Elimination of Transient Recovery Voltage of High Voltage Circuit Breaker In MATLAB/Simulink

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Abstract- *Due to continuous growth in the power system network the reliability of the power supply plays an important role while defining the system. There is an immense need to develop switchgear and protective system which is reliable as well as fast operating during faulty conditions. A very severe problem of transient recovery voltage is occurred which can affect the efficient operation of circuit breaker. This paper uses the developed Mayrs arc model for the elimination of transient recovery voltage of high voltage circuit breaker.*

Keywords- Transient Recovery Voltage, Circuit Breaker, Mayr's Arc Model, MATLAB/Simulink, Arc Interruption, Hit Crossing.

I. INTRODUCTION

Reliability of Power supply is playing a crucial role for developed as well as developing nation. Therefore, proper protection must be given to whole power system network which can be achieve by using switchgear equipments like Circuit Breaker, Relay, Current Transformer, Potential Transformer, etc. Each and every element in power system network must be taken a great care because if a single element of a network doesn't work properly or get damage, then it effects the whole power system network. Hence whole network must be properly monitories and if fault condition occurs then operation of protective devices like Circuit Breaker must take place otherwise the fault current can destroy electrical network and threaten human life.

Large amount of current which occur during abnormal condition in an electrical network can damage the whole system, hence for the protection of system Circuit Breaker are used. Circuit Breaker is an automatically operated electric switch designed to protect electric circuit from large current which flows during occurrence of fault. During the process of interruption contact of circuit Breaker are separated then an electrical arc of high temperature is produced and the area between the breaker contacts becomes conducting. Also, during this interruption process a voltage difference observed across the terminals of the circuit breaker and this voltage is known as Transient Recovery Voltage. In Short whenever circuit breaker is interrupted it results in a TRV which has deleterious effects. The electric arc plays an important role during the process of interruption and it is often known as switching arc. It is a plasma channel between the breaker terminals after a gas discharge in the extinguishing medium. Hence there is great need to study this abnormal phenomenon of TRV, which is practically not possible to study because it has high amplitude of current and frequency hence, we are using simulation in MATLAB to study the effects TRV on system and how we can reduce the TRV. Simulation gives us the knowledge about the system which are design to meet their requirement for safety, reliability and one can predict how system will behave on occurrence of fault. Also, by changing the values of parameters like inductance, capacitance and resistance one can check the system's performance and stability.

The interaction between the arc voltage and arc current is one of the important parameters and it has been recognized that arc voltage increases with arc length and it becomes elongated because of

- Increase in gap length
- Magnetic force of supply current
- Convection of the surrounding gas

So, this electric arc is been studied by using Electric Arc Modeling which are classified into 3 categories

- Black Box model
- Physical Model
- Models based on Graphics and Diagram

This paper uses Black box model in which the arc is described by simple mathematical equation which gives the relation between the conductance and measurable parameter like arc voltage and arc current. Aim to this model is to make mathematical model that represent the circuit breaker test and can be applied in predicting the behavior of circuit breaker during different conditions.

Arc Model Block set is an example of "black box" model it is library that contain several arc models like

- Cassie Arc Model
- Schwarz Arc Model
- Hamedan Arc Model
- Shoemaker Arc Model
- Mayr Arc Model

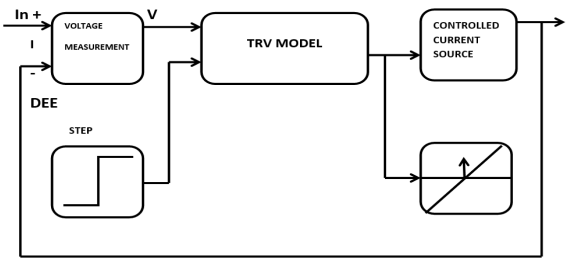
This paper uses the developed Mayrs arc model for the elimination of transient recovery voltage of high voltage circuit breaker.

II. SYSTEM DEVELOPMENT

Proposed architecture of transient recovery model in shown in following figure. Following components are present in the proposed system:

1. Voltage measurement unit
2. Transient recovery model
3. Step signal generator
4. Controlled current source
5. Zero crossing detectors

As discussed earlier in this proposed system O' Mayr arc Model is used to demonstrate Transient recovery voltage phenomenon



For better understanding of the current interruption process in high voltage circuit breakers and to be able to design interrupting chambers arc models are developed. Process of current interruption is very much complex that it is still not achievable to adopt these arc models for circuit breaker design because of its physical phenomenon during current interruption. The study of arc-circuit interaction is one of the very useful applications. The strong non linear behavior of circuit breaker arc is simulated by arc model. For this purpose, an appropriate treatment of the arc circuit problem is very necessary because it has nonlinear behavior and the very small-time constants involved.

The basic function of the circuit breaker is switching action that is to change from conductor to insulator under abnormal condition or when it is desirable. During the process of current interruption when breaker terminals are been separated an arc channel is formed between the breaker contact through which the fault current flows. Hence the current causes a voltage across contact of circuit breaker called as arc voltage as there is non-zero resistance of arc channel and the arc behaves as a non-linear resistance. Thus, both arc voltage and arc current cross the zero-value at the same time instant. If the arc is cooled sufficiently, at the time the current goes through zero, the circuit breaker can interrupt the current, because the electrical power input into the arc channel is zero. During current interruption, the arc resistance increases from practically zero to almost infinite in microseconds.[2]

Immediately after current interruption, the transient recovery voltage (TRV) builds up across the circuit breaker contacts. As the hot gas mixture in the interrupting chamber does not change to a complete insulating state instantaneously, the arc resistance is finite and a small current can still flow which is the post-arc current. Black-box arc models are mathematical descriptions of the electrical properties of the arc. This type of models does not simulate the complex physical processes inside the circuit breaker, but describes the electrical behavior of the circuit breaker. Measured voltage and current traces are used to extract the parameters for the differential equation(s) describing the non-linear resistance of the electrical arc for that specific measurement.

The arc models have been modelled as voltage controlled current sources. This approach is visualized in fig. 1, where both the Mayr arc model block and the underlying system are shown. Some of the elements in fig. 1 will be clarified here under. The equations of the Mayr arc model have been incorporated by means of the Simulink DEE (Differential Equation Editor) block. Therefore, the following system of equations is solved:

$$\frac{dx(1)}{dt} = \frac{u(2)}{\tau}\left(\frac{e^{x(1)}u(1)^2}{P} - 1\right) \qquad \frac{d\ln g}{dt} = \frac{u(2)}{\tau}\left(\frac{gu^2}{P} - 1\right)$$

$$y = e^{x(1)}u(1) \qquad i = gu$$

x (1) = state variable of the differential equation which is the natural logarithm of the arc conductance: ln (g)

x(0) = the initial value of state variable i.e. the initial value of arc conductance

u(1) = the first input of the DEE block which is the arc voltage: u

u(2) = the second input of the DEE block which represents

the contact separation of the circuit breaker: u(2)=0 when contact are closed and u(2)= 1 when contacts are being opened

y = the output of the DEE block which is the arc current: i
g = the arc conductance
u = the arc voltage
i = the arc current
□□= the arc time constant
P = the cooling power

Hit Crossing

The Simulink 'Hit crossing' block detects when the input, in this case the current, crosses the zero value. Therefore, by adjusting the step-size, the block ensures that the simulation finds the zero-crossing point. This is of importance while the voltage and current zero crossing of the circuit breaker, which behaves as a non-linear resistance, is a crucial moment in the interruption process that should be computed accurately.

Step

The Simulink 'Step' block is used to control the contact separation of the circuit breaker. A step is made from a value zero to one at the specified contact separation time. When the contacts are closed, the following differential equation is solved:

$$\frac{d\ln g}{dt} = 0$$

Therefore, the arc model behaves as a conductance with the value *g* (0). Starting from the contact separation time, the Mayr equation is solved:

$$\frac{d\ln g}{dt} = \frac{1}{\tau}\left(\frac{gu^2}{P} - 1\right)$$

Both the initial value of the arc conductance *g* (0) and the time at which the contact separation of the circuit breaker starts, are specified by means of the arc model dialog.[1]

MODELLING

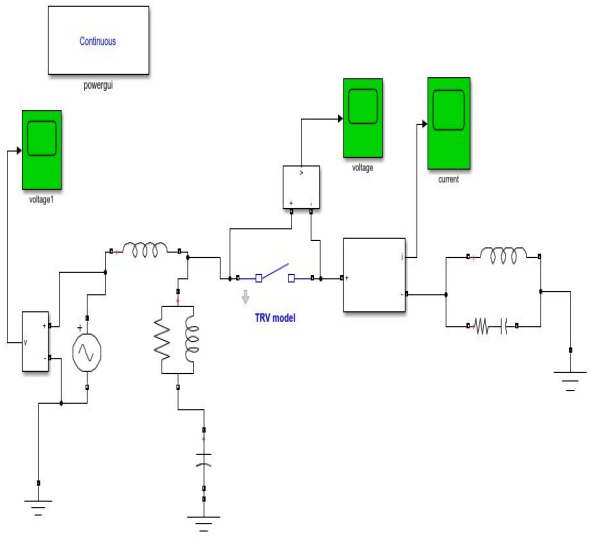


Fig. 1. Power System Transmission Line Model in MATLAB

Flowchart:

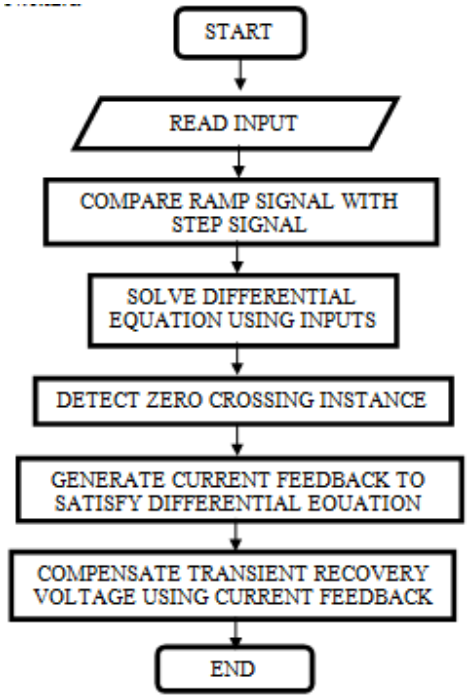


Figure 1. shows a Power system transmission line model in which various components are arranged in a specific order according to its working and function. The simulation of this model is performed in MATLAB-Simulink Software. There are various types of software available to perform simulation like PSCAD, PSB/AMB, XTrans, EMTP96/ATP.

Here the post arc current is observed by Mayr's type model which is caused by the TRV and the non-infinity resistance at the instant of current zero cross period. TRV oscillation frequency depends on the LC parameters of source

side circuit. Transient recovery model is monitoring the whole system and if abnormal condition occurs then this TRV model will control the transient recovery voltage across the terminal of a circuit breaker and hence the whole system gets protected. Shunt compensation is used in this model because with series compensation losses are increased which is not desirable hence shunt compensation is used.

Detailed behavior of voltage and current can be observed around current zero crossing when fault is interrupted by the circuit breaker. It is observed that the rapid increase in transient recovery voltage leads to reduction of arc current, until it gets the zero value and finally the arc gets extinguished. Hence model describes the arc characteristics during current zero-cross and the results are shown by graph during the current interruption. By using this model TRV can be eliminated and the fault arc current is minimized or get eliminated which can protect the system from the damage which is caused by TRV.

III. RESULTS

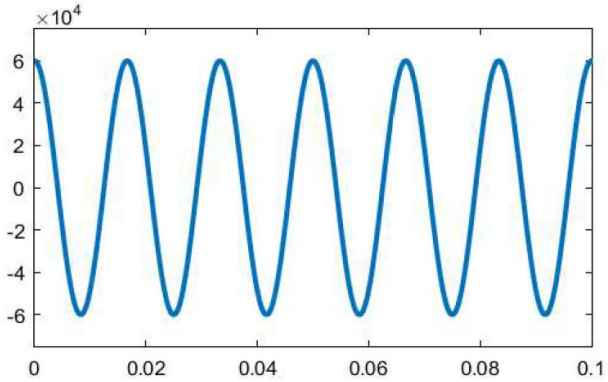


Fig. 2. Supply voltage waveform

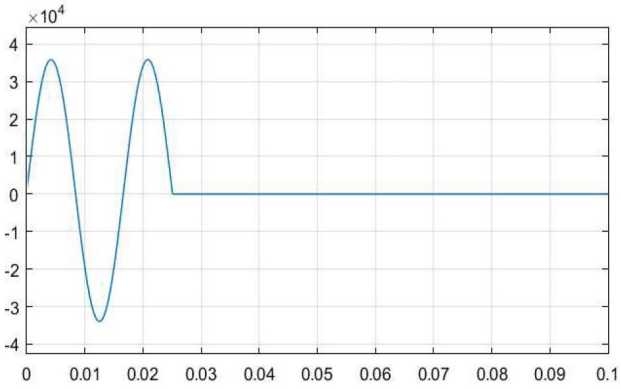


Fig. 3. Computed current when contact separation

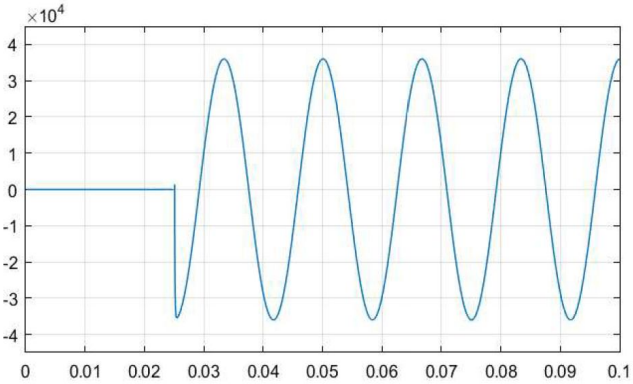


Fig. 4. Computed voltage when contact separation

Fig 5. Transient recovery voltage at over rated inductor

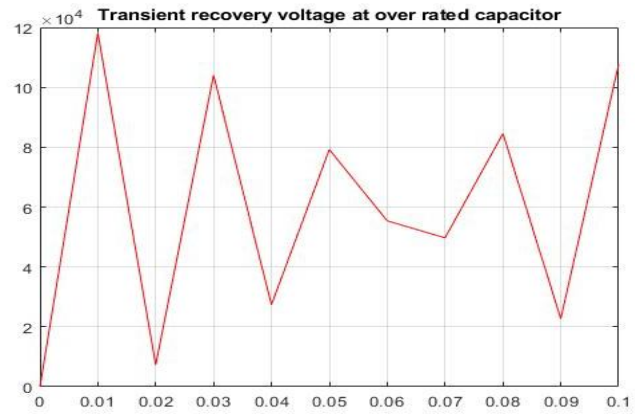


Fig. 6. Transient recovery voltage at over rated capacitor

In Figure 3, 4, it can be observed the detailed behavior of the voltage and current around the current zero crossing when the circuit breaker contacts start to separate. As it is shown, the rapid increase in the transient recovery voltage leads to the reduction of the arc current, until it gets the zero value and the arc finally disappears.

Different effects of the over rated inductor and over rated capacitor has also been shown in the figure 5,6.

IV. CONCLUSION

Transient recovery voltage is an important phenomenon which determines the operation of high voltage circuit breaker. The use of MATLAB/Simulink tools can help to improve these devices, reducing the need of preliminary models and testing and so, the cost to this optimal process. There are different black box arc models, here the Mayr arc model gets implemented. The type of model to be implemented is differ depending on the purpose of simulation.

Mayr arc modeling is absolute to study the transient recovery voltage, whereas in the case of the design of new circuit breakers or to increase the understanding of the interruption process, this model is the most appropriate, despite their complexity.

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