Report – PSCAD component “Breaker Arc”

Breaker Arc

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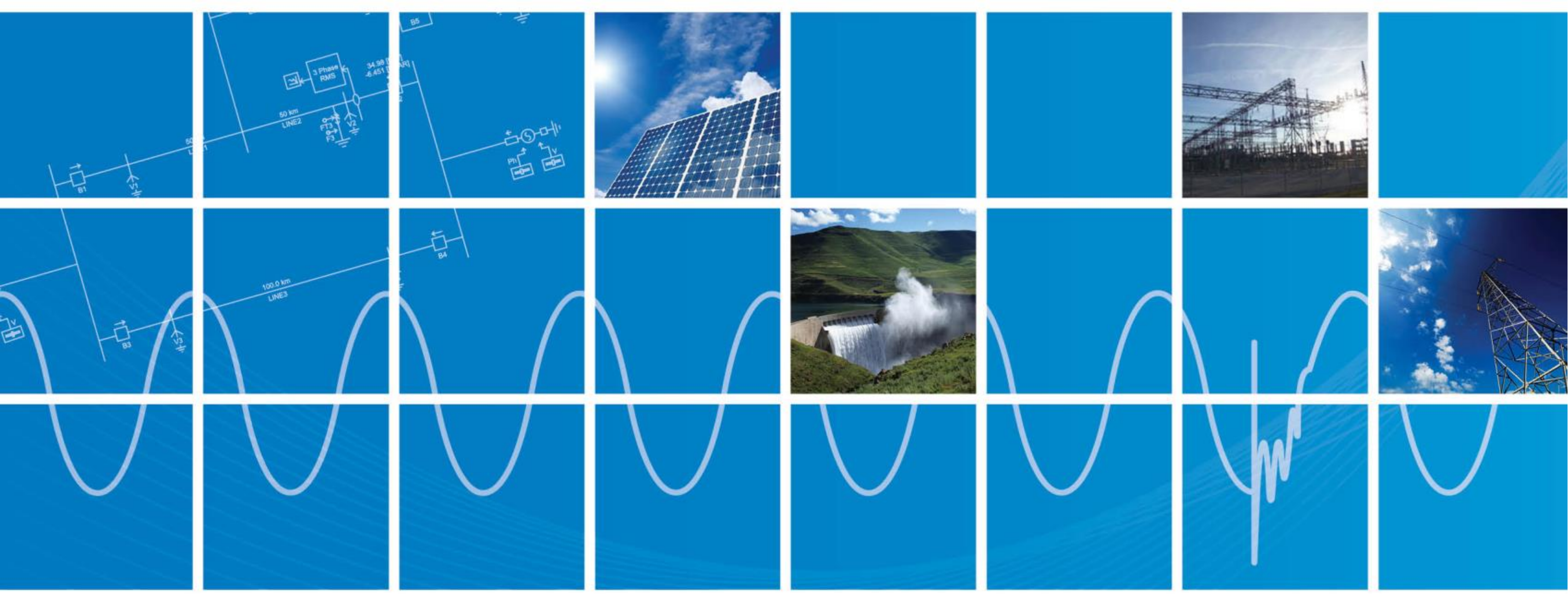

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1. Introduction

This report presents the study of the PSCAD component “Breaker Arc”.

For the analysis of simple switching transients and for carrying out large system studies, it is often sufficient to model a circuit breaker as an ideal switch. When studying arc–circuit interaction, the influence of the electric arc on the system elements is of importance [1].

The arc forms when the breaker contacts part. The physical phenomena of arc extinguish/reignition are complex. Breaker arc model can be classified as three categories based on different viewpoints and concerns:

1. Thermal and dielectric recovery models that describe the arc dynamical behavior considering the impact of different interrupter parameters such as nozzle size and geometry, type of quenching medium and speed of flow, pressure.
2. Parameter models are based on empirical form(s).
3. Models concerns with the arc-circuit interaction characteristics.

For the purpose of the simulation in the PSCAD, the arc-circuit interaction is of most concern. In this report several such models are introduced and the corresponding examples demonstrate arc-circuit characteristics such as arc extinction, arc reignition and post arc current.

This report is organized as following sections:

1. The introduction of the current interruption and the arc models.
2. Descriptions of the arc components in the PSCAD.
3. The examples to demonstrate the arc-circuit interaction.

1.1 The Switching Arc

Current interruption of a circuit breaker occurs normally at current zero within a time frame of microseconds. The arc is resistive and therefore the arc voltage across the contacts and the current reach the zero crossing at the same instant. Whether the interruption successes mainly depend on the energy fed into the arc channel which keep the arc hot, and the cooling power which quenches arc. After the current interruption (temporally due to the zero crossing), the still- hot gas between the breaker contacts is stressed by the transient recovery voltage (TRV) and in the resulting electric field the present charged particles start to drift and cause a hardly measurable so-called post-arc current. The post-arc current, together with the transient recovery voltage, results in energy input in the still-hot gas channel. When the energy input is large enough, the arc is created again and current interruption has failed. This is called a thermal breakdown of the circuit breaker. When the current interruption is successful, the hot gas channel cools down and the post-arc current disappears; still a dielectric failure can occur if the dielectric strength of the gap between the breaker contacts is not sufficient to withstand the transient recovery voltage [1]

2.2 Breaker Arc Modelling

The arc phenomena are associated with fluid dynamics, thermodynamics and electromagnetic dynamics. Precise modeling is complex and unnecessary for those who only concern the arc- circuit interaction in power network studies.

The classical arc-circuit models are Cassie model and Mayr model. In these models the arc behavior is mainly associated with the variation of the arc conductance. The arc conductance is a function of the power supplied to the plasma channel, the power transported from the plasma channel by cooling and radiation and time:

In the cassie model, the arc conductance is represented by:

$$\frac{1}{g_c}\frac{dg_c}{dt} = \frac{1}{\tau_c}\left(\frac{{u_{arc}}^2}{{u_c}^2} - 1\right) \qquad (1)$$

Where:
g_c: the arc conductance
r_c: the arc time constant
u_{arc}: the arc voltage across the breaker

The Cassie model is well suited for studying the behaviour of the arc conductance in the high-current time interval when the plasma temperature is 8000 K or more.

In the Mayr model, the arc conductance is represented by:

$$\frac{1}{g_m}\frac{dg_m}{dt} = \frac{1}{\tau_m}\left(\frac{u_{arc}.i_{arc}}{P_0} - 1\right) \qquad (2)$$

Where:
g_m: the arc conductance
r_m: the arc time constant
P_O: the cooling power constant
u_{arc}: the arc voltage across the breaker
i_{arc}: the arc current

The Mayr model is suited for modelling of the arc in the vicinity of current zero when the temperature of the plasma is below 8000 K.

There are other models which take advantage of Cassie and Mayr models, representing the arc conductance combining and refining the two equations [2].

2. Breaker arc components in PSCAD

This component is designed to simulate the arc behavior during the breaker open operation.

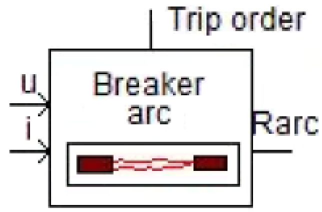

Figure 1 the "Breaker arc" component

Figure 1 shows the component "breaker arc". There are three input and one output signals:

"u" represents the voltage across the breaker, i.e., the arc voltage.

"i" is the breaker current- the arc current.

"Trip order" usually comes from "timed breaker logic". When the breaker is at close status, it is 0. The model outputs a small resistance (typically 1.0e-6Ω) to represent the close resistance of the breaker. Once the signal turns to 1 (breaker contacts start to open), the arc resistance calculation starts.

"Rarc" outputs a value calculated by specified arc model in the component. This value is used by a variable resistor to represents the breaker arc resistance.

There are three types of arc model: Mayr, Cassie and Schavemaker model.

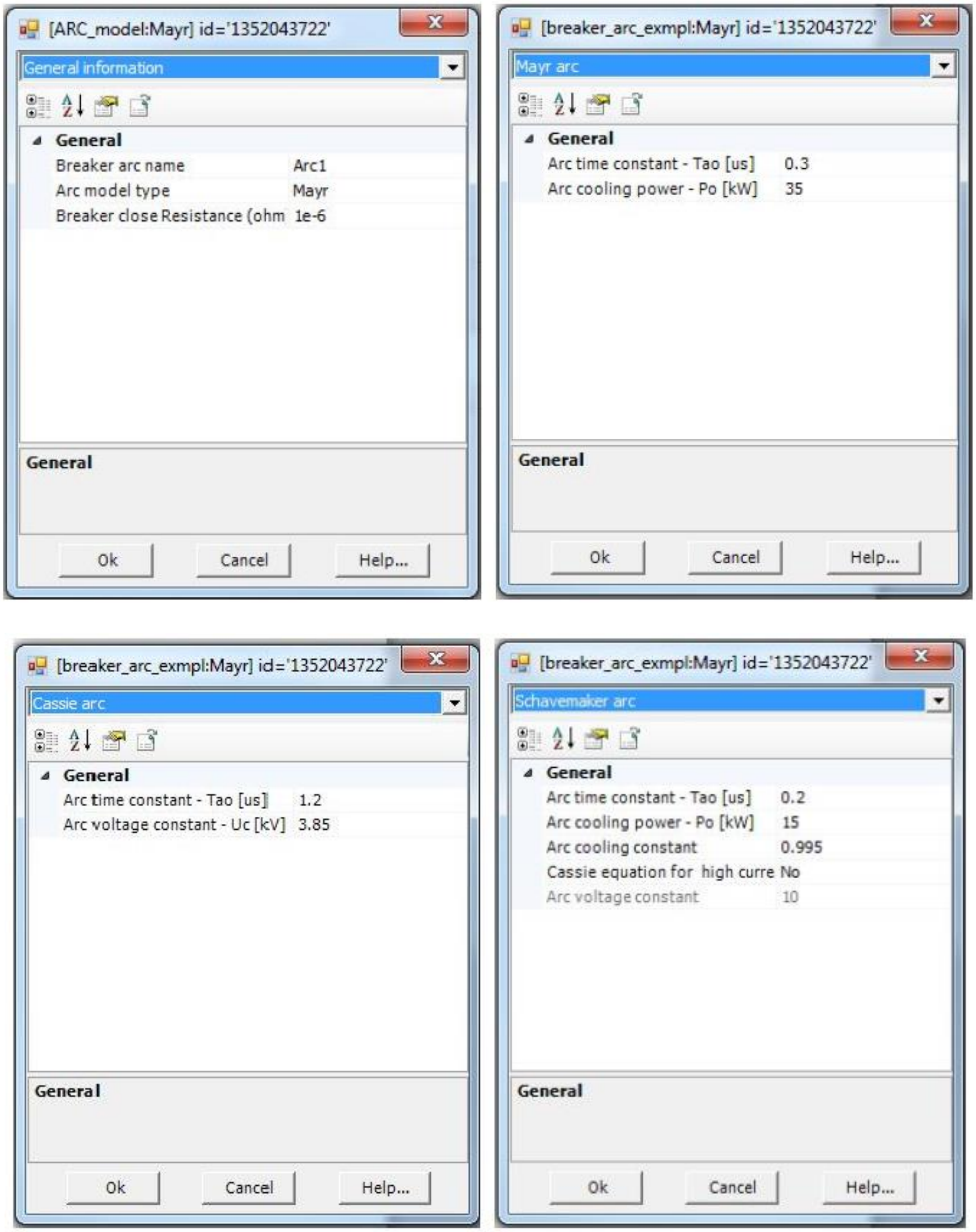

Figure 2 "breaker arc" input parameters

Input parameters:

General information

Breaker arc name	text	the name of the breaker name.
Arc model type	choice	Mayr, Cassie or Schavemaker arc model.
Breaker close Resistance	real	the resistance when the breaker closed (ohm).
Mayr arc		
Arc time constant – Tao	real	the arc time constant (us)
Arc cooling power – Po	real	the arc cooling power(kW)
Cassie arc		
Arc time constant – Tao	real	the arc time constant (us)
Arc cooling power – Po	real	the arc cooling power(kW)
Schavemaker arc		
Arc time constant – Tao	real	the arc time constant (us)
Arc cooling power – Po	real	the arc cooling power(kW)
Arc cooling constant	real	
Cassie equation for high current area	choice	Yes or No chose Cassie model in the high current area
Arc voltage constant	real	the arc voltage constant (kV) when the Cassie model is chosen in the high current area

3. Examples for arc model application

To examine whether the "breaker" works correctly and to better understand its setting (arc time constant Tao, cooling power constant Po and other parameters), an example is created in PSCAD.

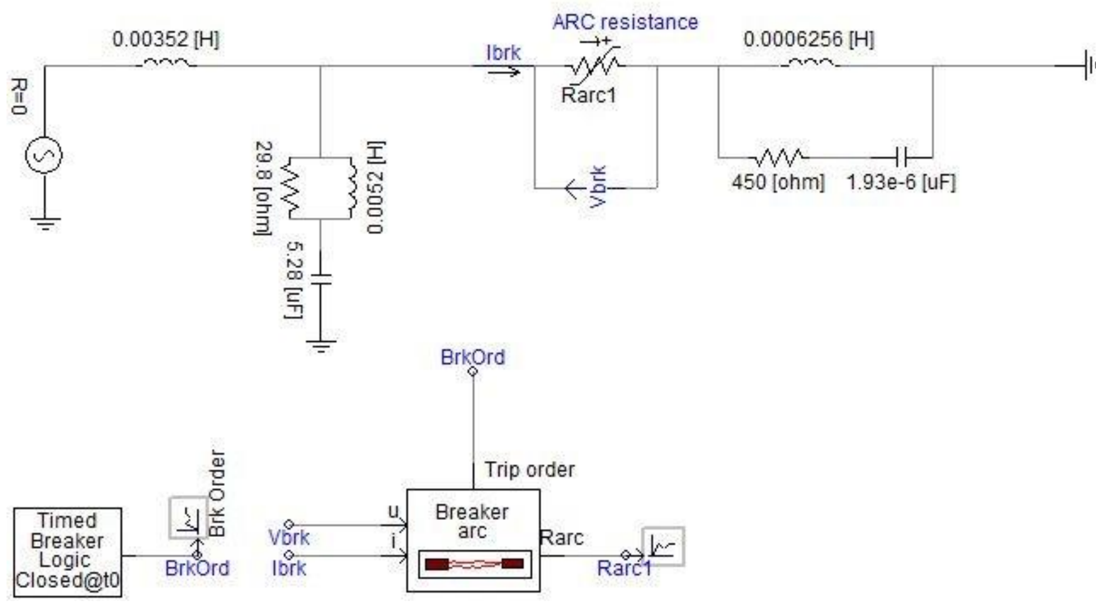

Figure 3 validation of "breaker arc"

See *Figure 3*, the test circuit refers the "arc model blockset" in MATLAB Simulink. The breaker is represented by a variable resistor. The resistance value is output by the breaker arc component "Breaker arc". At the source side of the circuit breaker a circuit is present for reproducing a (2-parameter IEC) transient recovery voltage, while the RLC circuit at the line side represents a short transmission line that is short circuited.

The simulation results with different models are shown in *Figure 4- Figure 8 the arc voltage and post arc current of the Schavemaker arc model* (details see PSCAD example 'breaker_arc.pscx').

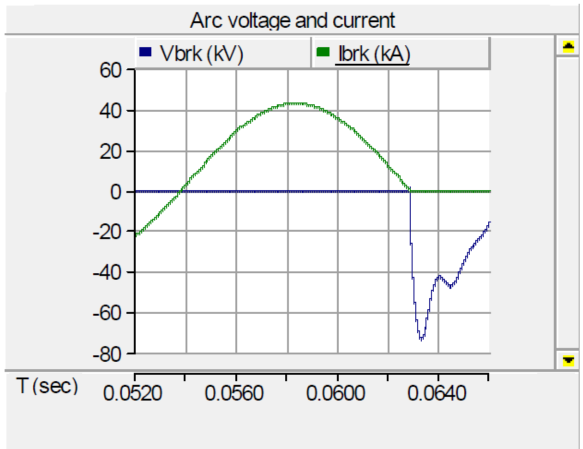

Figure 4 the arc voltage and current of the Mayr arc model

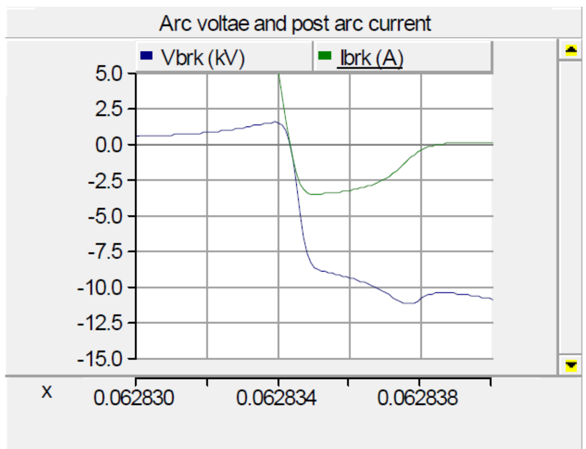

Figure 5 the arc voltage and post arc current of the Mayr arc model

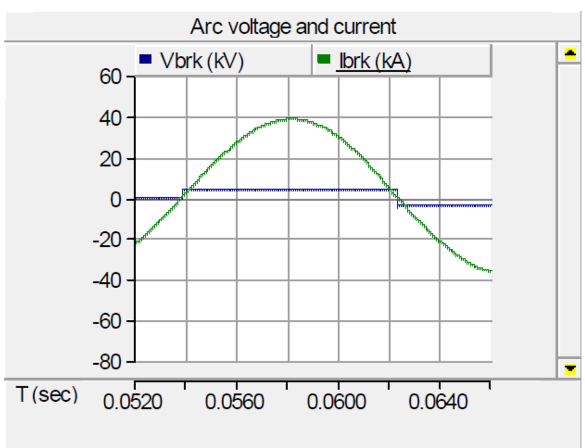

Figure 6 the arc voltage and current of the Cassie arc model

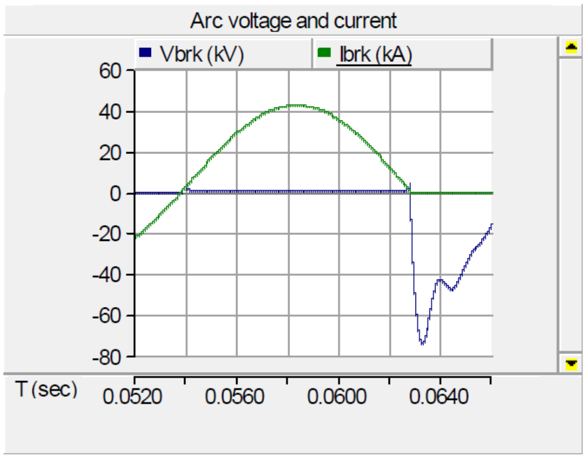

Figure 7 the arc voltage and current of the Schavemaker arc model

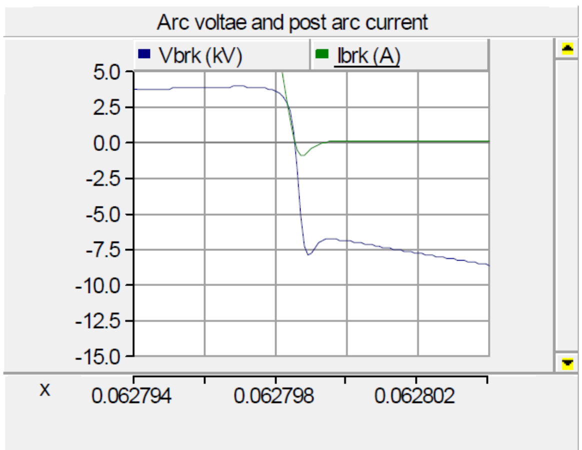

Figure 8 the arc voltage and post arc current of the Schavemaker arc model

4. Conclusions

The “breaker arc” component demonstrates the impacts of different arc models on the arc behavior:

1. The Mayr type (including Schavemaker model) describes the arc characteristic during current zero-cross, they can be used for arc-circuit interaction study.
2. The Cassie model represents the arc characteristic in high current area. It cannot be used to study the arc behavior during current zero cross period.
3. The post arc current observed using Mayr type model is caused by the TRV and the non-infinite resistance at the instance of current zero cross.
4. The TRV oscillation frequency depends on the LC parameters of source side circuit.

5. References

1. L. van derSluis, Transients in Power Systems, John Wiley & Sons, 2001.
2. P. H. Schavemaker and L. Sluis, “An Improved Mayr-Type Arc Model Based on Current- Zero Measurements”, IEEE Trans. Power delivery, vol. 15, no. 2,pp.580-584, April 2000.

Appendix

Case1: "breaker_arc_exmpl.pscx"

This case examines the breaker arc behavior of the "breaker arc" component.

The circuit of the example is shown in *Figure 9.*

The settings for different arc models are shown in *Figure 10*.

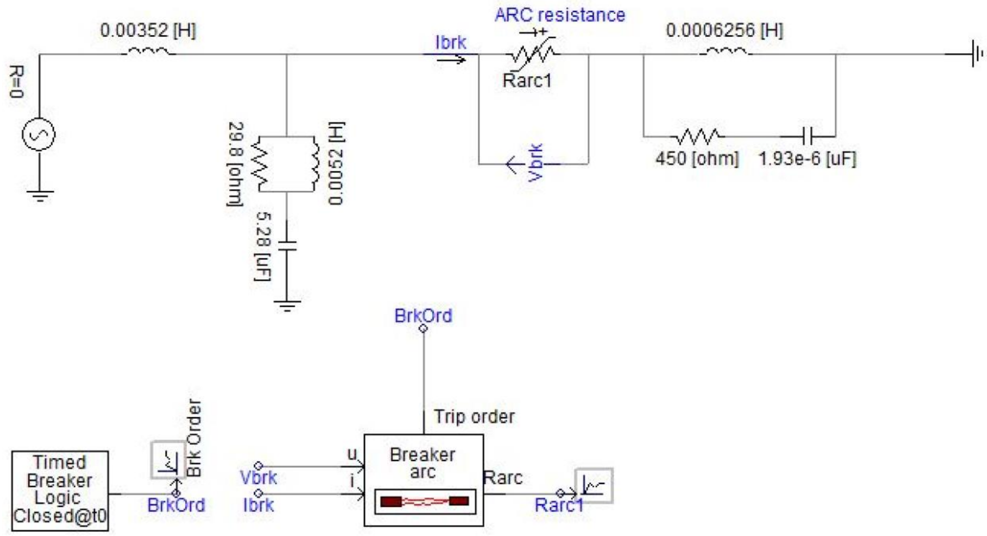

Figure 9 the circuit of "breaker_arc_exmpl.pscx"

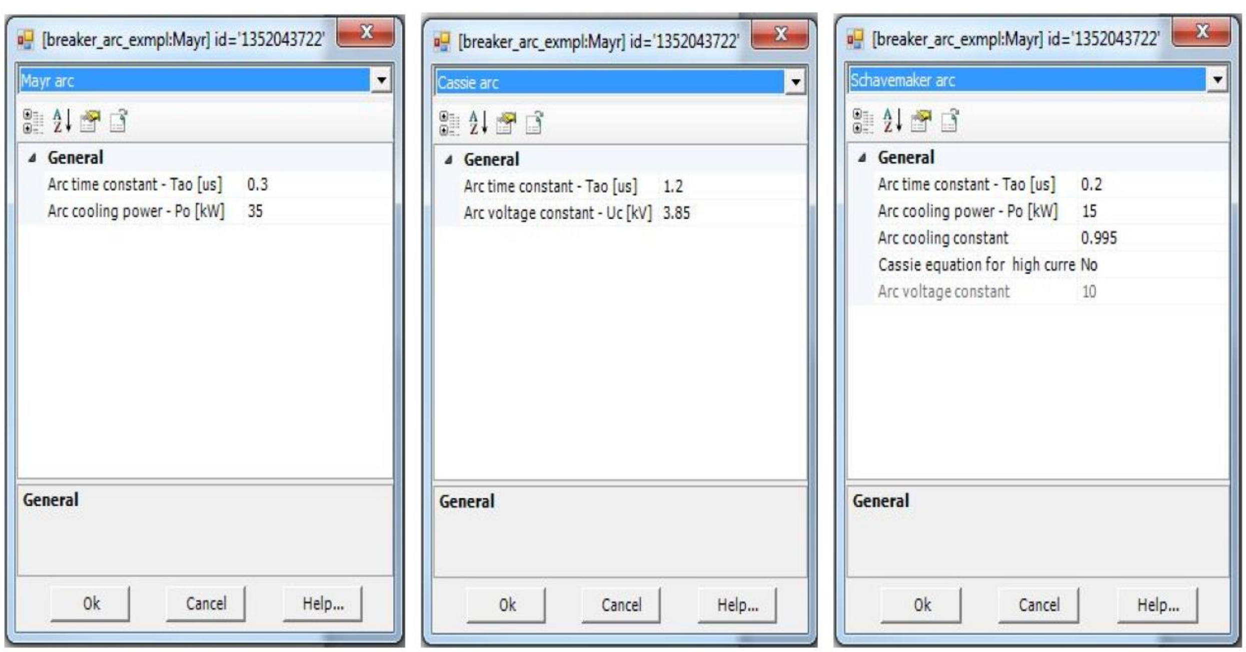

Figure 10 the settings of different arc models in "breaker_arc_exmpl.pscx"

DOCUMENT TRACKING

Rev.	Description	Date
0	First Issue Report	21/Jan/2013
1	Second Issue Report	21/Jun/2016
2	Update to the new Branding Guidelines	20/Sep/2018