Study on Overvoltage Suppression by Phase-Selection on 220V Voltage

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Abstract: We investigate the regulation of first breakdown process in switching on operation of disconnecting switch (DS), with 220V AC low-voltage. The selecting phase setup, mainly consisted of MCU and Electromagnetic Relay, prevent overvoltage by switching at around required phase that avoid the high-voltage breakdown. This phenomenon that relies on the voltage wave stimulation and high voltage technique opens new prospects to overvoltage suppression and preventing damage caused by electric connecting in household appliances.

Keywords: Phase-Selection, Overvoltage, First breakdown

1 INTRODUCTION

Geographic Information System (GIS) takes up fewer places as well as having higher reliability, longevity of repairing period and economic operating cost, thus wide spreading in electrical power system. The operating of disconnecting switch (DS) and circuit breaker (CB) causes very fast transient overvoltage (VFTO) in GIS and spread to connecting facilities. VFTO mainly has three feature: ①The amplitude is typically lower than 2.0p.u., in some cases higher than 2.5p.u. ②High frequency, usually 0.3~100MHz; ③High steepness. The wave-head time varies from a few nanoseconds to tens of nanoseconds. It does harm to different parts' insulation in GIS facilities such as switches, support design and insulation tubing of bus. Furthermore, it has negative impact on the reliability of facilities, even the connecting facilities insulation.

The mechanism of VFTO is as follow: In GIS, the DS routine operation will cause very fast transient overvoltage. All of the components are working in a slightly uneven electrical field. As a result, the speed of moving contacts decelerates. If the voltage-rising rate is higher than Critical value of electron avalanche in SF6, the pre-breakdown and repeated breakdown happen, then form high- steepness step voltage wave spreading along the fracture.

VFTO caused by conventionally operation of DS and CB in ultra-high voltage grid GIS result in internal breakdown and accidents in connecting facilities, even enormous energy loss to electrical power system.

Hence, avoiding overvoltage conditions requires advanced reactive power management solutions. We make a 220v AC voltage experiment to explore the first breakdown and design a phase selection equipment to avoid overvoltage.

2 PHASE SELECTION IN THE FIRST BREAKDOWN

The experiment is aiming at exploring how the amplitude of overvoltage is influenced by phase selection. The overvoltage is mainly affected by transmission line's trap charge. To avoid serious overvoltage, the unload bus is grounded to discharge before the experiment.

The experimental setup (Figure 1) relied on 220V AC voltage, connecting to Single Chip

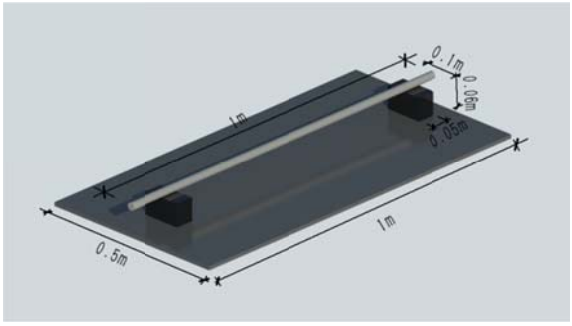

Figure 1 Experimental setup

Microcomputer (MCU) and Electromagnetic Relay. This setup is aiming at simulating the situation that high-voltage substation switching on unloaded bus.

Driving circuit: 220V AC voltage flowing through comparator output ±5V square wave voltage. Then the MCU reads the square wave voltage and output order that control the electromagnetic relay switching on order at required phase.

220V AC voltage was transformed by power transformer (PE4117-1 5VA) and two 1100Ω divided resistors and therefore output 5V sine wave.

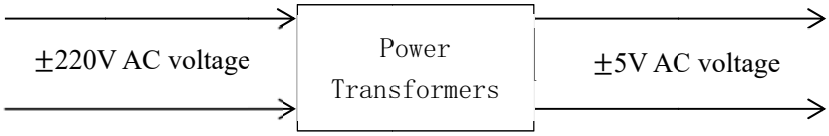

Figure 2 Logic connection of driving circuit

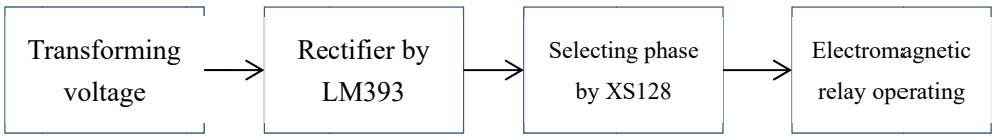

Figure 3 Wiring system of MCU. Main Mode of MCU is MC9S12XS128MAL.

5V sine wave was rectified by LM393 to square wave in order to motivate MCU. The Driving circuit was motived by 5V DC voltage. MCU read the square wave and count the step to switch on the required phase. The phase was selected in positive voltage, from a close vicinity of 20° (the minimum phase to avoid the time delay from the receiving of the closing signal) to 180°.

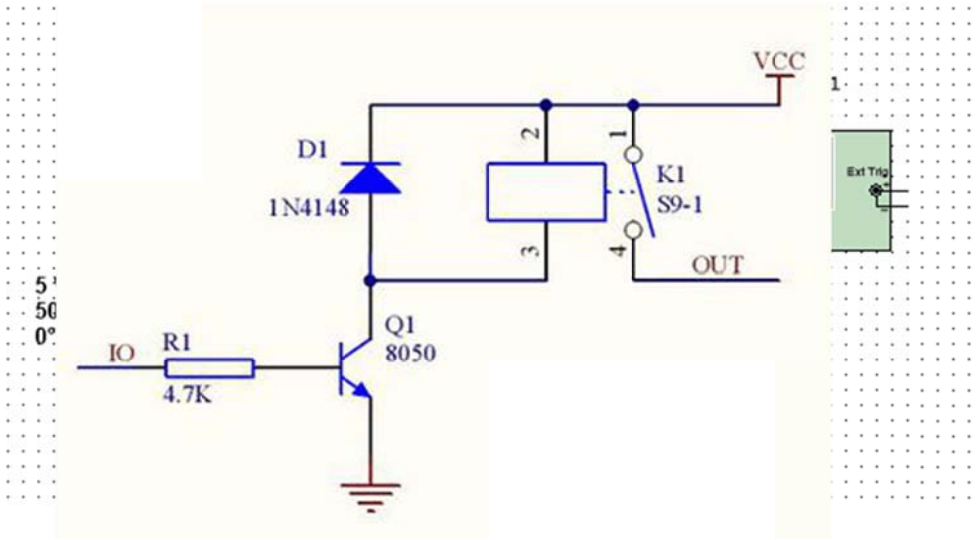

Figure 4 Driving circuit of LM393.

The experiments have been performed at room temperature (T = 20℃), at a relative humidity around 30%. Correspondingly, the background resistivity of the air is about 3×1014 Ω·m.

3 VOLTAGE WAVE ON UNLOADED BUS WHEN BREAKDOWN HAPPENS

The operation time of HH52P is less than 20 microseconds. This kind of over-voltage is mainly affected by transmission line's trap charge. The current flowing through the unloaded bus was measured by monitoring the voltage on the end of unloaded bus. The signal was recorded on a 200 MHz bandwidth oscilloscope.

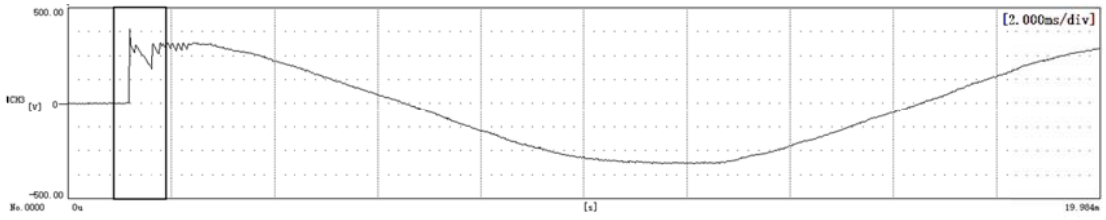

Figure 5 Driving circuit of HH52P.

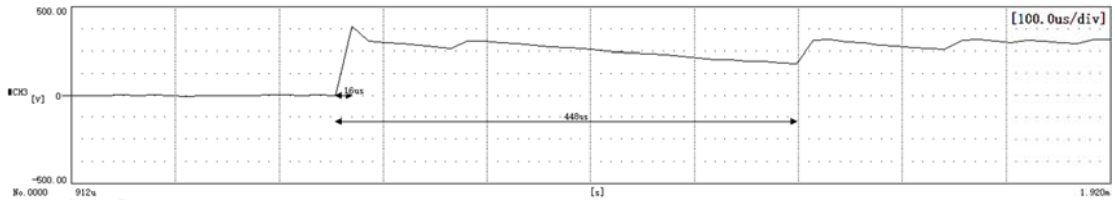

Figure 6 The stimulation of overvotage wave when switching at 67.10°. (a) TimeBase 2ms/div (b) TimeBase 100μs/div

Figure 6-(a) clearly illustrates that the unloaded bus potential transiently rise under high breakdown voltage, the rising time is within 16μs. The first breakdown voltage is highest and last for 1~2μs. Rapid periodic oscillation of overvoltage is also observed in the simulation results, then generally back to generator potential before arc self-extinction. It is clearly show in Figure 6-(b) that the overvoltage becomes much more flat with the time. With the decrease of two electric contacts, the breakdown voltage descends.

4 SUPPRESSION OF OVERWOLTAGE

The amplitude of overvoltage is proportional to the breakdown voltage between electric contacts. In the switching on process, the breakdown voltage descends. The first breakdown voltage amplitude reaches its maximum. Hence, we mainly analyze the first breakdown voltage.

Closed phase angle has important effect on first breakdown voltage on contactors. The experiment measures first breakdown condition at varied phase angle.

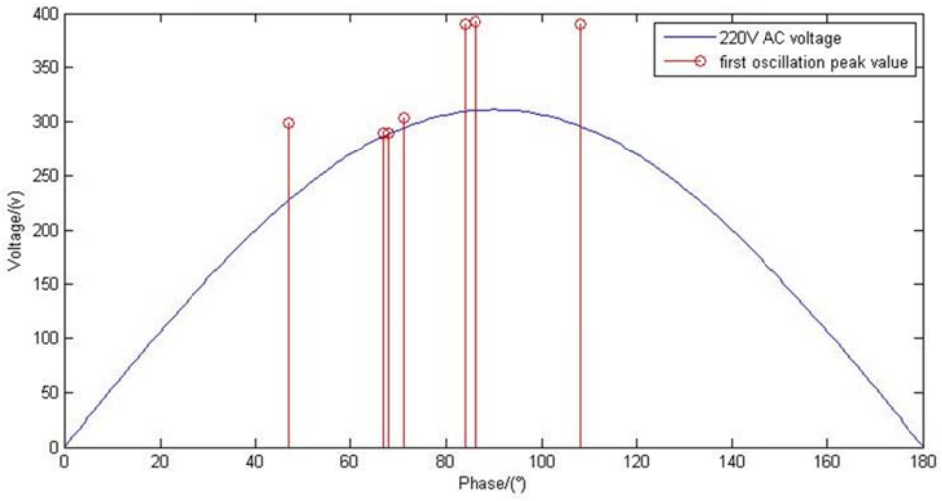

Figure 7 Overvoltage wave by switching at different phase angle under 220V AC voltage.

Figure 7 clearly illustrates overvoltage suppression by phase selection system. The first breakdown voltage varied from 1.26~0.96 (per-unit value). Furthermore, the breakdown voltage reaches its peak when the phase is around 90°, as the most serious breakdown. Hence, the overvoltage amplitude is the highest.

When the generator voltage is positive, reduce the switching phase slightly and clime over the peak voltage. The breakdown happens in the next period, as a result, the breakdown voltage become lower. That is the optimum switching phase. According to the experiment, the breakdown voltage is 0.96 (per-unit value), 30% lower than the most serious breakdown voltage. Hence, assuming that the switching operation speed is constant, the serious overvoltage can be suppressed by phase selection.

5 CONCLUSIONS

As a conclusion, we have designed the experiment to stimulate the regulation of unloaded bus potential and the first breakdown. Furthermore, we have observed suppression of overvoltage by phase selection.

(1) Unloaded bus potential transiently rises under high breakdown voltage in typically 16μs.

(2) By selecting phase, the setup can suppress the overvoltage, catering for different switches' demand. Not only can it be applied in high-voltage field to suppress VFTO, but can be used in household appliances for preventing damage caused by electric connecting.

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