

**RESEARCH OF ELECTRIC ARC MODEL FOR HIGH VOLTAGE
CIRCUIT BREAKER BASED ON MATLAB**Mr. Kushal V Saitwal¹, Assistant Prof. Prabodh Khampariya²¹ Electrical Power System, Shree Satya Sai University of Technology & Medical Science,² Electrical Power System, Shree Satya Sai University of Technology & Medical Science,

Abstract — Circuit breakers perform a very important role in electrical power system networks. They identify the faults and isolate faulted sections rapidly, clearly and reliably. They are also used for normal load switching. A circuit breaker is a switching device that is capable of making, carrying for a specified time and breaking current under specified abnormal circuit conditions such as those of short circuit. Cassie's and Mayr's electric arc the two models for expository deciding of electric circular segment parameters, which were presented in this paper. Therefore, the optimization of the operation of high voltage circuit breakers makes necessary a deep understanding of the phenomena involved in the appearance of the electric arc. High voltage circuit breakers working base is the electric arc that appears between their contacts when establishing or interrupting the electric current in the circuit. This electric curve is an unpredictable wonder where heaps of physic associations happen in a brief timeframe. Numerous strategies have been produced to test the circuit breakers and reproduced bend display. This is to be achieved by means of modelization and simulation tools. The aim of this paper is to showing the phenomena of the electric arc in high voltage circuit breakers, as well as the description of the mathematical, physical and software needs for its monetization and simulation.

Keywords — Interruption, Electric arcing contact, Physical Model, Black Box Model, Parameter Model, matlab

I. INTRODUCTION

Electrical switch is a device which can be worked as a physically and consequently to control the electrical power framework. It deals with a current and Designing of circuit breaker for safe interruption of arc produced during the operation of circuit breaker. It is huge important role in electric power system equipment related to quality of service, because they can isolate faults that otherwise could cause total power system breakdowns.

When circuit breaker contacts separate to initiate the interruption process an electric arc of a high temperature established the conducting medium in which the interruption of current will occurred.

Within the framework of this paper, the most suitable model of the switching phenomena in an a.c. low voltage vacuum circuit breaker is looked for, aiming to better predict the apparatus behaviour. From numerous and very attentive experimental investigations of the switching processes taking place at high currents interruption

The circuit breaker consist of plug that is connection with the contact when the circuit breaker is closed then current flows through the circuit. To interrupt the current the contact breaker and plug are separated and hence arc is formed between the contact of the circuit breaker.

High-voltage circuit breakers play an important role in transmission and distribution systems. They must clear faults and isolate faulted sections rapidly and reliably. To verify the interrupting performance the breaker is tested in the High-Power Laboratory. Arc-circuit computations with arc models, named 'digital testing', make it possible to enhance the information obtained from the rather costly tests in the High-Power Laboratory. A useful characteristic that can be computed is the 'quality of Interruption', being the margin between interruption and failure. Furthermore, this parameter indicates how good an interruption was (i.e. a comparison between interruptions) or how bad a Failure was (it. a comparison between failures).

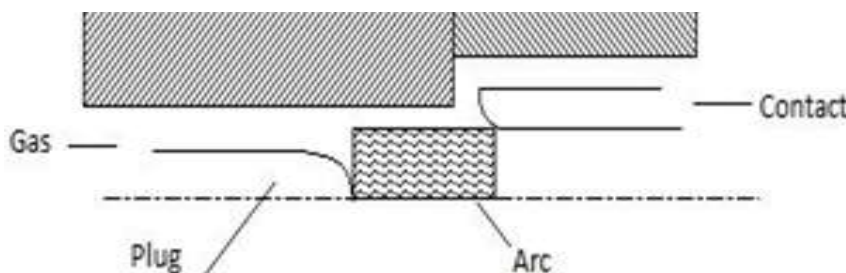


Figure 1: contact gap of circuit breaker

The short circuit current carries 40 to 100k ampere current. The subsequent arc temperature goes beyond 10,000 degrees (C), which is far above the melting point of any known material. This is much above the melting point of any known material. This paper describes the electric arc with interruption process in a high voltage device. in addition with Review of electric arc model using *MATLAB*.

II. LITERATURE SURVEY

2.1. Electric Arc In Circuit Breaker

The electric arc in a circuit breaker plays a very important role in the interruption process and is therefore frequently addressed as *switching arc*. The electric arc is a plasma channel between the breaker contacts moulded after a gas discharge in the extinguishing medium. When current flows through the contacts of the circuit breaker part, which is determined by the mechanism, the magnetic energy stored in the inductances of the power system make the current to flow. Before separation of contact, the contacts of breaker trace each other at a very small surface area and the resulting a very high current density made the contact material to melt. The melting contact material almost blasts and this indicates to a gas discharge in the surrounding medium such as air, oil and SF₆. The arc is a gas column, with an estimated straight path between electrodes and temperatures above 5000 and 9500 °C. Metallic contact surfaces are dropping in the cross section of the arc is detected near around them. In this way, these regions defined: a central zone or arc column and the anode and the cathode regions from the arc model in the following figure 2.

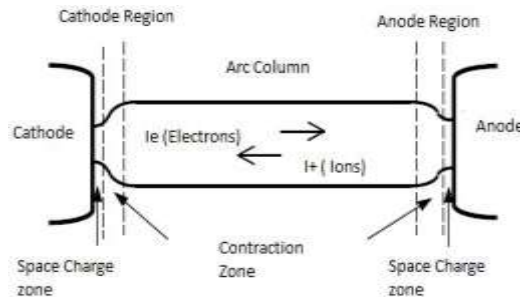


Figure 2: The arc model of arc column, a cathode, and an anode region

And hence temperature and potential gradient can be measured by this model. Below graph showing the potential gradient with the arc model between the breaker contacts.

2.2. Arc Model of cathode and anode region

A cathode made from *stubborn material* with a high boiling point starts with the emission of electrons when acute heat of temperature below the temperature of evaporation. The role of the cathode, enclosed by the cathode region, is to release the current-carrying electrons into the arc column this is called as thermionic emission. Current densities that can be gained with this type of cathode are in the order of 10000 A/cm². The cooling of the heated cathode spot is relatively slow compared with the rate of change of the transient recovery voltage, which appears across the breaker contacts after the arc has extinguished and the current has been interrupted. A cathode made from *non-refractory material* with a low boiling point, such as copper and mercury, experience significant material evaporation. These materials emit electrons at temperatures too low for thermionic emission and the emission of electrons is due to *field emission*. Because of the very small size of the cathode spot, cooling of the heated spot is almost simultaneous with the current decreasing to zero. The current density in the cathode region is much higher than the current density in the arc column itself. This results in a magnetic field gradient that accelerates the gas flow away from the cathode. This is called the *Maecker effect*.

2.3. Passive Or Active Function

The *passive or active is the function of the anode*. In the passive mode, the anode assists as a collector of electrons exit the arc column. In active mode the anode get already evaporates, in the anode section the iron metal vapour is to be vaporized, then it provide positive ions to the arc column. It provide a very high current for a active nodes and their anode spots formed ions distribute to the plasma. This is an unwanted effect because these anode spots do not stop emitting ions at the current zero crossing. Their volume of warmth allow the anode adverts to evaporate anode material even when the power input is nothing and thus can affect the vacuum arc not to extinguish. After the separation of contact when the arc burns, evaporation of contact material is the main source of charged particles. When the contact remoteness increases, the evaporation of contact material remainder the main source of charged particles for the vacuum arcs. For high-pressure arcs burning in air, oil, or SF₆, the effect of evaporation of contact material develops minimal with increasing contact separation, and the plasma depends mainly on the surrounding medium.

III. PROPOSED SYSTEM

3. ELECTRIC ARC INTTRUPTION METHODS

Operation of circuit breakers is generally based on the modification of the arc plasma conductivity, mainly by means of temperature control. Thus, interruption of the circulating current is based on arc cooling. In case of AC, the current passes through zero every half cycle, so the aim is to modify quickly the arc conductivity in the vicinity of the zero current. In contrast, DC current does not change its polarity, so it must be forced to zero.

3.1. Dc Interruption

When the contacts start to separate, the current does not disappear instantaneously but it keeps flowing through the arc established between contacts. As it has been said, DC current interruption has the disadvantage that there is no natural zero current, so it has to be forced to zero.

3.2. Arc Interruption

The interruption of AC currents is facilitated by their zero crossing, twice per cycle, being only necessary to prevent the resignation of the arc after the zero crossing of the current. If the circuit breaker is able to separate the contacts at the moment of zero current and does it with such a high speed that voltage between contacts cannot bridge the gap between them, the circuit is interrupted.

VI. METHODOLOGY

4.1. Black Box Models

In recorder models outline the interaction between the arc and therefore the electrical device behaviour of the arc and not however the interruption method develops. Several of those models are supported the equations projected by Cassie and Mayr, that represent the variation within the electrical phenomenon of the arc by an equation obtained from physical issues and implementation of simplifications . On this fashion, Mayr assumed that the arc has mounted cross-sectional space losing energy solely by radial thermal conductivity. In distinction, Cassie assumed that the arc incorporates a mounted temperature being cooled by forced convection therefore, "black box" models are generally portrayed by one equation relating the arc electrical phenomenon with magnitudes like voltage and arc current .

$$1/G \frac{dG}{dt} = 1/T(i, G) \cdot u_i / (P(i, G)) - 1 \quad (1)$$

Where:

G: Arc electrical phenomenon u: Arc voltage

i: Arc current

P, T: Parameters of the model

P and T parameters are calculated thus on acquire an honest correlation between calculated results and people obtained by testing. The models differ within the kind of useful dependence of model parameters and the way they're determined. Most of those models haven't any physical justification. the elemental purpose of "black box" model is to get a mathematical model that represents the fuse check and may be applied in predicting the behaviour of the fuse underneath totally different conditions .In different cases, like within the insulator region of breakdown processes, these models don't seem to be directly applicable. Throughout the present interruption method.

The aim of this section is to show some examples of different simulations, for "black box" models. Regarding "black box" models, a significant example is the Arc Model Blockset [4].

The Arc Model Blockset is a library that currently contains seven arc models to be used in combination with the *Matlab* Power System Blockset. In this application, the arc is represented as a non-linear resistance, mathematically defined by a differential equation whose purpose is to the study of arc circuit interaction. In particular, the arc models incorporated in the Arc Model Blockset are: Cassie, Habedank, KEMA, Mayr, Modified Mayr, Schavemaker and Schwarz.

V. ARC INTRUPTION THEORY

Over the years many researchers have advanced a variety of theories. Some of the very important theories are:

- Cassie's Theory
- Mayr's Theory

Cassie's Theory- The Cassie's theory is also called Energy balance theory. Cassie recommended that the restitution of arc or interruptions of an arc both are energy balance method. If the energy continues to increase the arc, this arc restrikes and if not, arc will interrupted. Theory makes the following assumptions.

Arc consists of a cylindrical column having uniform temperature at its cross section. The power dissipation was assumed to be blast arc and was represented by following differential equation (2)

$$R \frac{d}{dt} (1/R) = 1/\theta [(V/V_0)^2 - 1] \quad (2)$$

The energy distributed in the column is uniform. The temperature remains constant. The cross section of the arc adjusts itself to accommodate the arc current. Power degeneracy is comparative to cross sectional area of arc column interruption Theories Cassie arc model was presented by Cassie in 1939. Cassie supposed that the arc has a fixed

temperature being cooled by forced convection. This indicates that the cross-section area of the arc is proportional to the current and that the voltage over the arc is constant. This model is appropriate for arcs with high magnitude of currents.

$$\frac{1}{g} * \frac{dg}{dt} = \frac{d \ln g}{dt} = \frac{1}{\tau} * \left(\frac{u^2}{U_c^2} - 1 \right)$$

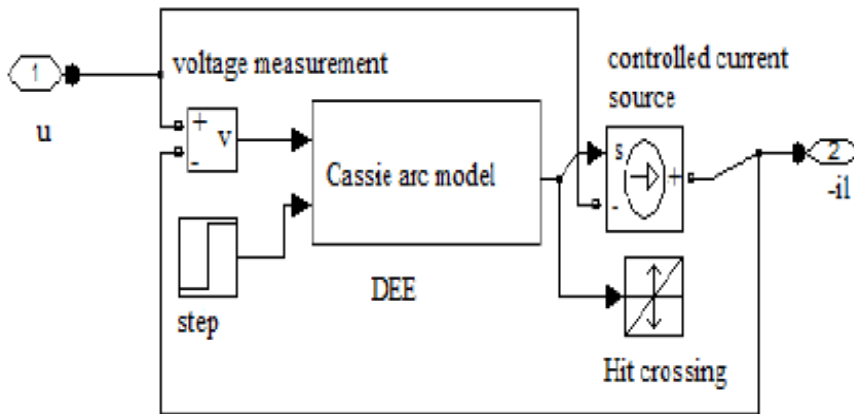


Figure 4. Cassie's arc model

Mayr's Theory-Mayr arc model was introduced in 1943. Mayr assumed that power losses are caused by thermal conduction and the arc conductance is dependent on temperature. The cross-section area of the arc is assumed constant. Mayr arc model is fit for currents near zero. Schwarz developed a modified Mayr arc model in 1971. The time constant and the cooling power in the model are dependent on the arc conductance. This model was described by differential equation (3).

$$Rd/dt(1/R) = 1/\theta\{(V_i/W_0)^2 - 1\} \quad (3)$$

Where i is the arc current at any instant and W_0 is the energy loss from periphery of the arc at steady state. The arc models have been modeled as voltage controlled sources and the differential equation representing the electric arc is combined by means of the simulink Differential Equation Editor. The arc models can be implemented in a circuit in a straight forward way.

$$\frac{1}{g} * \frac{dg}{dt} = \frac{d \ln g}{dt} = \frac{1}{\tau} * \left(\frac{ui}{P} - 1 \right)$$

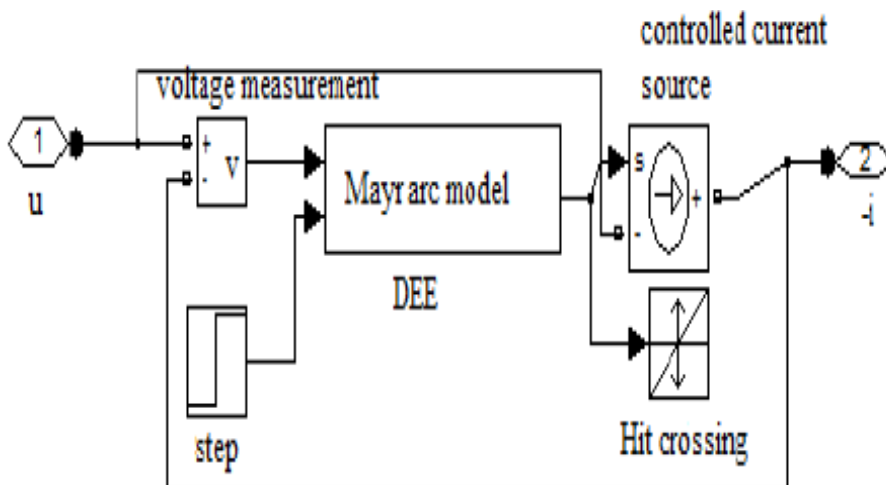


Figure 5. Mayr's arc model

VI. Combination of Cassie-Mary Arc Model

Two identical circuits are displayed: one with a Cassie and one with a Mayr arc model. The circuit is a simple representation of a circuit breaker interrupting short-line fault.

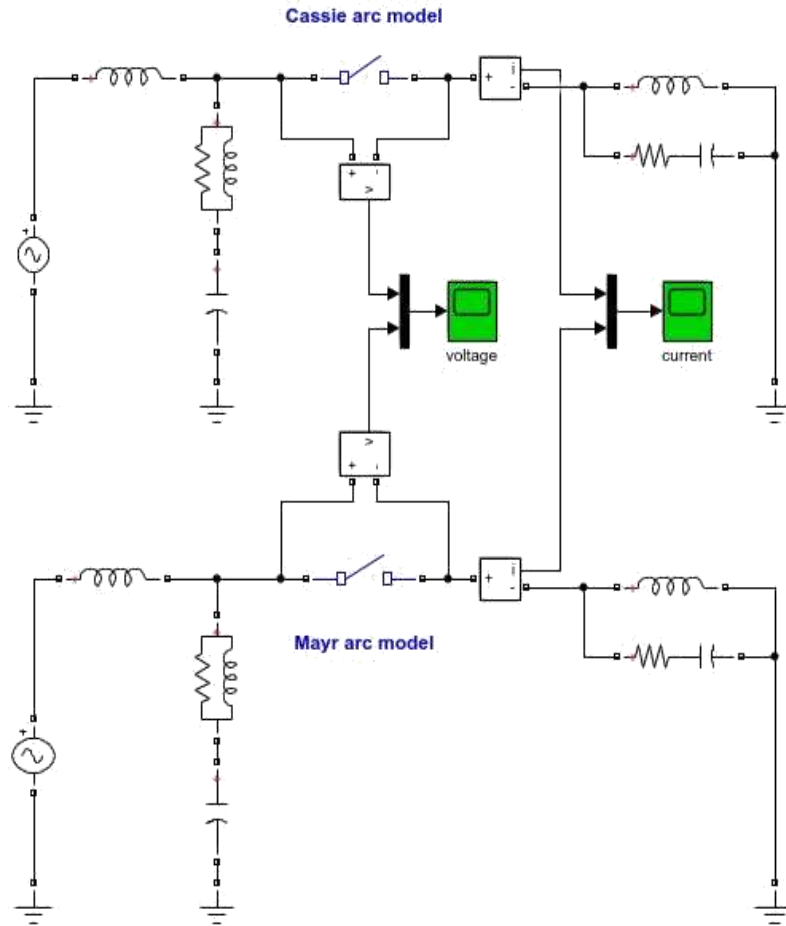


Figure 6. Combination of Cassie-Mayr arc model

VII. RESULTS

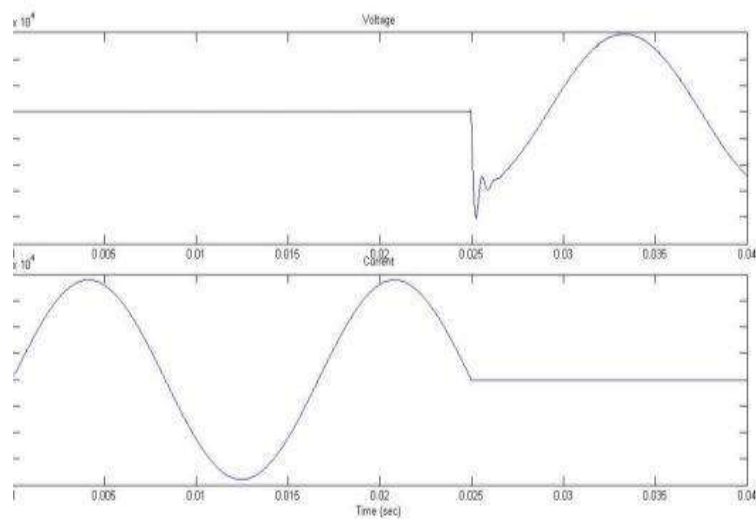


Figure 7. Voltage and Current waveform of Mayr's arc model

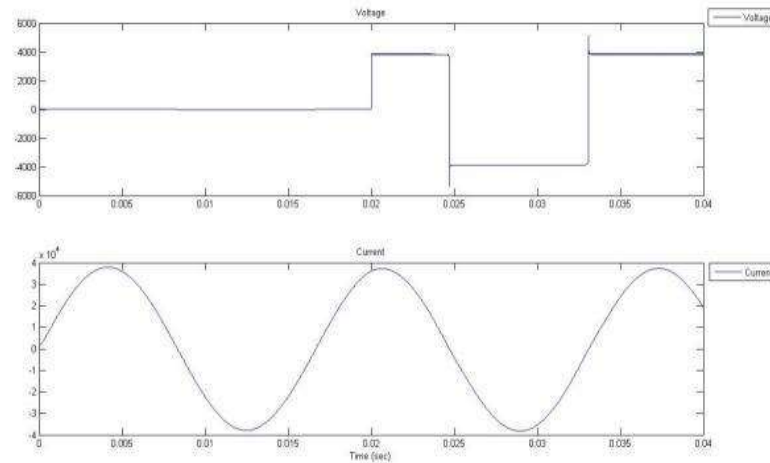


Figure 8. Voltage and Current waveform of Cassie arc Model

CONCLUSION

Cassie-Mayr arc model has been studied and implemented as a black-box model in MATLAB/SIMULINK. The electric arc is an important phenomenon which determines the operation of high voltage circuit breakers. The use of modeling and simulation tools can help to improve these devices, reducing the need of prototype development and testing. The simulation produced current and voltage waveform are very useful for studying complex current interrupting process in the circuit breakers without considering the underlying complex physical phenomenon

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