be hazards to the rectifier, meet the test requirements. With this method, the test progress carried out smoothly, the test waveforms are as follows:

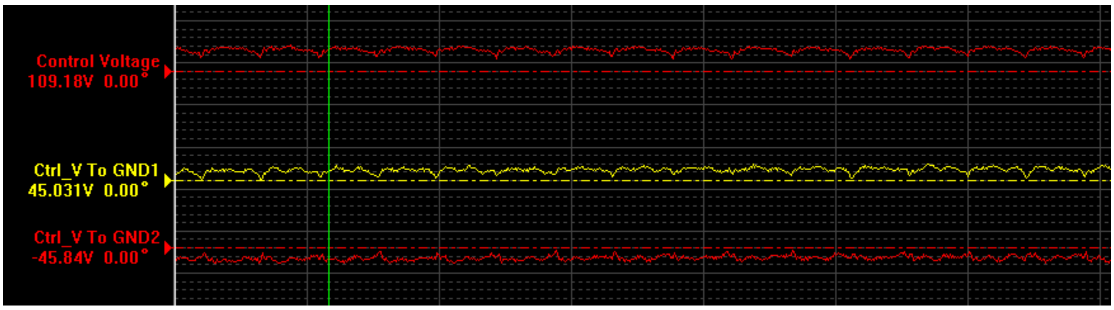
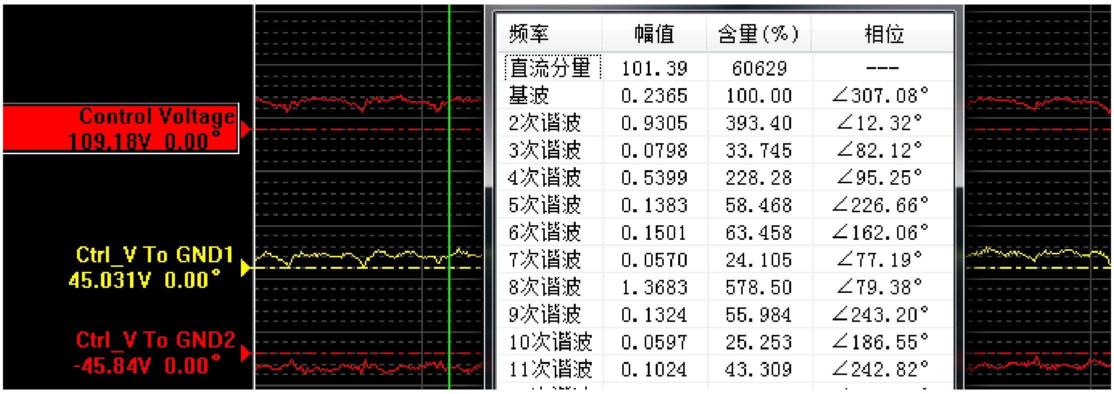


Figure 7 - Measured control winding voltage and voltage to earth



频率	幅值	含量(%)	相位
直流分量	101.39	60629	---
基波	0.2365	100.00	∠307.08°
2次谐波	0.9305	393.40	∠12.32°
3次谐波	0.0798	33.745	∠82.12°
4次谐波	0.5399	228.28	∠95.25°
5次谐波	0.1383	58.468	∠226.66°
6次谐波	0.1501	63.458	∠162.06°
7次谐波	0.0570	24.105	∠77.19°
8次谐波	1.3683	578.50	∠79.38°
9次谐波	0.1324	55.984	∠243.20°
10次谐波	0.0597	25.253	∠186.55°
11次谐波	0.1024	43.309	∠242.82°

Figure 8 Control winding voltage harmonic analysis

5. Conclusion

PSCAD is effective for solving the risks of temperature-rise test, ensure the smooth progress of the test, the simulations also verified by experiments controllable reactor characteristic impedance variations and harmonic levels.

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(1)IEC 76.2 1993 Power transformer Second 2： Temperature Rise