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Spark Gap Modeling Using PSCAD/EMTDC

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***Abstract*—This paper develops a model of spark gap using PSCAD/EMTDC software. The spark gap is sometimes called gas discharge tube (GDT). Spark gap is commonly used in surge protective device (SPD) to divert the surge to ground in low-voltage power systems. In developing this model, the concept is taken from Basso's model. By developing the charge and discharge control circuit, it is possible to create the spark gap model in PSCAD/EMTDC software. The simulation results are compared with the results obtained by previous researchers and they are matched.**

***Index Terms*—Overvoltage protection, PSCAD, spark gap, arresters, surge protection.**

I. Introduction

THE installation of surge protective device (SPD) is vital to protect the sensitive equipment from failing due to lightning and switching surges. The most commonly used component for SPD is the metal oxide varistor (MOV) or spark gap. Spark gap is capable to reduce the large surge current in the protected equipment by diverting surge current to ground. Under normal conditions the spark gap acts as high impedance state. When exceed a threshold voltage, the spark gap will be shorted as the protected circuit is connected to ground via a very low impedance switch. Spark gap usually connected in parallel on the power supply circuit of the equipment being protected (see Fig. 1). Studies of the spark gap modeling using personal computer simulation program with integrated circuit emphasis (PSpice) and electromagnetic transient program (EMTP) were carried out by previous researchers [1]. However, as the authors' knowledge are concerned, none of the paper has been published on the spark gap modeling with electromagnetic time domain transient simulation (PSCAD/EMTDC) software. The MOV component with default I-V characteristic available in the PSCAD/EMTDC whereas the spark gap component is not included in master library. Therefore, in order to incorporate spark gap in our simulation circuit, the spark gap model needs to be developed. The component of spark gap is difficult to simulate in PSCAD/EMTDC since the electrical discharge mechanisms [1] need to be included in the simulation to control the spark gap.

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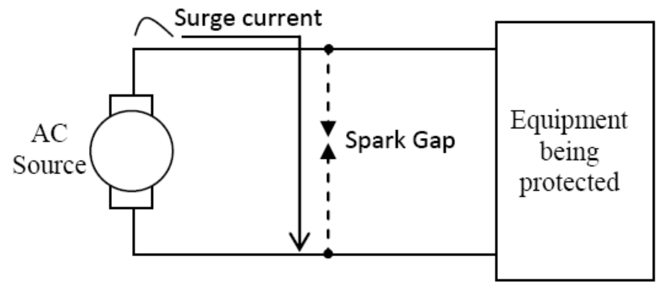

Fig. 1. Spark Gap Installation.

The concept of the electrical discharge as presented by Basso [2] can be used in developing the spark gap component in PSCAD/EMTDC. In this paper, a circuit model is proposed to enable students and engineers to model and simulate spark gap using PSCAD/EMTDC.

II. Simulation model

In this paper, the spark gap is modeled using a circuit breaker as a switch with MOV to represent the arcing voltage. The simulated circuit incorporated with control circuit is shown in Fig. 2 and 3.

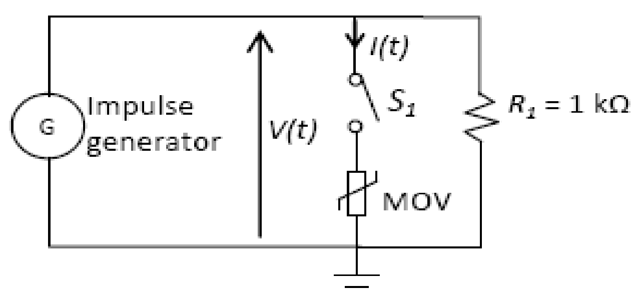

Fig. 2. Spark gap simulated circuit.

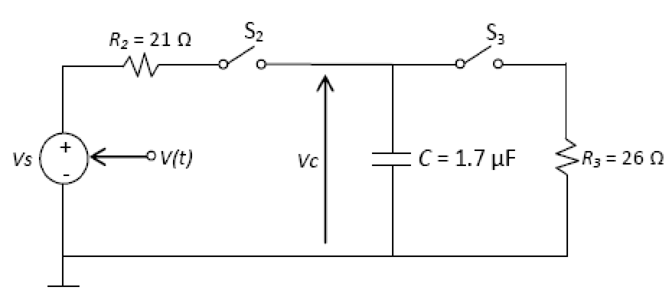

Fig. 3. Control circuit for switch S1

Fig. 2 represents the spark gap under normal condition and short circuit condition with the switch S_1 open and closed respectively. The MOV in the circuit to represent the arc voltage during spark gap arcing. R_1 represents the leakage resistance of the spark gap. In PSCAD/EMTDC, S_1 are modeled using the circuit breaker as a switch. When the voltage across the spark gap exceeds the dynamic breakdown voltage, the switch S_1 is closed and begins to conduct.

Fig. 3 is the control circuit to emulate breakdown mechanism and recovery of gap in the spark gap when the current can no longer sustain the arching

The switch S_1 is controlled by the voltage (V_c) across capacitor *C*. Accumulated charge in capacitor *C* represent the develop plasma channel between the gap terminals. Capacitor *C* is charged from controlled voltage source V_s. The capacitor *C* will only being charge when the voltage between the spark gap exceeds breakdowns which are achieved by closing S_2. Therefore, switch S_2 is controlled by voltage *V(t)* which is the voltage across the spark gap. If switch S_1 closed, *V(t)* will drop and cause switch S_2 to re-open. Once the switch S_2 is opened, the charge gets trapped in capacitor *C* and maintains the voltage *Vc*. Therefore, switch S_1 will remain closed and the spark gap remains under arcing condition.

Once the discharge current no longer can sustain the arcing, the spark gap supposes to change state to high impedance again. This is achieved by opening switch S_1. In other word, capacitor voltage should drop and allow the switch S_1 to open. This is achieved by having switch S_3 which will close whenever the discharge current can no longer maintains the arcing between the spark gap terminals.

The switch S_3 is depending on the current *I(t)* and the voltage *V(t.)*. The voltage *V(t)* is also required to control switch S_3 in order to prevent the switch S_3 in closed state during charging of the capacitor *C*. Otherwise, the capacitor *C* will not be charged if switch S_3 in closed position.

Based on the requirement above, logic circuit is developed in order to control the switch S_1, *S2* and S_3. The logic circuit is shown in Fig. 4. The numerical instability may happen because of the threshold values are wrongly selected. Therefore, the values should be carefully selected.

III. Simulation Results

The simulation has been done using the combination waveform 1.2/50 µs impulse voltage for open-circuit conditions and 8/20 µs impulse current for short-circuit conditions generator. The schematic diagram of the combination wave generator is shown in Fig. 5 [3]. Each combination wave impulse voltage and current (e.g. 1 kV/0.5 kA) is simulated based on the suggested waveform of the MS IEC 61643-1:2007 [4] for class III combination wave test. The wave shape of the open-circuit voltage is shown in Fig. 6.

When the combination waves of 0.5 kV, 1 kV and 2 kV are applied to the spark gap model, the generated surge voltages across the spark gap is illustrated in Fig. 7. For comparison, the results obtained from simulations are compared with data simulations from [1].

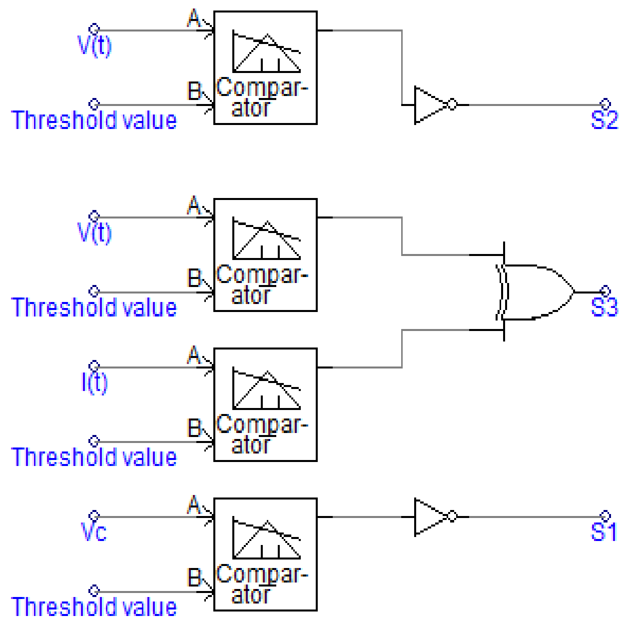

Fig. 4. Logic control circuit

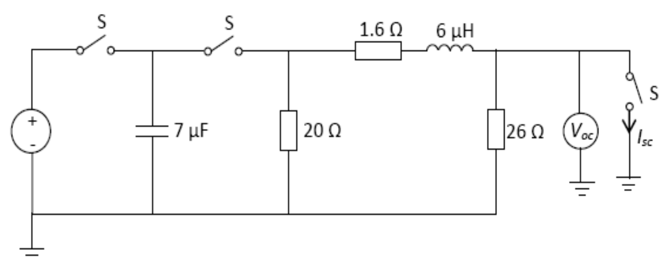

Fig. 5. Circuit of impulse generator.

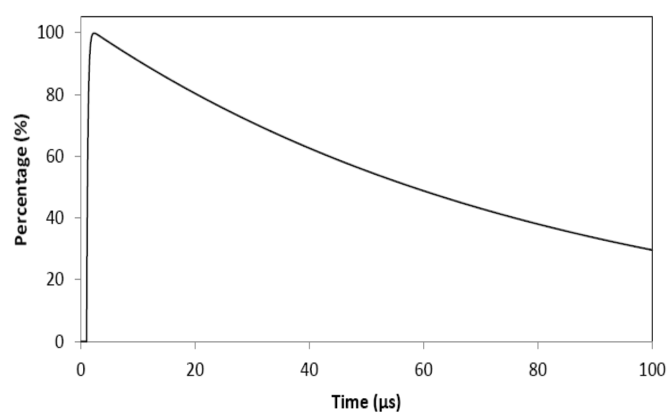

Fig. 6. Open-circuit voltage waveform.

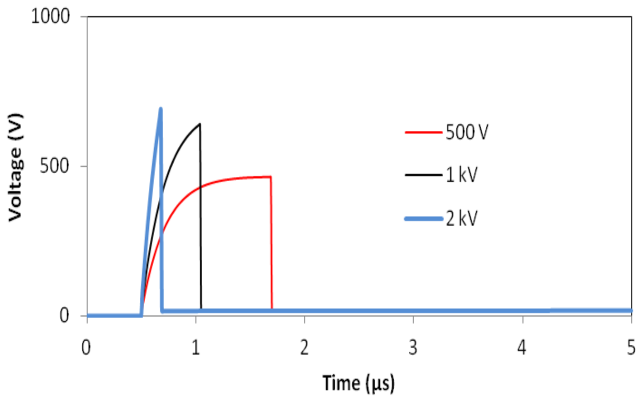

Fig. 7. The PSCAD/EMTDC simulated voltages at the spark gap.

IV. Conclusion

This paper has developed the spark gap model due to the unavailability of this model in the PSCAD/EMTDC master library. This model is numerically stable provided that the threshold values are correctly selected. The simulated results showed a good agreement between the results obtained by previous researchers (Section I).

The spark gap model has been developed to be able to simulate the component as a part of the SPDs in low-voltage power systems. The simulation model is straightforward and may allow the designer and student for their use as a source of research and study.

V. References

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VI. Biographies

Hamzah Ismail was born in Penang, Malaysia. He received his B. Elect. Eng. (Hons) from Institut Teknologi MARA, Malaysia in 1995. He is a Professional Engineer registered with the Board of Engineers Malaysia. He is currently pursuing his Masters Degree at the College of Graduate Studies of Universiti Tenaga Nasional. His research interest includes power transformer, lightning protection and power quality.

Ahmad Qisti Ramli was born in Perak, Malaysia. He received his B. Sc. in Electrical Engineering from University of Houston, USA in 1988, Master in Electrical Engineering (Power) from Universiti Teknologi Malaysia in 1997 and PhD in Electrical Engineering & Power System from University of Manchester, UK in 2007. Currently, he is an Associate Professor at Universiti Tenaga Nasional, Malaysia. His research interest includes power system, transformer, high voltage and numerical simulation.