ALTERNATIVE METHOD FOR SYNTHETIC MAKING TEST OF THREE-PHASE HIGH-VOLTAGE CIRCUIT BREAKER

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Abstract: The synthetic short-circuit making test to adequately stress the circuit breaker has been specified as the mandatory test duty in the IEC 62271-100. If the interrupting chamber of circuit breakers is designed as the type of common enclosure or the operation is made by the gang operated mechanism that three-phase contacts are operated by one common mechanism, three-phase synthetic making test is basically required. KERI has developed the new alternative three-phase making circuit. This circuit uses three-phase current source and a set of making test device such as plasma making switch, step-up transformer, ITMC circuit and auxiliary breaker.

1 INTRODUCTION

The international standard [1] specifies the testing procedures to verify making performance of circuit breaker against the high short-circuit current.

The verification test for making performance should meet two conditions because the pre-arc energy and the peak current (asymmetrical current) differently influence the breaker performance. To get the maximum pre-arcing energy, the maximum peak voltage should be applied between contacts. Also to get the maximum dynamic force, the three-phase making current should be flow in all phases.

2 MAKING CAPABILITY

2.1 Making Operation

The circuit breaker is stressed by the applied voltage and current during the making operation. Typically, three intervals are introduced to characterize the making operation [2]; high-voltage interval, pre-arcing interval and latching interval.

The dielectric strength of the contact gap of a closing circuit breaker is going to be reduced. This phenomenon can be linearized and then expressed to RDDS (Rate of Decay of Dielectric Strength) [3]. The breakdown will occur when RDDS line and applied voltage line (imaginary line) between contacts are met. The maximum pre-arcing time can be got when the pre-strike (breakdown) starts near the crest of the applied voltage. The pre-arcing time is the minimum when the pre-strike occurs near zero of the applied voltage. This kind of arc stress has impacts on both contact face and mechanical operation because of the elevation of gas pressure caused by arc energy. The current initiated by pre-strike has only symmetrical component if the breakdown occurs near the crest of the applied voltage because the power system has mainly reactive circuit components. There will be asymmetrical component of the current if the breakdown occurs near zero of the applied voltage and maybe the maximum peak current will flow. The asymmetrical current impacts on mechanical operation because the highest dynamic forces are introduced between phases. Thus the circuit breaker should be closed and latched against the pressure caused by arc energy and dynamic force caused by magnitude of current.

2.2 Requirements on Making Performance

The regulations for making test can be found in following standards;

IEC 62271-100 [1] sub-clause 6.102.4.1: "The verification test for making consists of two three-phase making operations under the same condition ..."

STL guide for IEC 62271-100 [4] sub-clause 6.102.4.1 : "... a single-phase test with all the three poles electrically connected in series may be carried out.", "The three-phase verification test for making with full symmetrical current and maximum pre-arcing may be made with a three-phase current source at a reduced voltage combined with a single phase synthetic making circuit."

Based on above regulation, the three-phase current flow is required for three-phase circuit breaker and the specified voltage should be applied in the phase which in the maximum pre-arcing time can be achieved. The related standard for synthetic test [2] introduces the test circuit as below. It consists of two sources and the permissible time delay of making device is specified for this test circuit.

1) The voltage circuit

- Supply the voltage during the high-voltage interval

- Supply ITMC (Initial Transient Making Current) during the pre-arcing interval, by discharge of the ITMC-circuit

- ITMC current shall be maintained to the instant that the power frequency current of current source is superimposed through the gap-switch (CH).

2) The current circuit

- Supply the making current during the pre-arcing and latching intervals

Also the time delay of making device (from pre-arcing to current flow) should be lower than 300 μs.

The Figure 1 shows the single-phase synthetic test circuit. The ITMC circuit should have sufficient time constant to ensure that the current (I_t) should maintained during the time from initiation of pre-strike to the operation of making device (CH).

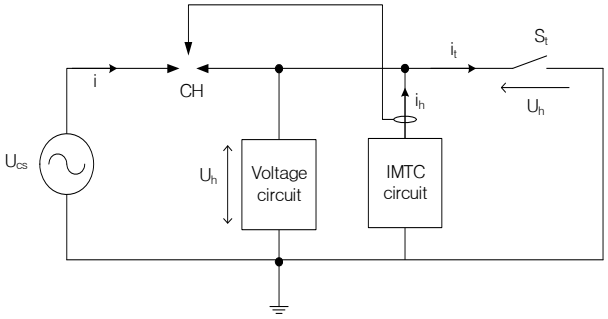

Figure 1: Typical circuit for single-phase synthetic make test

With the same point of view, The Figure 2 shows the three-phase synthetic test circuit. The voltage circuit can be replaced to the capacitor bank with reactor to introduce oscillating voltage or without it to maintain dc voltage.

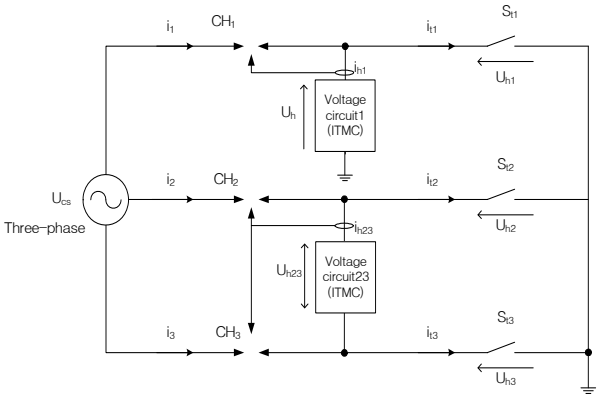

Figure 2: Typical circuit for three-phase synthetic make test (k_{pp} of 1.5)

3 THREE-PHASE SYNTHETIC MAKING TEST CIRCUIT OF KERI

As an effective testing circuit to estimate both the pre-arcing performance and electro-dynamic performance during the three-phase making operation, KERI(Korea Electrotechnology Research institute) has developed the new alternative three-phase making test method to cover the circuit breaker up to rated on 3 phases 245 kV 63 kA. The Figure 3 shows the circuit for this test method. It is similar with three-phase current and single voltage source circuit but there are some differences as follows:

1) Voltage circuit is applied between phases. (which is step-up transformer)

2) ITMC circuit is applied between phases.

3) Earthing of test circuit is connected to supply side of the test breaker.

4) Voltage distribution circuit is adopted between two phases. (which is combined with voltage circuit)

This circuit uses three-phase current source and a set of making test device such as plasma making switch, step-up transformer, ITMC(Initial Transient Making Current) circuit and auxiliary breaker. Because the neutral of current source and load side of test breaker is not earthed, special consideration may be needed to ensure the circuit insulation.

Test procedure and operation of this test circuit are as follows:

1) The voltage circuit applies voltage between phases (two times rated phase voltage = U_h).

2) The charged voltage in ITMC circuit is applied to S_{t1} and S_{t2} in series.

3) The voltage distribution circuit regulates this voltage to two poles (S_{t1} and S_{t2}) according to the ratio (maybe $0.5U_h$ in each pole).

4) ($0.5U_h$ - $U_{cs.phase\ 3}$) is applied to the other pole (S_{t3})

5) The source phase voltage of phase 3 ($_{Ucs.phase\ 3}$) is very small compare to the U_h. Thus, the voltage between S_{t3} is almost $0.5U_h$. (a little small)

6) The applied voltage in all three poles is same except the polarity and the pre-arc during the making operation may be initiated at the same time.

7) The invalid test caused by insulation recovery will not happen.

8) If the pre-strike occurs near the crest of the applied voltage in two phases (or all three phases), the current from ITMC circuit will flow.

9) The sensor will detect i_h and trigger plasma making switch (CH) within 300 us.

10) The current including symmetric and asymmetric components in all three phases will flow.

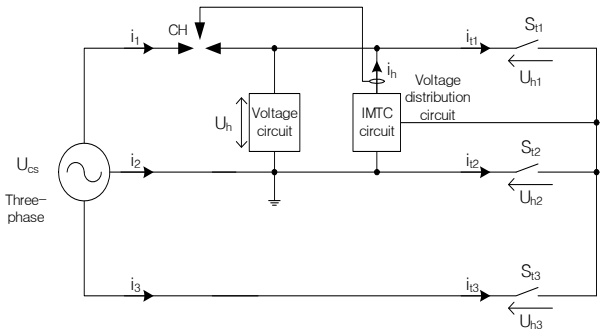

Figure 3: Three-phase synthetic make test circuit developed at KERI

Line-to-line and line-to-enclosure of the test breaker should withstand two times rated phase voltage because this voltage is applied to the front of S_{t1}. Two dividers in front of S_{t1} and S_{t3} and one divider on short circuit point of test breaker are located to minimize the number of voltage dividers.

3.1 Application to Making Test of Proposed Circuit

By using the proposed circuit, the test is performed on the live-tank type GCB rated on 145 kV, 40 kA, 50 Hz with gang operation mechanism. The pre-strike is initiated near the crest of the applied voltage in phase B and C and the current asymmetry was also obtained. The oscillogram shows that there is no insulation recovery phenomenon and the current flows in all phases. Below oscillogram shows that the time delay from the pre-strike to the start of current flow is about 98 us. This is lower than specified value 300 us in the standard.

4 CONCLUSION

Other alternative test circuit for three-phase making test has already developed and verified [3]. Other alternative method have also suggested due to the limitation of test facilities [2][4]. But some modifications of test circuit are required. Therefore, several testing laboratories have developed and proposed their own testing circuits and facilities to properly evaluate the making performance of the circuit breaker. The main focus for them is to have the equivalence with the three-phase making operation that consists of symmetrical current to give the maximum pre-arcing energy and asymmetrical current to give the maximum electro-dynamic force. With these technical backgrounds, KERI has developed the new alternative three-phase making test circuit. This circuit uses minimum number of voltage circuit, measuring device for current and voltage, plasma making switch and auxiliary breaker. Special consideration should be required for the test of dead tank GCB intended for GIS (gas insulated switchgear) because two times rated phase voltage is applied between line and enclosure. But this voltage level is within AC power frequency capability of the circuit breaker and this method can be regarded with the effective method.

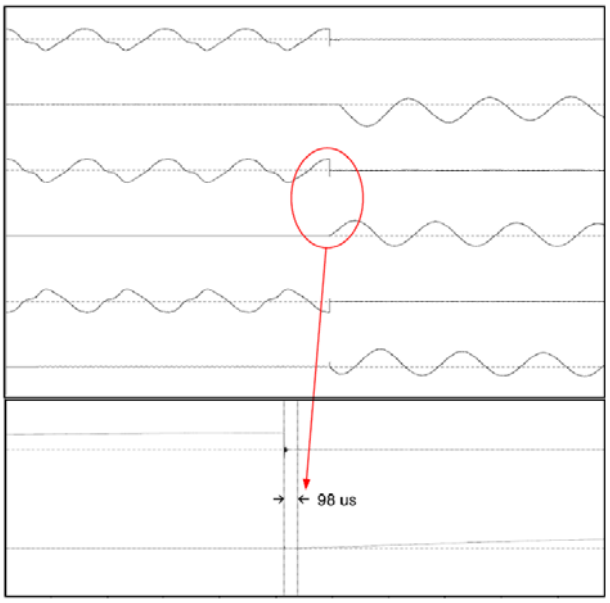

Figure 4: Test result on 145 kV, 40 kA GCB

5 REFERENCES

[1] International Standard IEC 62271-100 Ed. 2.0, 2008-04

[2] International Standard IEC 62271-101 Ed. 1.1, 2010-11

[3] Rene Peter Paul Smeets, Wim A. van der linden, “Verification of the Short-circuit Current Making capability of High-Voltage Switching Devices”, IEEE Trans. Power Delivery, vol.16, no.4, pp.611-618, Oct. 2001

[4] STL(Short-circuit Testing Liaison): Guide to the interpretation of IEC 62271-100 Ed. 2.0, 2008-04