ISSN 2349-7815

International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)
Vol. 3, Issue 2, pp: (46-52), Month: April 2016 - June 2016, Available at: www.paperpublications.org

Study of Secondary Arc Current Suppression Effects under Different Fault Location on Extra High Voltage Line

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Abstract: **Overhead transmission lines are an essential component of power systems, being the most economical means of transmitting electricity from remote sources of generation to the customer. It is therefore, vital that they be protected and maintained in service to ensure the security of the supply to the end-user, and to protect the capital investment of the power companies. When single phase grounding fault occurs in high voltage transmission line, secondary arc current and recovery voltage must be suppressed in order to ensure that single phase auto-reclosing operates reliably and successfully. Automatic single phase reclosing is used to clear single-phase-to-ground-faults, which are 80% of the transient faults. In order to have successful fast reclosing, different methods are used to extinguish the arc. One of the common methods is to use a single-phase reactor in the neutral of shunt reactor, when the transmission line is compensated with shunt reactors. In this paper, exact arc modeling is used for transient simulation of neutral reactor and guidelines for selecting the appropriate amount for the neutral reactor are proposed, then uses MATLAB software to simulate suppression effect about different fault point locations towards an example of 735 KV double ended sources high voltage transmission line. According to the simulation results, suppression effects about different locations are distinct.**

Keywords: **High voltage transmission, single phase auto reclosing, secondary arc current, shunt reactor, neutral small reactor.**

1. INTRODUCTION

There are two main types of arcs appearing on power systems: arcs in open air, such as those found on transmission lines, and constrained switching arcs, such as those found in circuit breakers. The work in this thesis will be concentrated on arcs in open air.

Arcing faults on transmission lines can be divided into two separate periods: the primary arc and the secondary arc. Soon after the fault, the two line end breakers will open (faulted phase only in this case) to isolate the fault. However, the other line(healthy phases) are still energized. There is inductive and capacitive coupling between the faulted line and the healthy phases, as well as between other conductors of parallel circuits.

2. GENERATION THEORY OF SECONDARY ARC CURRENT

Secondary arc is an electromagnetic transient phenomenon generated in the process of single-phase autoreclosing operation. In figure 1 when the single phase (i.e. phase C) to ground fault occurs, the breaker at both ends of the fault phase will be tripping and short circuit current which is provided with power system from both ends to the fault point will be cut off. But this time the sound phases (phase A and B) are still running. There are loads current (Ia, Ib) flows through and two phases still keep working voltages(Ea, Eb). Due to the function of inter-phase capacitance Cm and mutual inductance M, the secondary current Ic is generated at the fault point Q and it contains two parts : capacitive component and inductive component.

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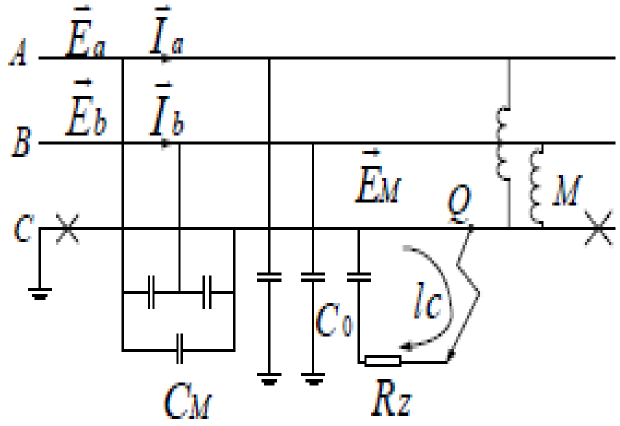

Fig 1: single phase to ground fault and generation of Secondary Arc Current

3. METHODS OF SECONDARY ARC CURRENT EXTINCTION

Nowadays there are two main suppression measures applied for secondary arc extinction, first Shunt reactor with neutral small reactor and second is High speed grounding switches. These methods are used for suppress secondary arc current by reducing its amplitude and shortening its burning time. In Japan HSGS method is used because EHV lines are short and the lines are not transposed, so it is not practical to use shunt reactor. Whereas Shunt reactor with neutral small reactors have been widely used in many counties as well as in INDIA.

(1) Shunt Reactor

When transmission line is energized, large charging current can be generated by shunt capacitance which exists between each phases of line and between phase conductors and ground [7]. Due to charging current, Ferranti phenomena, the voltage of receiving end can be greater than that of sending end, can occur. To prevent Ferranti phenomena and compensate the line, shunt reactor is used with transmission line.

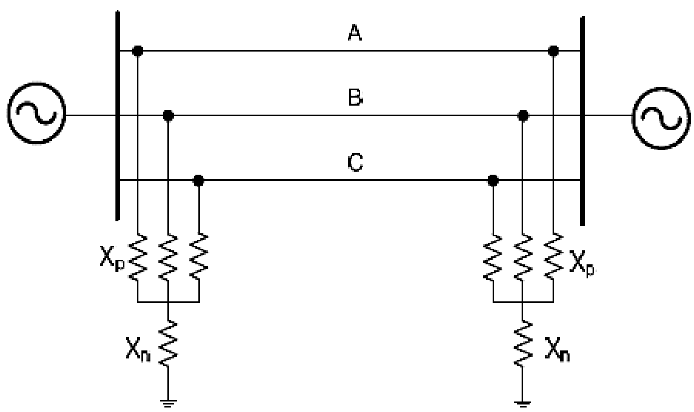

Figure 2: Transmission Line with Shunt Reactor

As shown in Fig shunt reactors are connected to both ends of transmission line in parallel. When single phase to ground fault occurs, shunt reactors can compensate voltage to line by providing lagging current. The reactor bank extinguishes secondary arc by neutralizing the secondary arc current. In compensation scheme, compensation degree an important factor because the capacity of reactor is decided by compensation degree.

(2) High Speed Grounding Switches:

HSGS can extinguish the secondary arc rapidly by using the grounding switch that has smaller impedance than that of secondary arc path. However, HSGS has a disadvantage in cost aspects [9]. HSGS are installed at both ends of the UHV transmission line shown in Figure1.17.

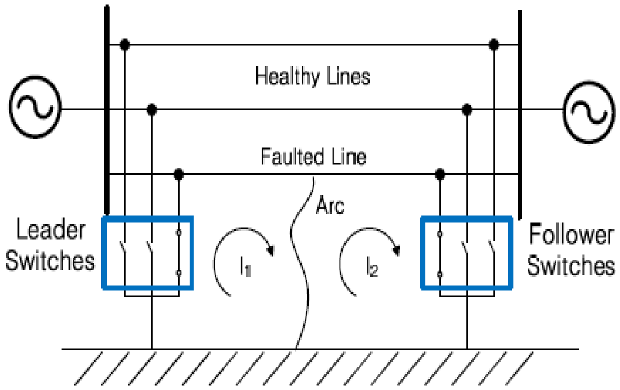

Fig 3: Transmission Line with HSGS

When single phase to ground fault occurs, HSGS grounds the fault phase and provides new path that arc current flows. The operating sequence of HSGS is as follow:

1) Single phase to ground fault is occurred and primary arc is generated.
2) Circuit breakers of fault phase are tripped and secondary arc is generated.
3) Leader switch of HSGS closes, and then closed loop is formed through the arc path and electromagnetic induction current (I1) flows in that path.
4) Follower switch of HSGS closes, and then another closed loop that electromagnetic induction current (I2) flows in is formed.
5) HSGS are opened.
6) Circuit breakers are closed to recover the line.

4. ANALYSIS RESULT

Impact of change of Fault Location on secondary arc:

As the fault point varies from the beginning to the end of **line,** the final steady value of secondary arc current reduces at first and then increases after the middle. It is clearly that when the fault occurs at two ends of line, the suppression effect is a little worse. When the fault point locates in the middle of line, the effect reaches the best.

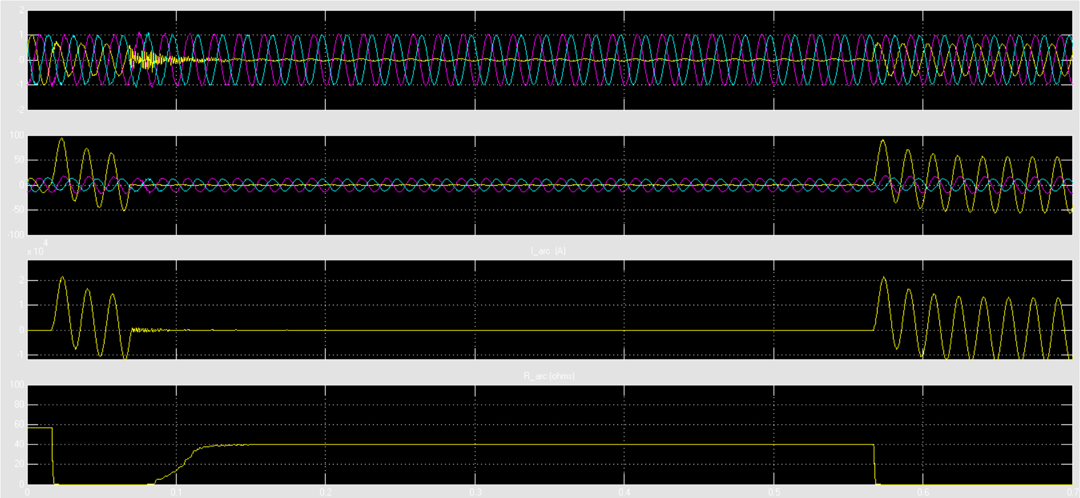

Fig 4: Waveform when Shunt Reactor is not connected

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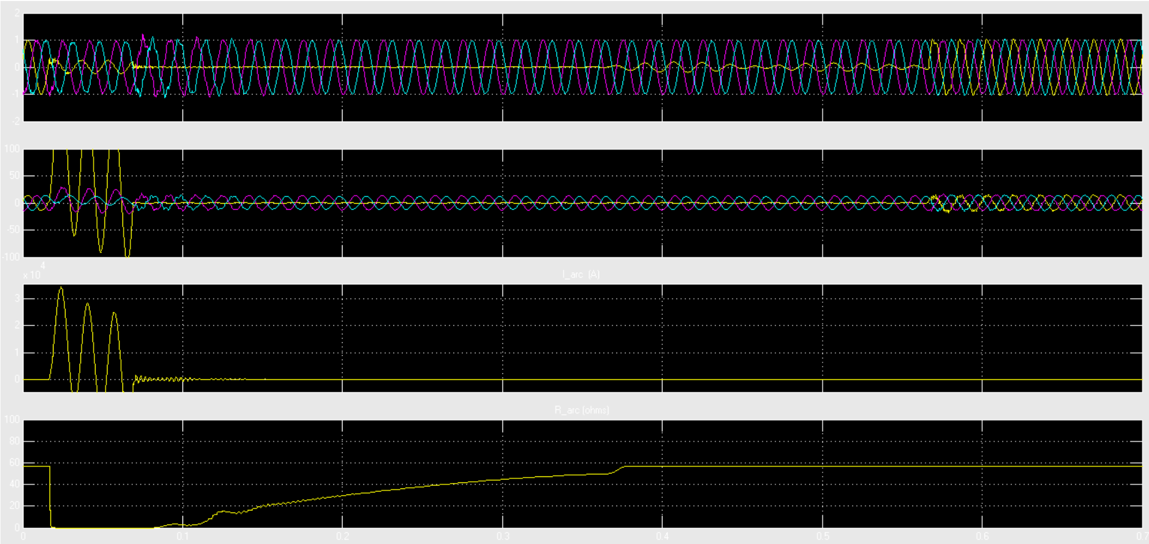

Fig 5: Waveform when fault location 15 km from point A

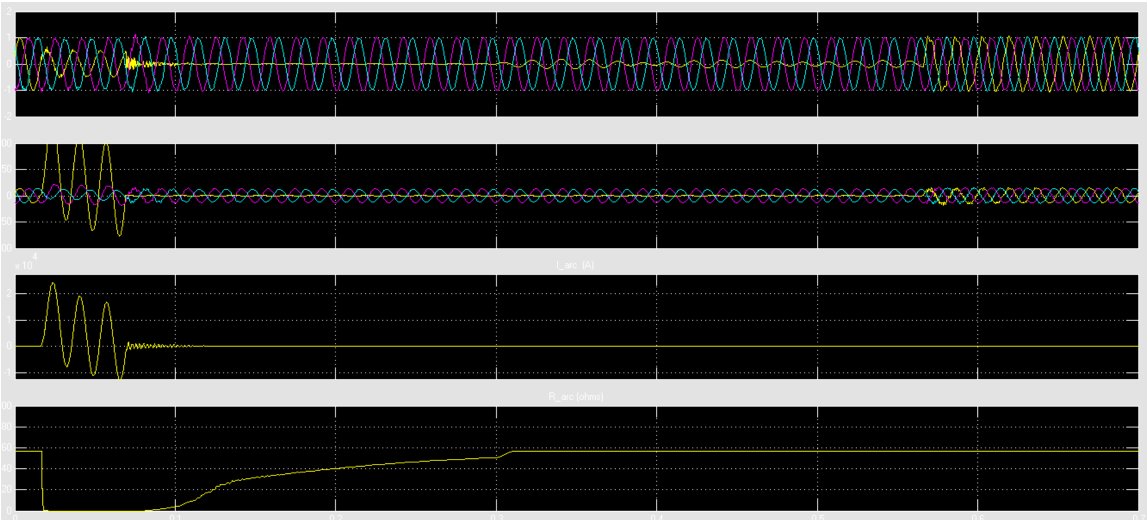

Fig 6: Waveform when fault location at 50 km from point A

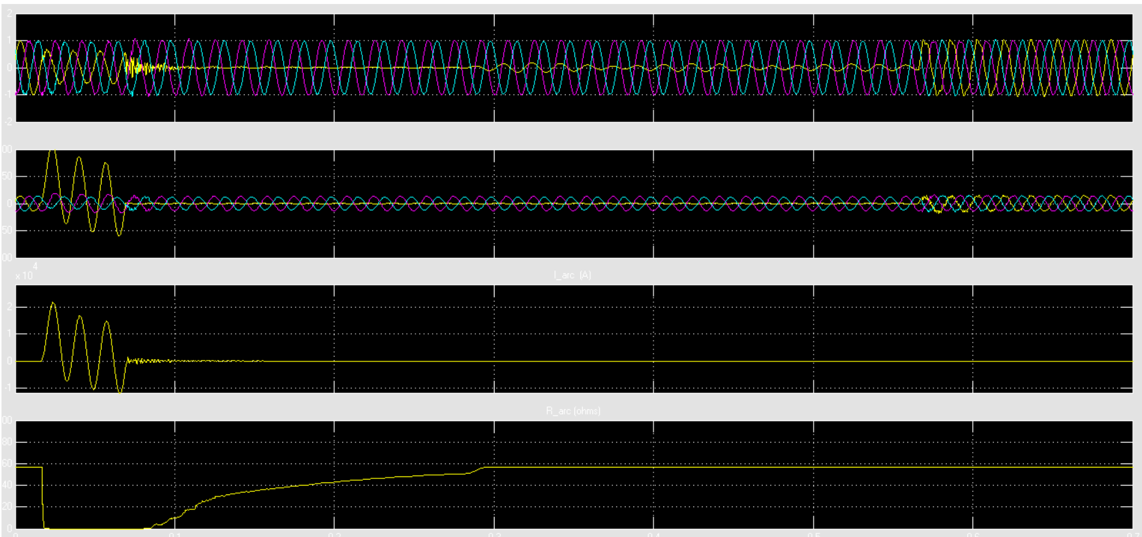

Fig 7: Waveform when fault location at 80 km from point A

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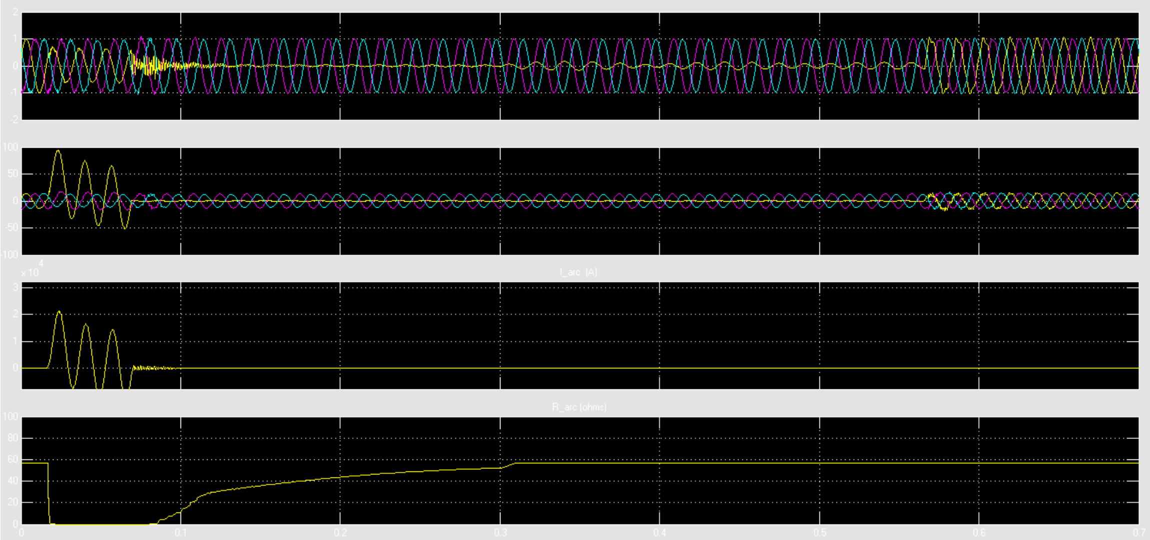

Fig 8: Waveform when fault location at 100 km from point A

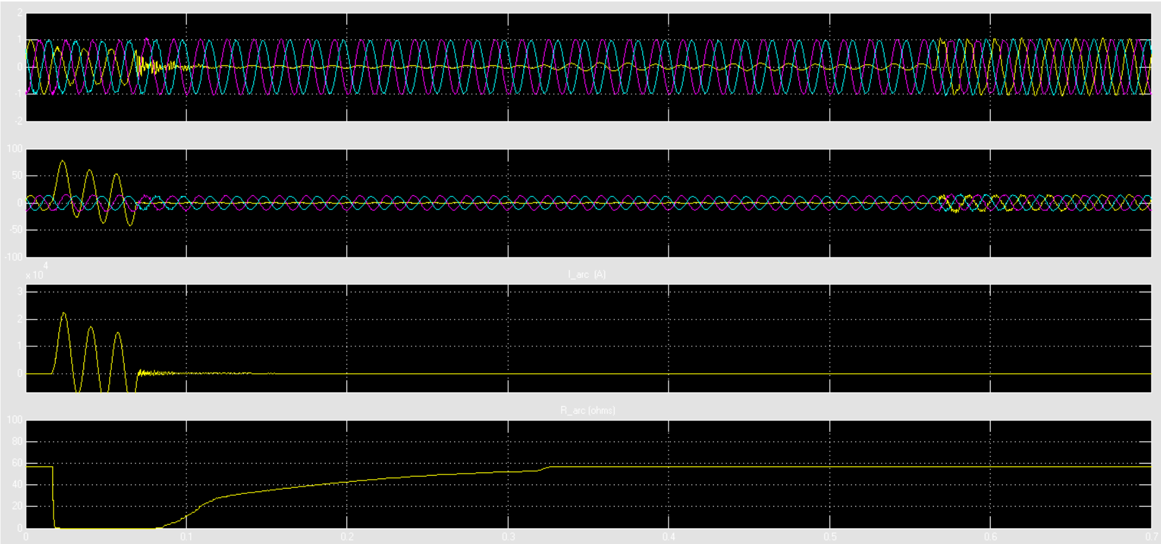

Fig 9: Waveform when fault location at 130 km from point A

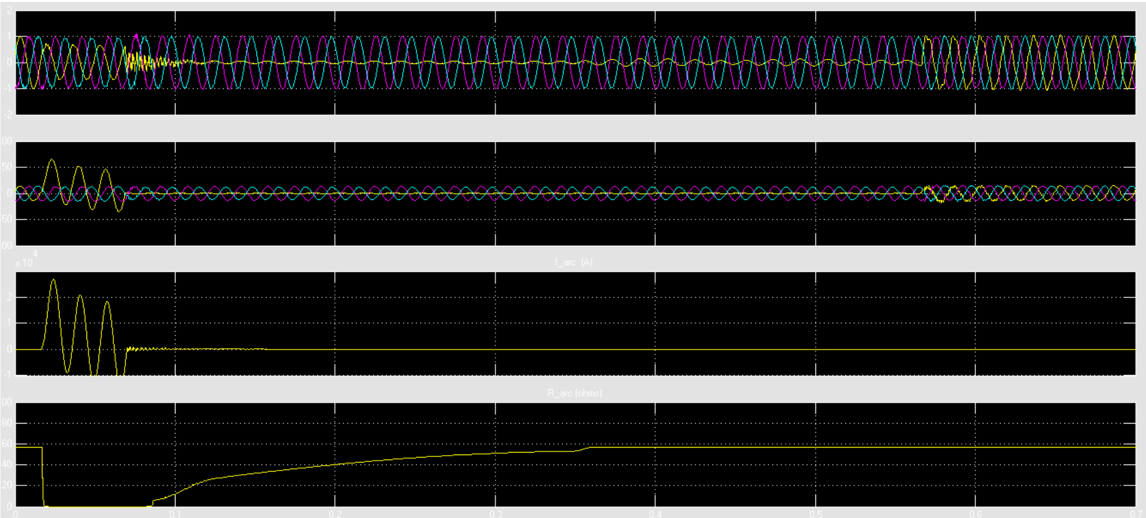

Fig 10: Waveform when fault location at 160 km from point A

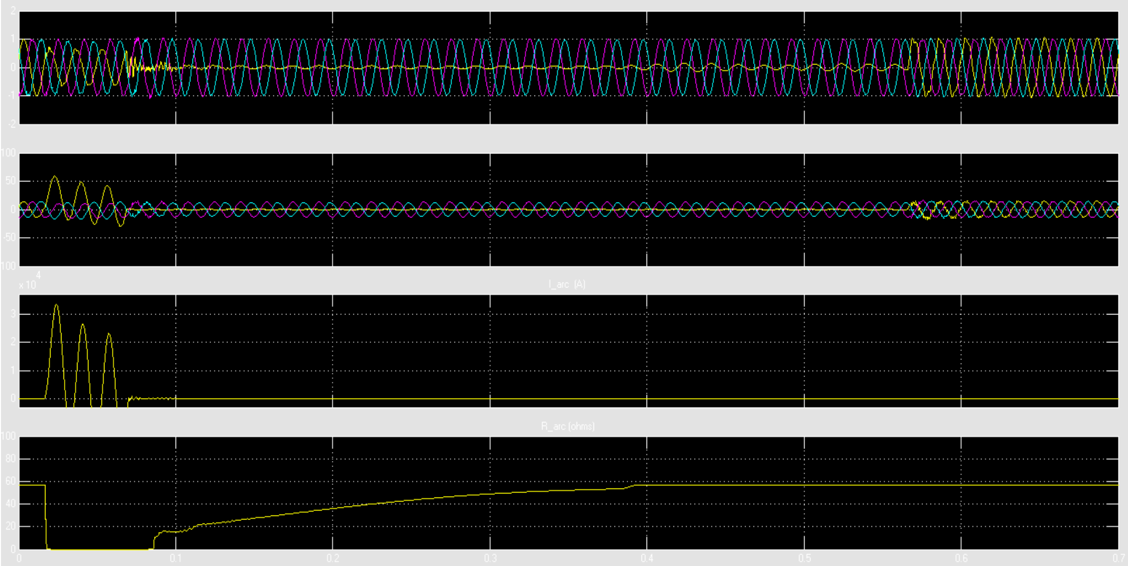

Fig 11: Waveform when fault location at 180 km from point A

Secondary arc current values for different fault locations

Fault location from end A Distance (km)	15	50	80	100	130	160	180
Secondary arc current first peak Current (kA)	35	25	22	21	23	27	33

5. CONCLUSION

This work studies the suppression theory of shunt reactor with neutral small reactor towards secondary arc current, uses MATLAB SIMULATION software to simulate the different suppression effects of varying locations and at different phase angle, finally gets conclusion. Due to highly random and complex behavior of secondary arc it is very difficult to reproduce the exact arc duration by digital simulation. First, the simulation model of secondary arc is established by MATLAB Simulink software. Then faulted phase voltage and secondary arc are simulated in different close angle. However the model elaborated in this work can be employed successfully to examine the performance of arc suppression scheme in auto reclosure study. According to the simulation results, the suppression effects at different locations are different. Moreover this measure can suppress secondary arc current effectively. It ensures success of single phase auto reclosing operation and finally achieve security and stability of power system.

This system can be considered very efficient, because in this system secondary arc current gets suppressed in very short time. This time is very less as compared to other system. So the protection scheme can be considered as much as faster.

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