A New Technique For Transient Recovery Voltage Suppression on Generator Circuit Breaker For Generator Fed Faults

CONFERENCE PAPER · JUNE 2013

Mousa Abdullah
Benha University

Abdelsalam Hamza
Benha University

Tamer Hamama
Benha University

A NEW TECHNIQUE FOR TRANSIENT RECOVERY VOLTAGE SUPPRESSION ON GENERATOR CIRCUIT BREAKER FOR GENERATOR FED FAULTS

M. A. ABD-ALLA	Ebrahim A. BADRAN	Abdelsalam H. HAMZA	Tamer ELYAN
Faculty of Engineering	Faculty of Engineering	Faculty of Engineering	Faculty of Engineering
Benha University, Egypt	Mansoura University, Egypt	Benha University, Egypt	Benha University, Egypt
mousa_abdulah@yahoo.com	ebadran@mans.edu.eg	Ashamza55@yahoo.com	tamerhamama@yahoo.com

ABSTRACT

In this paper, the generator circuit breaker (GenCB) is simulated using ATP- EMTP software package. Four main stages of the breaker's operating processes are considered, namely; the closed contacts stage, the arc burning stage, the arc extinguishing stage and the opened contacts stage. Therefore, not only the dynamic conductance during current zero are considered but also the effects of arc voltage on the arcing times are included. The simulation is tested in a representative network and the results are compared with IEEE Generator Circuit Breaker standards. A new mitigation technique is introduced to reduce the transient recovery voltage and the rate of rise of re-striking voltage during switching period. The results show that the new technique reduces both the TRV and RRRV effectively with respect to previous ones.

INTRODUCTION

Generator-fed fault currents are subjected to very demanding condition called "Delayed current zeros". This unique characteristic of the fault current comes from the very high X/R (inductive reactance to resistance) ratio of the circuit and the operating conditions of the generator, which can combine to produce a DC component of the fault current exceeding 100%. This means that the asymmetrical fault current peak becomes so high, and its decay is so slow, that the first current zero can be delayed for several cycles [1].
Since circuit breakers rely on current zero crossing in order to interrupt, generator circuit breakers must be able to withstand longer arcing times and greater electrical, thermal and mechanical stresses when interrupting this kind of fault. Different mathematical circuit breaker models exist and are mostly characterized by experimentally measured parameters to describe the dielectric properties of different phenomena which take 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 [2-3]. On the other hand, most of the models mainly focus on describing the breaker behavior during the current zero period and ignore the importance of arc voltage. In this paper, the arc voltage is undertaken in the simulation. Furthermore, a new technique to suppress TRV and to decrease RRRV is introduced.

MODELLING OF THE GENERATOR CIRCUIT BREAKER

The generator circuit breaker is modeled as a black-box 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 modeling the closed circuit breaker and constant resistance of 1MΩ is used for the open circuit breaker model after successful arc extinguishing.
The arcing stage and the extinguishing stage are modeled by using a series connection of a Cassie and Mayer arc model as given in equations (1) and (2) [6-8].

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

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

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

$$\frac{1}{g} = \frac{1}{g_c} + \frac{1}{g_m} \qquad (3)$$

Where; i is the current through the breaker, g_m 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 is 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.

GENERATOR FED FAULTS

Fig. 1 shows the two key unique fault current conditions encountered by generator circuit breakers [1, 2]. ATP-EMTP is used to simulate the generator fed fault at B in Fig. 1. The simulation network of a generator fed fault by using the Habedank arc model for modeling the circuit breaker is shown in Fig. 2 [7]. 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.

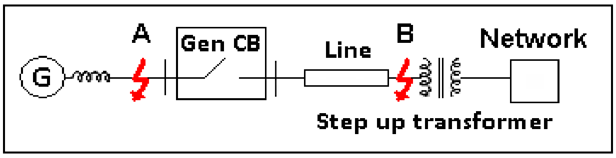

Fig. 1: System fed fault of GenCB

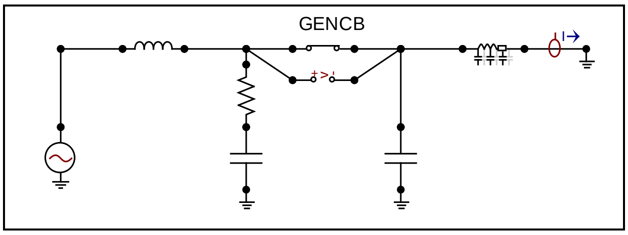

Fig. 2: ATP-EMTP model of GenCB

The voltage across the circuit breaker at current interruption of 20 kA 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 20.4 kV.

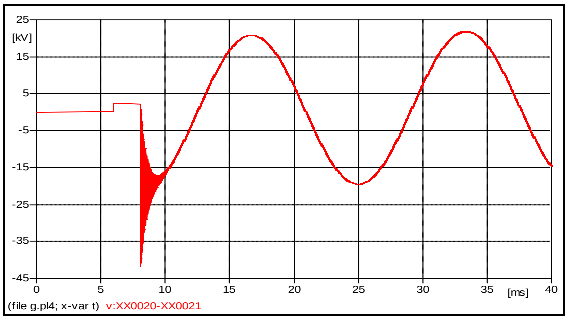

Fig. 3: TRV of 20 kA short circuit

Fig. 4 shows the voltage across the circuit breaker at current interruption of 20 kA 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 41.801 kV in time of 10.9 µs, i.e. the RRRV is 4.511 kV/µs. Following the decay of transient, the voltage oscillates at 60 HZ with 20.4 kV.

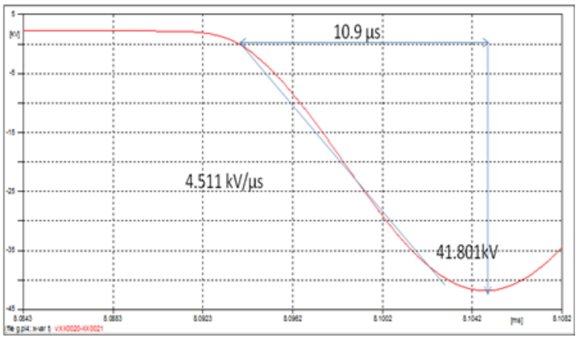

Fig. 4: RRRV of the TRV of 20 KA short circuit

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

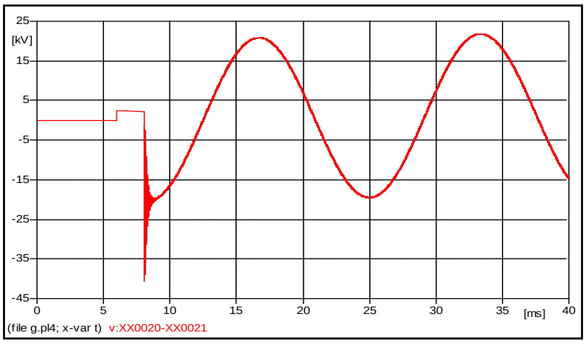

Fig. 5: TRV of 60 kA short circuit

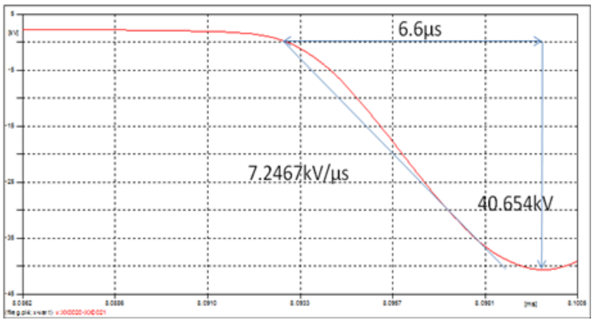

Fig. 6: RRRV of TRV of 60 KA short circuit

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

The voltage across the circuit breaker in case of 100 kA and 130 kA short circuit is shown in Fig. 9. It is seen that the circuit breaker fails to interrupt the two short circuit levels.

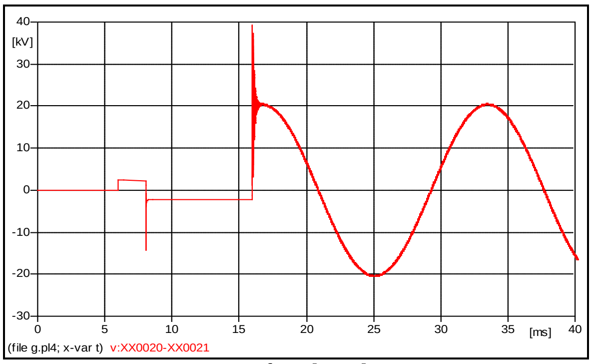

Fig. 7: TRV of 80 kA short circuit

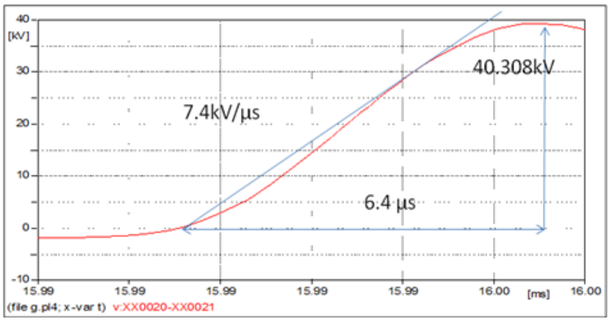

Fig. 8: RRRV of the TRV of 80KA short circuit

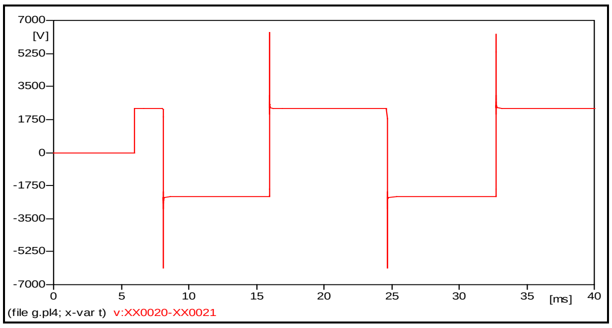

Fig. 9: Voltage across the circuit breaker at 100 kA and 130 kA

MITIGATION OF THE TRV

It is proposed to use capacitor-resistance surge suppressor across the GenCB to suppress the TRV. Fig. 10 shows the voltage across circuit breaker with proposed C-R suppressor of R=30Ω and C=300nf. By comparing Fig. 10 and Fig. 3, which represents the voltage without using mitigation techniques, it is noticed that the use of C-R suppressor reduces the voltage oscillation remarkably. The use of C-R suppressor reduces the TRV from about 41.8 kV to about 33.98 kV. Also, it reduces the RRRV from about 4.51 kV/µs to about 0.63 kV/µs. It is also shown that high frequency oscillation is effectively damped.

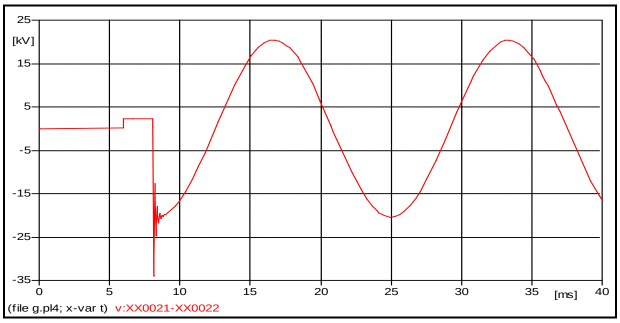

Fig. 10: Voltage across the circuit breaker at 20 kA short circuit with C=300 nF and R=30 Ω suppressor

Fig. 11 shows a zoom-in view of voltage oscillation at instant of GCB opening with and without C-R suppressor. It is clear that the oscillation is damped effectively with using C-R suppressor.

Fig. 12 shows the TRV versus the capacitance value of the proposed C-R suppressor at different short circuit currents. It is noticed that as the value of the capacitance increases the TRV is decreased. The TRV decreased by 5.622 kV when the capacitance increases from 40 nF to 300 nF, at 20 kA short circuit. As the short circuit current increases from 20 kA to 130 kA at capacitance of 40 nF, TRV decreases by 4.198 kV.

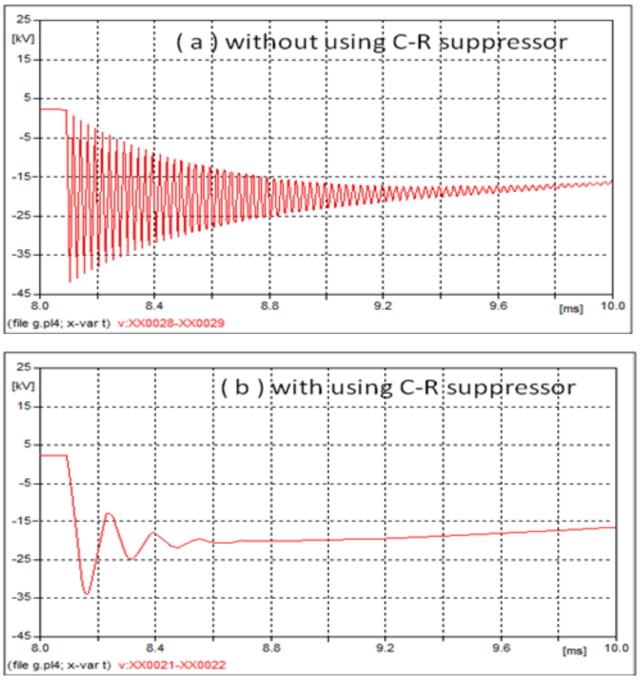

Fig. 11: voltage across contacts at instant of GCB opening at 20 kA short circuit current

Table 1: TRV, RRRV, and the time to crest of TRV at 20 kA in case of C-R suppressors with R=30Ω

Capacitance (nF)	TRV (kV)	RRRV (kV/µs)	Time to crest of TRV (µs)
40	39.512	1.531	25.8
80	37.912	1.282	34.8
120	36.818	1.044	41.5
160	35.978	0.893	47.4
200	35.292	0.791	52.5
240	34.712	0.715	57.1
280	34.209	0.659	61.1
300	33.980	0.634	63.1

Fig. 13 shows the RRRV versus the capacitance of the proposed C-R suppressor at different short circuit currents. It can be seen that as the value of capacitance increases the RRRV is decreased. When the value of capacitance increases from 40 nF to 300 nF at 20 kA short circuit the RRRV decreases by 0.897 kV/µs. The RRRV increases by 2.542 kV/µs when the short circuit current increases from 20 kA to 130 kA at capacitance of 40 nF.

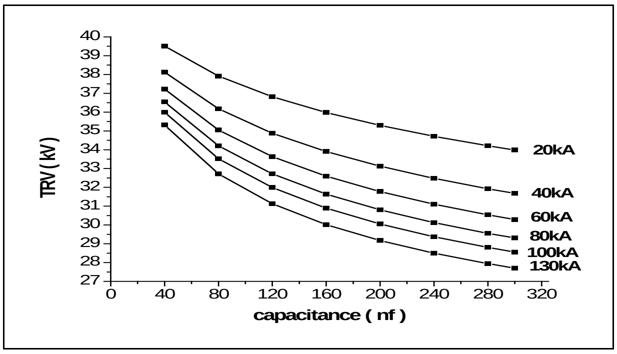

Fig. 12: TRV versus capacitance of suppressor with R=30 Ω at different short circuit current

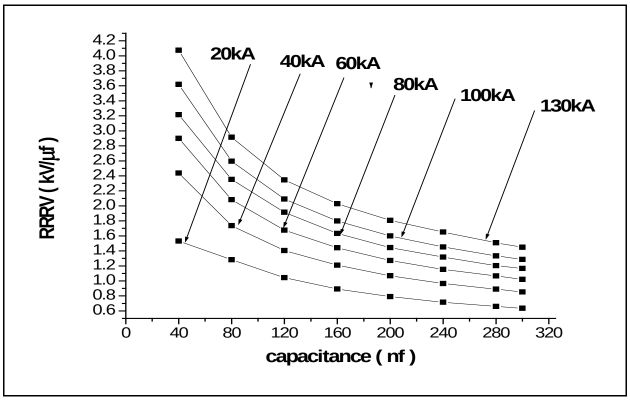

Fig. 13: RRRV versus capacitance of suppressor with R=30 Ω at different short circuit current

The change of time to crest with the capacitance values at different short circuit currents is shown in Fig. 14. It is noticed that as the value of the capacitance increases the time to crest increases. Also, it can be found that at a certain value of the capacitance, the time to crest increases as the short circuit current decreases. The time to crest is increased by about 37.3 µs as the surge capacitance increased from 40 nF to 300 nF at 20 kA short circuit current. The time to crest decreases from 25.8 µs to 10.2 µs as the short circuit current increases from 20 kA to 130 kA, at capacitance of 1 µF.

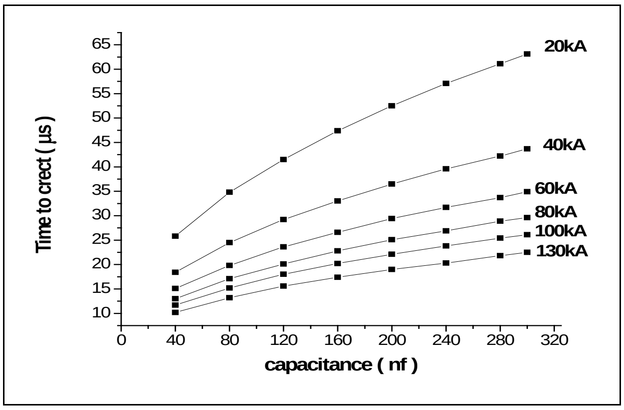

Fig. 14: The time to crest versus capacitance of suppressor with R=30 Ω at different short circuit current

CONCLUSIONS

The voltage across the GenCB oscillates with a high frequency and reached a high value which can be as high as 2 pu in very small time which can be as low as 6 µs. The proposed mitigation techniques using C-R suppressor, effectively reduced both TRV and RRRV. As the capacitance of C-R suppressor increases, the TRV and RRRV are decreased, while the time to crest is increased. At a certain value of capacitance, as the short circuit increases, the TRV and time to crest are decreased while RRRV is increased.

REFERNCES

[1] Václav Ježek, 2010, "Prespective Generator Circuit Breaker", Intensive Programme "Renewable Energy Sources", pp.107-110.

[2] IEEE Standard for AC High-Voltage Generator Circuit Breakers Rated on a Symmetrical Current Basis, IEEE Standard C37.013 – 1997

[3] R.P.P. Smeets and L.H. te Paske, 2011, "Testing of SF6-and Vacuum Generator Circuit breakers", International Conference on Electric Power equipment-Switching Technology,pp.146 -110.

[4] S. Y. Leung, Laurence A. Snider and Cat S. M. Wong, 2005, "SF6 Generator Circuit Breaker Modeling", International Conference on Power Systems Transients (IPST'05), Montreal, Canada.

[5] P.H. Shavemaker and L. Van Der Sluis, 2002, "The Arc Model Blokset", Second IASTED International Conference. Power Engineering Systems, pp.1310-1315.

[6] R. P. P. Smeets and W. A. van der Linden, 1998, "The Testing SF6 Generator Circuit Breakers", IEEE Transactions on Power Delivery, Vol. 13, No. 4, pp. 1188-1193.

[7] Grega Bizak, Peter Zunko, and Dusan Povh, 2004, "Combined Model of SF6 Circuit Breaker for Use in Digital Simulation Programs", Transactions on Power Delivery, Vol. 19, No. 1, pp. 174-180.

[8] G. Ala and M. Inzerillo, 1999, "An Improved Circuit Breaker Model in Models Language for ATP-EMTP", International Conference on power Systems Transient, IPST'99, pp.493-498.