Mitigation of the Transient Recovery Voltage on Generator Circuit Breaker During Generator Fed Faults

ARTICLE *in* INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH · NOVEMBER 2013

Mitigation of the Transient Recovery Voltage on Generator Circuit Breaker during Generator Fed Faults

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Abstract- This paper simulated a generator circuit breaker model using ATP-EMTP simulation package. The frequency of oscillations produced at current zero is reduced as the short circuit current increased. At 80 kA short circuit a resignation is happened at first current zero, while the success interruption is happened at the second current zero, at a capacitance of 8.3nF. As the short circuit current increases, more than 80 kA, the circuit breaker fails to interrupt with the small terminal capacitor, i.e. 8.3nF, 10nF and 20nF. The TRV is decreased as the value of the terminal capacitor increased. At a certain value of the terminal capacitor, the TRV is increased with increasing the short circuit current. The RRRV decreases as the value of the terminal capacitor increased. Also, at a certain value of the terminal capacitance, the RRRV decreases with decreasing the short circuit current.

Index Terms- Modeling, Mitigation, Transient recovery voltage TRV, Rate of rise of restricking voltage RRRV, Time to crest.

I. INTRODUCTION

Generator circuit breakers, GenCB, are located between generators and step-up transformers in power networks and their ratings usually range from 100MVA to 1300MVA. GenCBs face much higher current and voltage stress than distribution circuit breakers and the current interruption requirements of GenCBs are significantly higher than the distribution networks at similar voltages [1, 2, 3]. Modern GenCBs implement self-blast interrupting principles in order to reduce the operating energy of the circuit breaker. With this special design, GenCBs are capable of interrupting short circuit currents with high asymmetries. During a breaking operation by an SF6 GenCB, the arc voltage modifies the behaviors of the short circuit current. Therefore, GenCBs usually exhibit significant arc voltages with short arcing times. A few different mathematical circuit breaker models exist and are mostly characterized by experimentally measured parameters to describe the dielectric properties of different phenomena taking place in the breaker opening process. At the moment there is no existing precise universal arc model because of the complexity of the arc physics. On the other hand, most of the models mainly focus on describing the breaker behaviors during the current zero periods and ignore the importance of arc voltage. This paper focuses on the modeling, simulation taking the arc voltage into consideration. A mitigating technique to suppress TRV produced across the GenCB as a result of switching generator using GenCB is studied at different short circuit current.

II. MODELING OF GENCB

The proposed contact model is a black-box model with variable conductance. The value of conductance is determined by a mathematical model, which comprises four sub-stages: a closed breaker stage, an arcing stage, an arc extinguishing stage and an open stage [4, 5].

A constant resistance with a value of 1μΩ is used for modelling the closed circuit breaker stage and a constant resistance of 10MΩ is used to model the open circuit breaker stage after successful arc extinguishing. The arc extinguishing stage is modelled by using a series connection of a Cassie and Mayer arc model.

$$\frac{dg_c}{dt} = \frac{1}{\tau_c}\left(\frac{i^2}{U_C^2\, g_c} - g_c\right) \qquad (1)$$

$$\frac{dg_m}{dt} = \frac{1}{\tau_m}\left(\frac{i^2}{p_0} - g_m\right) \qquad (2)$$

The total conductance of the arc model during this stage is calculated using equation (3) and applied in the simulation for the arc extinguishing stage.

Where; i is the current through the breaker, gm is the conductivity of mayer's model part, g_c is the conductivity of cassie's model part, τ_m is the Mayer time constant, τ_c,is the Cassie time constant, U_c the constant voltage for Cassie arc model, and p_o is the constant power of Mayer arc model.

The four sub-models form a combined contact model. Once the contact receives open signal, each sub-model is activated at the corresponding time.

III. GENERATOR FED FAULTS

Figure 1 show a generator circuit breaker located between the generator and the step up transformers. The two key unique fault current conditions encountered by generator circuit breakers are shown in Figure 1.

ATP-EMTP simulation package is used to simulate the generator fed fault, fault at B, of Figure 1.The simulation network of a generator fed fault by using the Habedank arc

ISSN 2250-3153

model for modelling the circuit breaker is shown in Figure 2 [6]. There is usually a cable connected between the GenCB and the step up transformer, hence the demonstration circuit comprises a voltage source, a GenCB, a cable and a fault initiated at the end of the cable.

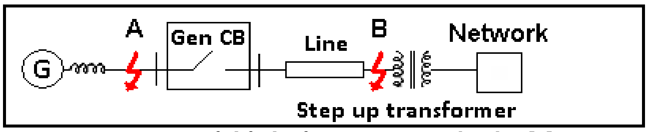

Fig.1.System fed fault of generator circuit breaker [6]

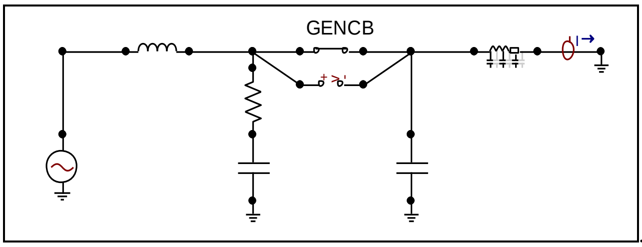

Fig.2.Demonstration circuit for generator fed fault

The voltage across the circuit breaker at current interruption of 20kA short circuit current is shown in Fig. 3. It is noticed that at current zero, the voltage oscillates with a high frequency. After the period of high oscillation the voltage oscillates at 60 HZ, with a value of 20.4kV.

Figure 4 shows the voltage across the circuit breaker at current interruption of 20kA short circuit current. It is noticed that at current zero the voltage oscillates with a high frequency and reached from zero to crest value of TRV of 41.801kV in time of 10.9 µs, i.e. the RRRV is 4.511 Kv/ µs. Following the decay of transient, the voltage oscillates at 60HZ with 20.4kV.

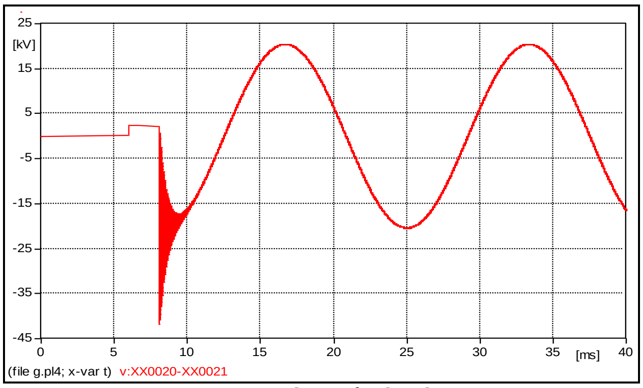

Fig.3.Transient recovery voltage of 20kA short circuit.

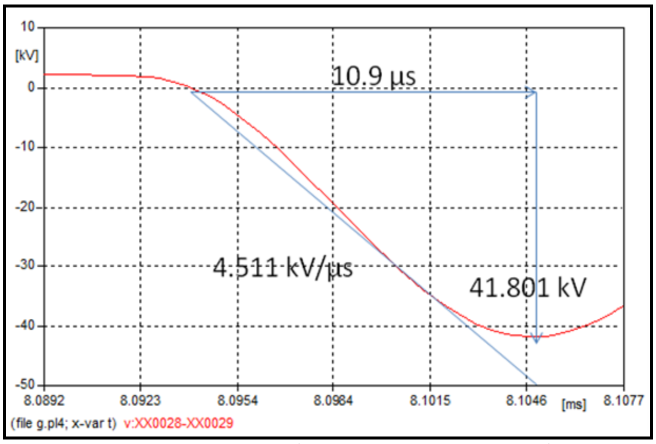

Fig.4.Crest value and RRRV of transient recovery voltage of 20KA short circuit current

Figure 5 and Figure 6 show the voltage across the circuit breaker at current interruption of 60kA short circuit. It is noticed that the TRV oscillates with lower oscillation than the previous case of 20kA short circuit. At current zero the voltage oscillate with high frequency and first TRV peak of oscillation reaches a value of about 40.654kV in a time of 6.6 µs. The RRRV is about 7.2467 kV/ µs which is larger than that of the 40kA case. Following the decay of transient, the voltage oscillates at 60HZ with 20.4kV.

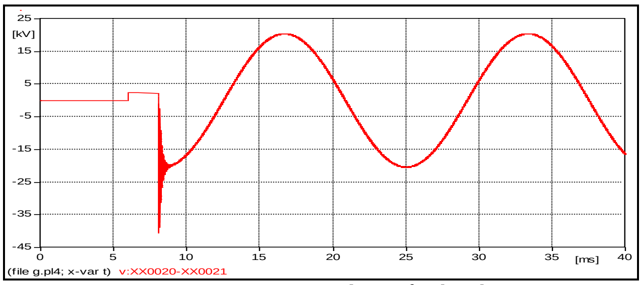

Fig.5.Transient recovery voltage of 60kA short circuit

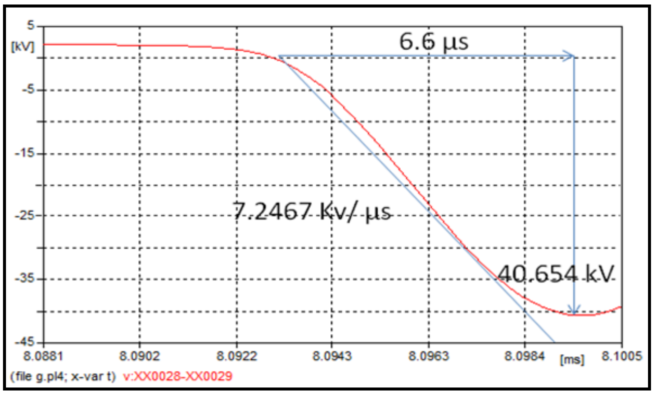

Fig.6.Crest value and RRRV of transient recovery voltage of 60KA short circuit

The voltage across the circuit breaker at current interruption of 80kA short circuit is shown in Figurers 7 and 8. It is noticed that the reignition is happened at first current zero and the interruption of short circuit current is happened at the second current zero. After that the TRV oscillates with high oscillation and the first TRV peak of oscillation reaches the value of about 40.308kV in a time of 6.4 µs. The RRRV is about 7.4 kV/ µs. Following the decay of transient, the voltage oscillates at 60HZ with 20.4kV.

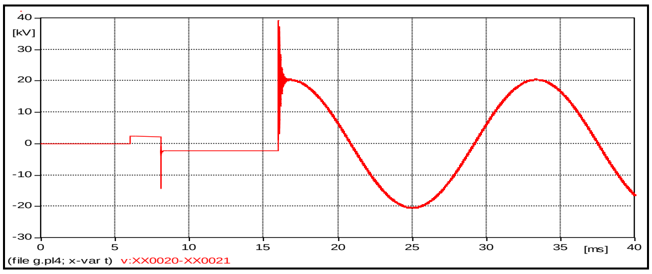

Fig.7. transient recovery voltage of 80kA short circuit

The voltage across the circuit breaker in case of 100 KA and 130 KA short circuit currents is shown in Figure 9. It is seen that the circuit breaker fail to interrupt the two short circuit levels.

IV. Mitigation of the TRV

A capacitor can be used at the terminal of the generator to suppress the TRV effectively. Figures.10 and Figure 11 show the voltage across circuit breaker at two different values of capacitances, 8.3nF and 30μF, respectively. It is noticed that the first waveform has a high voltage oscillation with using a capacitance of 8.3 nF. The TRV and the RRRV are about 41.801kV and 3.834 kV/μs, respectively. While with using a capacitance of 30μF, the TRV and the RRRV are about 27.088kV and 0.092 kV/μs, respectively. It is also shown that the high frequency oscillation is removed with using a capacitor of 30μF.

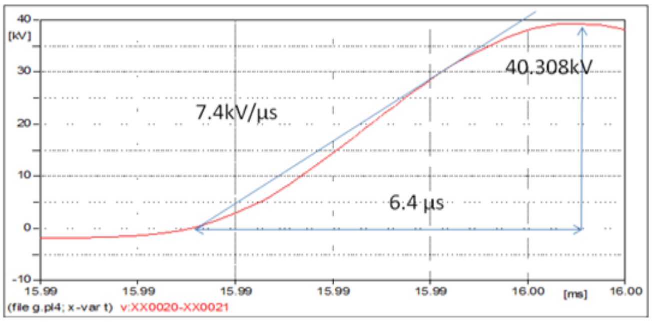

Fig.8. the crest value and RRRV of transient recovery voltage of 80KA short circuit

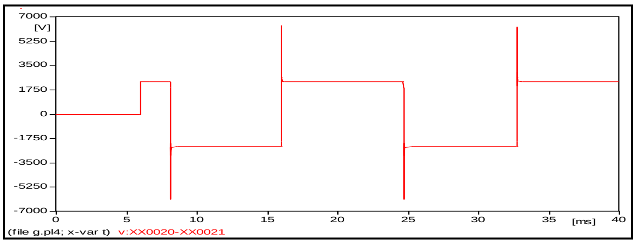

Fig.9 the voltage across the circuit breaker

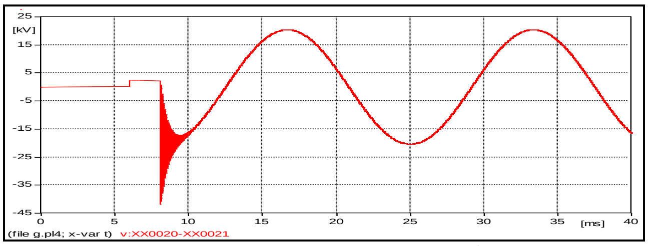

Fig.10.The voltage across the circuit breaker in case of 20kA short circuit and 8.3 nF capacitor

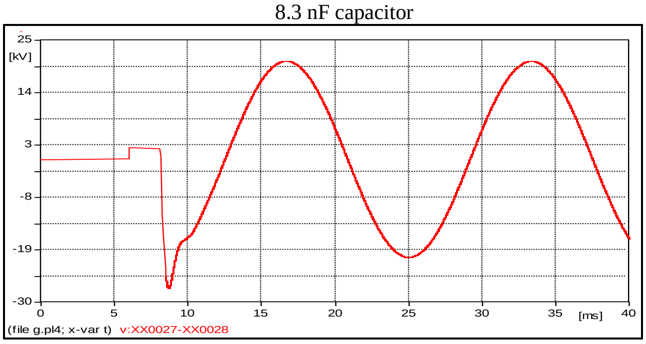

Fig.11.The voltage across the circuit breaker in case of 20kA short circuit and 30 μf capacitor

Figure 12 shows the TRV versus the capacitance value of capacitor at generator terminal. It is noticed that as the value of the capacitance increased the TRV is decreased. Also, the TRV is increased as the short circuit current increased, at a certain values of terminal capacitor. It must note that the capacitance should not exceed a certain limit to prevent resonance in the network. The TRV will be decreased by about 13.34 kV as the capacitance increased from 8.3 nF to 20 μF, at 20 kA short circuit current. The TRV will be decreased by about 5.65 kV as the short circuit current increases from 20 kA to 130 kA, at a capacitance of 1.0 μF. At 100 kA short circuit the circuit breaker is failed to interrupt with a terminal capacitor of 8.3nF and 10nF, while at 130 kA the circuit breaker is failed to interrupt with a terminal capacitor of 8.3nF, 10nF and 20nF.

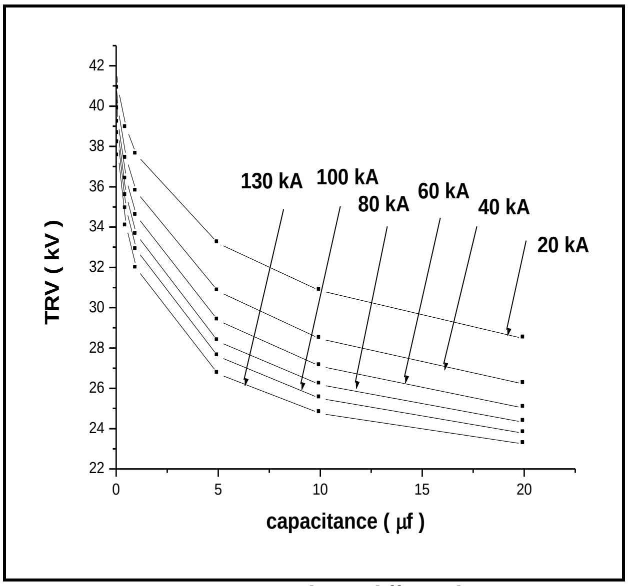

Fig.12 TRV versus capacitance values at different short circuit current

The RRRV versus the capacitance values, at different short circuit currents is shown in Figure 13. It is illustrated that as the value of the capacitance increases, the RRRV is decreased. Also, the figure shows that, at a certain value of the capacitance, the RRRV decreased as the short circuit current decreases. The RRRV will be decreased from about 4.51 kV/μs to about 0.07 kV/μs as the capacitance increased from 8.3 nF to 20 μF, at 20 kA short circuit current. The RRRV will be increased from about 0.27 kV/μs to about 0.87 kV/μs as the short circuit current increases from 20 kA to 130 kA, at a terminal capacitance of 1μF.

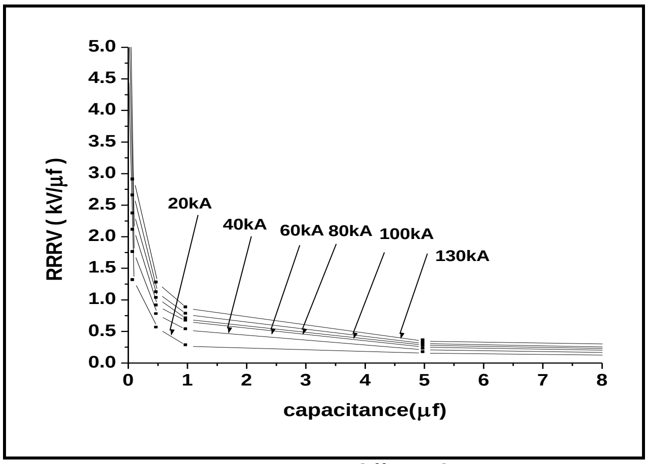

Fig.13.RRRV versus capacitance at different short circuit current

The change of time to crest, T2, with the capacitance values at different short circuit currents is shown in Fig.14. It is noticed that as the value of the capacitance increase the time to crest is increased. Also, at a certain value of the capacitance, the time to crest is increased as the short circuit current decreases. The time to crest is increased by about 453.6 μs as the capacitance increased from 8.3 nF to 20 μF, at 20 kA short circuit current. The time to crest decreased from about 116.3 μs to about 43.4 μs, as the short circuit current increases from 20 kA to 130 kA, at a terminal capacitance of 1μF.

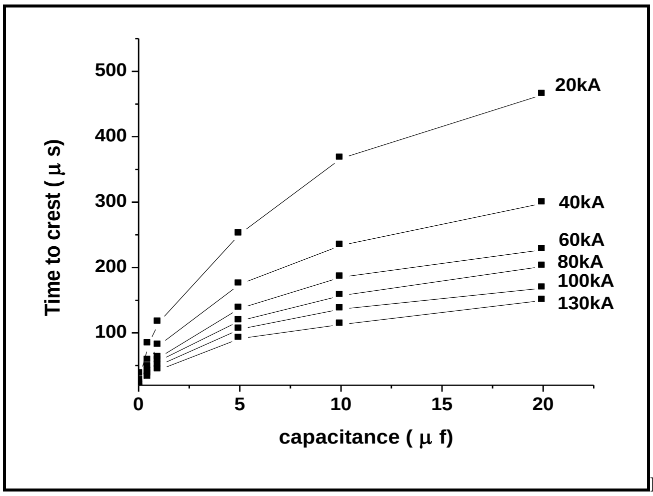

Fig. 14 the time to crest versus capacitance values at different short circuit current

V. CONCLUSIONS

1. The frequency of oscillations produced at current zero is reduced as the short circuit current increased.
2. At 80 kA short circuit current a reignation is happened at first current zero, while the success interruption is happened at the second current zero, with a terminal capacitance of 8.3nF.
3. At 100 kA short circuit current the circuit breaker is failed to interrupt with a terminal capacitor of 8.3nF and 10nF, while at 130kA short circuit current the circuit breaker is failed to interrupt with a terminal capacitor of 8.3nF, 10nF and 20nF.
4. The TRV decreases with increasing the value of the terminal capacitor.
5. At a certain value of terminal capacitor, the TRV is increased with increasing the short circuit current.
6. The RRRV decreases with increasing the value of the terminal capacitor.
7. At a certain value of the terminal capacitor, the RRRV decreases with decreasing the short circuit current.

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