COMPARISON OF PROPOSED ARC MODEL FOR POWER CIRCUIT BREAKERS AGAINST THE CASSIE MAYR'S MODELS

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ABSTRACT

This paper address the possibility of designing and describes a comparison between Mayr's and Cassie's arc models and proposed model during contact separation of circuit breaker by using Matlab Simulink. This design of the propose model has been simulated in MATLAB Simulink. The design of proposed model successfully made. Through the simulation made, simulation results of several contact separation time, arc voltage, time interval of arc and post arc current zero was determine. This result found and compare to the Mayr's and Cassie arc model. This project it is a successful because if compared to exist model, the results approximately close from the proposed arc model.

Keywords:
Circuit-breaker model, Arc Model, Mayr's arc , Cassie's arc

1.0 INTRODUCTION

1.1 Objective

The objective of this project is to model and simulate the SF_6 circuit breaker arc behavior using Matlab simulink and compare it with classical arc model of Cassie and Mayr's. Research is conducted to determine the best parameter of the purposed model of SF_6 circuit breaker arc behavior. From the simulation can give result either purpose model is the similar to the well known classical arc model of Cassie and Mayr's.

1.2 Scope of Work

This project involves the study on contact separation of circuit breaker especially SF_6 circuit breaker, the arc principle, behavior and black box arc model equation. The black box arc model is Cassie and Mayr's. This project will design the purposed model of arc of SF_6 circuit breaker using Matlab Simulink. The purposed model of arc of SF_6 circuit breaker result will compare with clasical arc model Cassie and Mayr's.

2.0 LITERATURE REVIEWS

2.1 Historical Overview

The history of circuit breaker modeling goes back many years. Back around 1900 static models were used that described the arc as a resistance which is an algebraic function of some parameters. An example arc voltage equation introduced by Ayrton are shown below,[9]

$$Va = A + Bd + (C + Dd)/Ia \qquad \textit{Equation (1)}$$

where: Va = arc voltage,
Ia = arc current,
d = arc length,
and A, B, C and D constants.

For copper contacts in air the constants are ; A = 19 [V]; B = 11,4 [V/m]; C = 21,4 [VA]; D = 3 [VA/m].The electric arc is the switching element in a high-voltage circuit breaker. Arc interruption is a very complex process. The earliest attempts to develop theories about arc interruption in air and oil as extinguishing medium are from

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Slepian (1928) and Prince (1931). While the first models describing the conductivity of the electric arc were developed by Cassie (1939) and Mayr's (1943). Since Cassie and Mayr's model introduced their differential equation for describing the dynamic arc behavior, other models have been developed, such as the Adnonin model, Hochrainer Model,Urbanek Model and KEMA Model, which are capable of simulating thermal breakdown of the arc channel.

2. 2 Power Circuit Breaker

Power circuit breaker is a manual or automatically-operated electrical switch designed to protect an electrical circuit from damage caused by overload short circuit breaker. The function of circuit breaker is to control electrical power network by switching on, by carrying load and switching circuit off under manual or automatic supervision. The circuit breaker contacts must carry the load current without excessive heating, and must also withstand the heat of the arc produced when interrupting the circuit .When a current is interrupted in the circuit breaker, an arc is generated.

2.3 Description of Switch Arc

The electric arc in a circuit breaker is a major rule in the interruption process and it's addressed as switching arc. The electric arc is a plasma channel between the breaker contacts formed after a gas discharge in the extinguish medium. This is the scenario of interruption, just before contact separation, the breaker contacts touch each other at a very small surface area and resulting high current density makes material to melt.

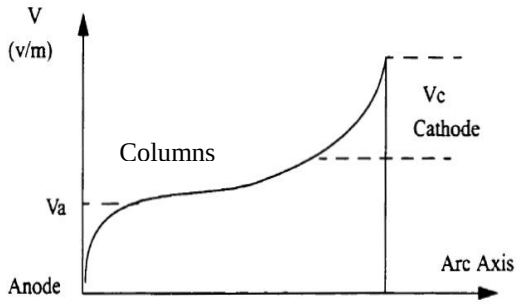

Figure 1:Typical potential distribution along an arc channel

The melting material virtually explodes and this leads to gas discharge in the surrounding medium such as air, oil or SF_6 .The arc can be generally divided into three regions: the column region, the cathode region and the anode region. Figure 1 shows the distribution of the potential along the axis of the arc.

2.3 Black Box Model

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. Arc modeling can be classified in three categories:[1]

i. Black Box Models
ii. Physical Model
iii. Parameter Models

The most common arc modeling uses black box model, also called and measurable parameter, such as arc voltage and arc current. The arc model used consists basically of a series association of Cassie and Mayr,s models [2]. The arc conductance can be calculated as:

$$\frac{1}{g} = \frac{1}{g_m} + \frac{1}{g_c} \qquad \textit{Equation (2)}$$

$$\frac{dg_c}{dt} = \frac{g_c}{\theta_c}\left[\left(\frac{u_a}{U_o}\right)^2 - 1\right] \quad \textit{Equation (3)}$$

Mayr's Model

$$\frac{dg_m}{dt} = \frac{g_m}{\theta_m}\left(\frac{u_a.i_a}{P_o} - 1\right)$$

Equation (4)

Cassie Model

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where,

g_m arc conductance — Mayr model

g_c arc conductance — Cassie model

U_a arc voltage

i_a arc current

U_o arc voltage constant

P_o power less constant

θ_c thermal constant Cassie model

θ_m thermal constant Mayr model

3.0 METHODOLOGY

3.1 Arc Model Computations

\The arc models can be implemented in a circuit in a straightforward way from the Matlab simulink demo . An circuit containing an arc model is shown in Figure 3.1

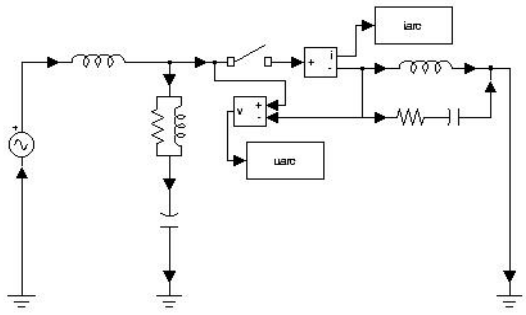

figure 3.1: Circuit Containing an Arc Model

The parameter was taken in using Cassie and Mayr's arc model to simulate arc of SF_6 circuit breaker. The SF6 circuit breaker parameters can be set by means of the following dialog. Figure 3.3 showed Cassie arc model block parameter and Figure 3.4 showed Mayr's arc model block parameter.

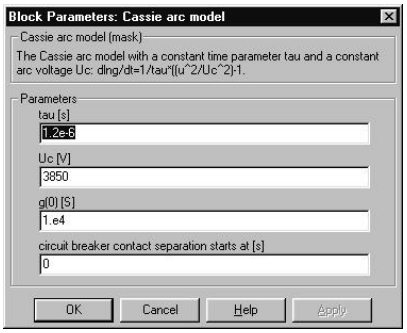

Figure 3.2 : Cassie arc model block parameter

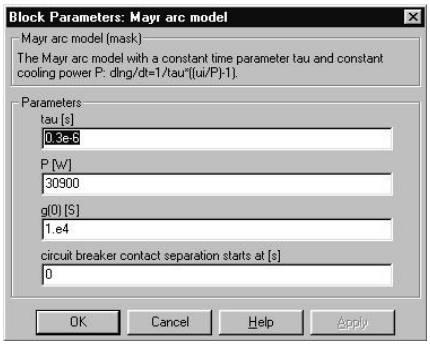

Figure 3.4 : Mayr's arc model block parameter.

The initial conductance of the arc $g(0)$ can be altered. Furthermore, the time at which the contact separation of the circuit breaker takes place can be specified. Until that time the arc model behaves as a conductance with the value $g(0)$. The SF_6 circuit breaker parameters showed in Table 3.1.

Table 3.1: SF_6 circuit breaker parameters

Parameter of SF_6 circuit breaker	Values (Cassie arc model)	Values (Mayr's arc model)
arc time constant (τ [s])	1.5 µ	1.5 µ
constant arc voltage (Uć[V])	3850	-
cooling power (P[W])	-	4M
arc conductance (g(o)[s])	10 K	10 K

3.2 Simulation Work

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For propose model, first step, design the circuit to produce the arc. Figure 3.1 is the model of arc.

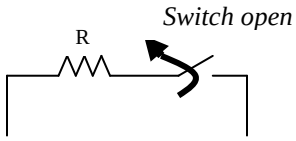

Figure 3.1: Model of arc

To simulate switch open, ideal switch been used, the ideal switch used to switch on and off the circuit. The Timer block is used to generates a signal changing at specified transition times. It is use this block to generate a logic signal (0 or 1) and control the opening and closing times of Ideal Switch block. Lastly the model of arc and the lumped model circuit breaker in are combined in figure 3.2, the circuit is known as proposed model.

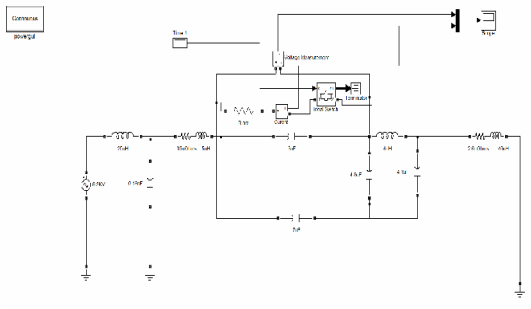

Figure 3.2: Purposed arc Model

The model of classical arc model Cassie and Mayr's was taken in Matlab Simulink demo and do some little modification in order to show voltage and current together . Figure 3.4 show the Cassie arc model and Figure 3.3 show Mayr's arc Model .

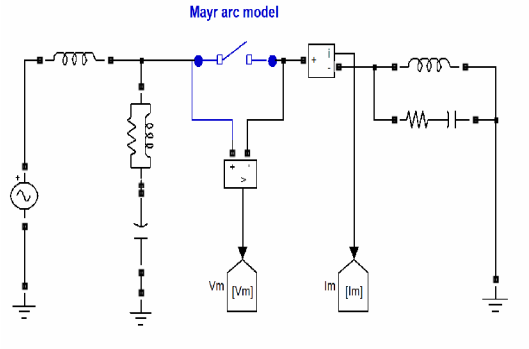

figure 3.3: Mayr arc model

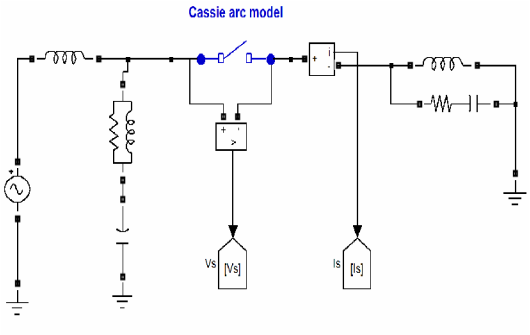

Figure 3.4: Cassie arc Model

The parameter was taken in using Cassie-Mayr arc model to simulate arc of SF_6 circuit breaker. The contact separation time of circuit breaker was simulate in order to determine the arc voltage, time interval and post arc current zero. The separation time of 0.0001second, 0.001 second and 0.01 second was chose. The result of simulating arc voltage and time interval of Cassie Mayr model was compared to the proposed model.

4.0 RESULT AND DISCUSSION

4.1 Simulation Comparison

The simulation was employed using three different types of arc model and with three contact separation time. Simulation results are presented in MATLAB.

i. Separation Contact Time, t= 0.0001 second

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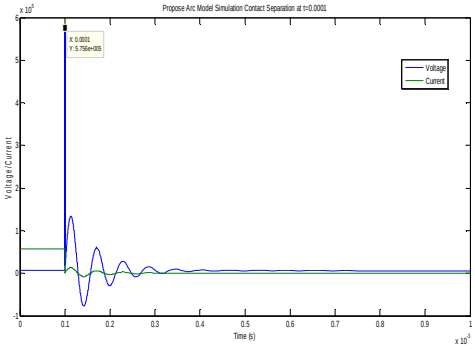

Figure 4.1 Arc behavior of proposed arc model for first simulation

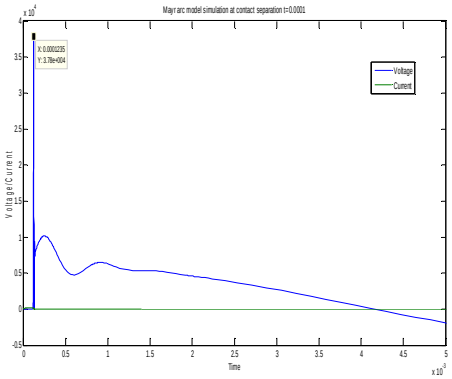

Figure 4.2 Arc behavior of Mayr's arc model for first simulation

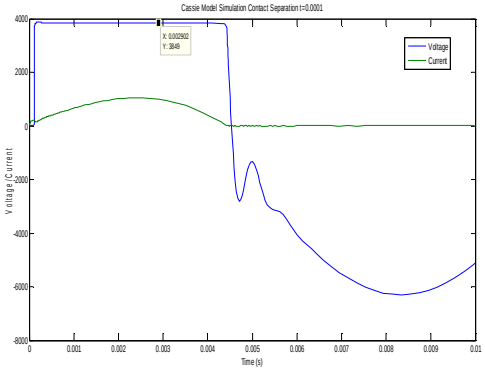

Figure 4.3 Arc behavior of Cassie arc model for first simulation

ii. Separation Contact Time, t= 0.001 second

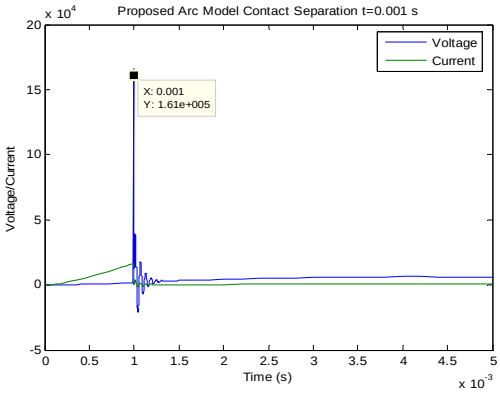

Figure 4.4 Arc behavior of proposed arc model for second simulation

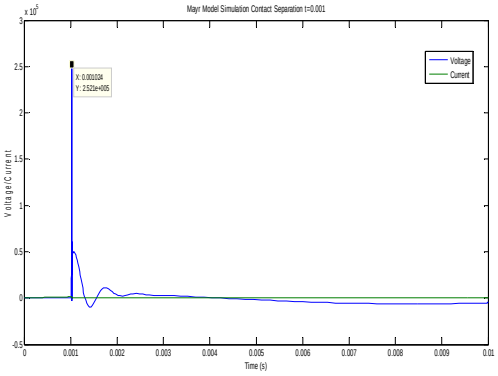

Figure 4.5 Arc behavior of Mayr's arc model for second simulation

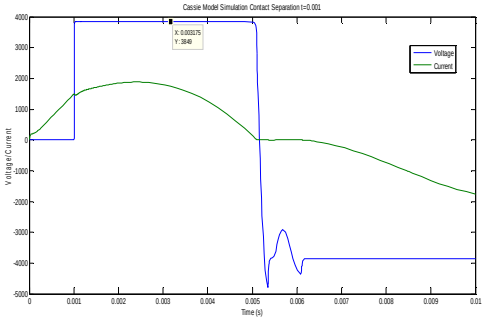

Figure 4.6 Arc behavior of Cassie arc model for second simulation

iii. Separation Contact time, t=0.01 second

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Arc Behaviors	Proposed Arc Model	Mayr's Arc Model	Cassie Arc Model
Over Voltage (V) (+Cycle)	540 kV	37.4 kV	-
Over Voltage (V) (-Cycle)	690kV	0 V	-
Post Arc Current Zero (A)	130 A	104 A	-
Time Interval of Arc (s)	0.19 ms	1.1 ms	-
Voltage arc (V)	-	-	3850V

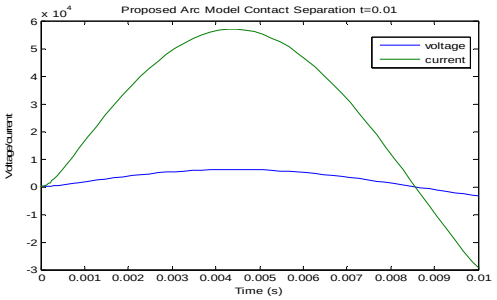

Figure 4.7 Arc behavior of proposed arc model for third simulation

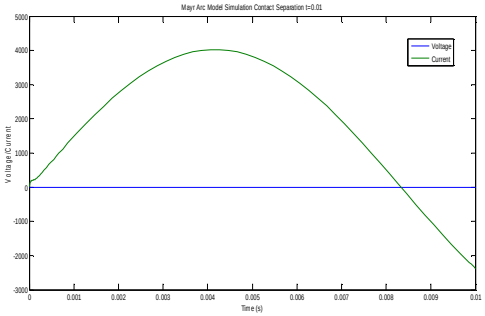

Figure 4.8 Arc behavior of Mayr's arc model for third simulation

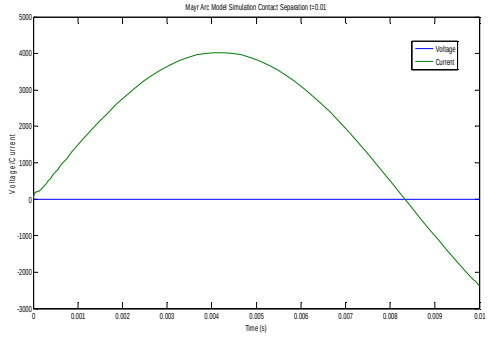

Figure 4.9 Arc behavior of Cassie arc model for third simulation

Based on the result, propose model successfully interrupted at the separation contact time at 0.0001s and 0.001s while t=0.01s, it's failed to interrupt. The Mayr's arc model also successfully interrupted at the opening operation time 0.0001s, 0.001s while t=0.01s failed to interrupt, mean while the Cassie arc model fail to interrupt in any separation time. In theory, Cassie model can interrupt in very high current. In my observation, arc diameters decreased not constantly, but irregularly, toward current zero. The rate of decrease of the arc diameters depends opening operation time of circuit breaker. The result show in table 4.1and table 4.2

Table 4.1:Simulation Result the separation contact time t=0.0001s

Table 4.2 :Simulation Result the separation contact time t=0.001s

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Arc Behaviors	Proposed Arc Model	Mayr's Arc Model	Cassie Arc Model
OverVoltage (V) (+Cycle)	161 kV	24.7 kV	-
Over Voltage (V) (-Cycle)	20.3kV	8.72 kV	-
Post Arc Current Zero (A)	295A	126 A	-
Time Interval of Arc (s)	0.24 ms	1.3 ms	-
Voltage arc (V)	-	-	3850V

5.0 CONCLUSION AND FUTURE DEVELOPMENT

To date, most arc models focus on describing certain aspects of the arc phenomena and the energy conservation during the circuit breaker arcing period. When the ideal switch is used to model the SF6, simulation results cannot reflect the actual transient phenomena of the energy interaction occurred between the circuit breaker contacts and the connected network. The objective of this project is to proposed circuit and technique to produce arc in the circuit breaker, unfortunately real data is not available and thus comparison against the model could not be made. In this paper proposed arc is physical model while Mayr's and Cassie arc model is black box model. Black box model is more accurate than physical model. For future development, this proposed arc can be improved and able to determine arc voltage and from arc voltage it's can find the power of arc. Investigate the arc models behavior after current zero more thoroughly and arc conductance should also been considered in future development.

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