A New Fault Location Algorithm for Series Compensated Lines Using Synchronized Phasor Measurements

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Abstract: In this paper, a novel fault location algorithm based on phasor measurement units (PMUs) for series compensated lines has been proposed Traditionally, the voltage drop of series device has always been predicted by the device model in the fault locator of series compensated lines, but some of the errors are induced from the inaccuracy of the series device model or from the uncertainty of the protection function of series device. The proposed algorithm does not need the series device model and information of the protection function of series device to predict the voltage drop. Instead, two iteration steps, pre-location step and correction step, are used in the proposed algorithm to calculate the voltage drop and fault location. Thus, the more accurate fault location for series compensated lines can be achieved. The proposed technique can be easily applied to any series FACTS system. The accuracy of the fault location algorithm is tested by the EMTP generated data with respect to a 300km 345 kV transmission line under different fault locations, fault resistances and fault inception angles. The results show the high accuracy up to 99 5%.

Keywords: series compensation, synchronized phasor measurement units, FACTS.

I. INTRODUCTION

In the last two decades, the power electronic applications to AC power systems have provided many benefits. Applying series compensation in power systems can increase power transfer capability, improve transient stability and damp power oscillations. However, since the variation of series compensation voltage remains uncertain during the fault period, the protection of power systems with series compensated lines is considered as one of the most difficult tasks and is an important subject of investigation for relay manufacturers and utility engineers.

Series compensated systems can be mainly catalogued into switched capacitors (SCs) systems and thyristor controlled switched capacitors (TCSCs) [2,3] systems. Typically, the main problem in designing series capacitors protection systems is over-voltage protection of the capacitor itself. Since the nonlinear devices of MOV [1] and TCR incorporate with their protection function [4] introduce in series compensation devices, the voltage drop of the series device is not easily calculated. Recently, some studies associated with the analysis of simplified series device models have been proposed in [5-7] and all produce satisfactory results. However, these algorithms must consider the model of series device to compute voltage drop and the model considered in those papers are simplified. Thus, the accuracy of those papers is limited.

The synchronized PMUs based fault detector/locator technique has been proven effective for fault relaying of transmission line without series compensation device [8-10]. However, when the series compensation device is installed in the transmission line, the previous proposed technique [8-10] must be incorporated with the series device model to estimate voltage drop of series device in fault location computation.

This paper proposes a new approach, only considering synchronous measurement data from both ends of the transmission line, to estimate fault location of a series-compensated transmission line. The proposed algorithm excludes voltage drop calculation of the series compensation device. Instead, two-iteration step, pre-location and correction steps are used to calculate voltage drop and estimate fault location. This simplifies precise fault location estimation. Besides, since this algorithm does not use the series device mode, the proposed fault locator is easier to design and implementation.

When the series compensation device is installed in the transmission line, the fault locator must decide the correct fault side with respect to the series compensation device. In this paper, a skillful fault side selector is presented.

The rest of this paper is organized as follows. Section II begins by describing the theory utilized to determine the fault location of a TCSC-compensated, short single-phase transmission line, whose capacitance charging effect is ignored. The proposed fault location technique is then extended into a two-step fault location algorithm for cases involving transmission line shunt capacitors. Furthermore, this section proposes a skillful selector for selecting the correct faulted sides with respect to series compensation device. Next, Section III uses a 345 kV sample system i to evaluate the accuracy of the proposed algorithms with respect to different fault types, fault locations, and fault resistance. These simulation results come from extensive EMTP [14] tested case. Conclusions are finally made in Section IV..

II. PRINCIPLES

The proposed algorithm is derived using the following assumptions:

1. the fault impedance is pure resistance.
2. the fault type is known.

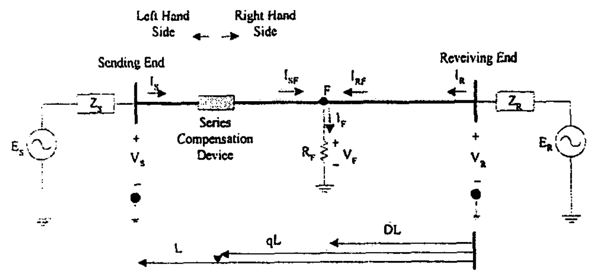
The assumptions above are common in the literature dealing with the fault location issue.

The basic principle of the proposed algorithm is first illustrated via a simple single-phase case and is then extended to the case of a three-phase transmission line with shunt capacitance.

SINGLE PHASE — Illustrative Case

To illustrate the basic idea of the proposed algorithms, this work first considers the single-phase series compensated line represented in Fig.1 It considers the line as a short distance transmission line, that is, it ignores the shunt capacitance of the line. The series compensation device is installed at a distance of q [p.u.] away from the receiving end of the considered line.

First, the fault is assumed to be located on the right side of the series compensation device. According to Fig.3, the midway fault occurs at point F which is $x = \mathbf{D}_R L$ (km) away from the receiving end R of transmission line SR. The total length of the transmission line is L kilometers, and $\mathbf{D}_R$ (p.u.) is the per unit distance from receiving end to fault location. When a fault occurs at point F, the transmission line



is divided in two line sections. One is line section SF, while the other is line section RF.

Using the assumption 1, it is easy to obtain that the phase relationship at point F can be expressed as:

$$\mathrm{Arg}(\mathbf{V_F})=\mathrm{Arg}(\mathbf{I_F}) \quad (1)$$

where the Arg(•) represents the phase angle.

Since the ground fault occurs on the right-hand side of the series compensation device, the line section RF can still be regarded as a perfect transmission line (no series device). Thus, the voltage at any point on the line section RF (including the fault end point) can be easily solved by KVL, i.e.

$$\mathbf{V_F}=\mathbf{V_R}-\mathbf{I_R D_R Z_L}=\mathrm{Re}\{\mathbf{V_F}\}+j\mathrm{Im}\{\mathbf{V_F}\} \quad (2)$$

where $\mathbf{Z_L}$ is the total impedance of the considered line, and $\mathbf{D_R}$ is the per-unit value of the fault location.

Additionally, the currents $\mathbf{I_{RF}}$ at line section FR and $\mathbf{I_{SF}}$ at line section SF also equal the currents measured on receiving and sending ends (ignored shunt capacitance), respectively. Thus, the fault current $\mathbf{I_F}=\mathbf{I_{RF}}+\mathbf{I_{SF}}$ can also be obtained as:

$$\begin{aligned}\mathbf{I_F}&=\mathbf{I_{RF}}+\mathbf{I_{SF}}\\&=\mathbf{I_S}+\mathbf{I_R}\\&=\mathrm{Re}\{\mathbf{I_F}\}+j\mathrm{Im}\{\mathbf{I_F}\}\end{aligned} \quad (3)$$

Therefore, the measured data ($\mathbf{V_S}$, $\mathbf{I_S}$) and ($\mathbf{V_R}$, $\mathbf{I_R}$) and (1) can be used to calculate the $\mathbf{V_F}$ and $\mathbf{I_F}$, i.e., by substituting (2) and (3) into (1), giving

$$\mathrm{Re}\{\mathbf{V_F}\}\times\mathrm{Im}\{\mathbf{I_F}\}=\mathrm{Re}\{\mathbf{I_F}\}\times\mathrm{Im}\{\mathbf{V_F}\} \quad (4)$$

Notably, the only unknown variable in the above equation is the per-unit distance $\mathbf{D_R}$. The series device model is not used in deriving (4). Therefore, the per-unit fault location $\mathbf{D_R}$ is easily calculated and the series compensation device model is not needed.

THREE-PHASE CASE — with Shunt Capacitance

Since this case considers the shunt capacitance of the line, the currents $\mathbf{I_{RF}}$ and $\mathbf{I_{SF}}$ entering the fault point F, as indicated in Fig.3, will not equal the currents $\mathbf{I_R}$ and $\mathbf{I_S}$ as measured at the receiving and sending ends, respectively. The distributed model of the long distance transmission line can be used to calculate these currents. However, the current $\mathbf{I_{SF}}$ can't be calculated with the transmission line model, since the voltage on the right-hand side of series compensated device is unknown. Thus, the relation of (3) is difficult to achieve and the proposed algorithm cannot be directly applied in this case.

Applying the idea mentioned above to a three-phase transmission line with shunt capacitance, the proposed fault location algorithm must be modified and extended to a two-step algorithm — the pre-location and correction steps. The pre-location step is to calculate feasible initial fault location, providing an initial value close to the correct fault location. Then, the correction algorithm is applied to calculate the correct fault location, meaning the model of the series compensated device is still not needed.

Since the fault location with respect to the series compensation device is unknown prior to fault location estimation, the proposed fault location algorithm will first calculate two locations via subroutines 1 and 2 simultaneously. These two faults are assumed to occur at right and left-hand sides of the series device, respectively. Then, this paper presents a skillful selector for exactly distinguishing the true fault site. The following subsection explains this skillful selector.

Subroutine 1 — Fault location for the right side of the series compensation device

The description of subroutine 1 is divided between the pre-location and correction steps.

Pre-location Step

The basic concept in the simple illustrative cases is extended and modified to become the pre-location step. This study discusses the pre-location algorithm using three phase shorted fault case. For other types of fault, the following procedures can be easily extended.

1. Three phase shorted fault case:

Herein, we only use the positive sequence component. The equations of fault voltage and fault current on the fault location $x=\mathbf{D_R}$ can be expressed as follows [13]:

$$\begin{aligned}\mathbf{V_F}&=\mathbf{V_{F1}}\\&=\frac{\mathbf{V_{R1}}+\mathbf{I_{R1}Z_{C1}}}{2}\exp(\gamma_1\mathbf{D_R}\mathbf{L})+\frac{\mathbf{V_{R1}}-\mathbf{I_{R1}Z_{C1}}}{2}\exp(-\gamma_1\mathbf{D_R}\mathbf{L})\\&=\mathrm{Re}\{\mathbf{V_{F1}}\}+j\mathrm{Im}\{\mathbf{V_{F1}}\}\end{aligned} \quad (5)$$

$$\begin{aligned}\mathbf{I_F}&=\mathbf{I_{F1}}\\&=\mathbf{I_{RF1}}+\mathbf{I_{SF1}}\\&=\left[\frac{\mathbf{V_{R1}}+\mathbf{I_{R1}Z_{C1}}}{2}\exp(\gamma_1\mathbf{D_R}\mathbf{L})-\frac{\mathbf{V_{R1}}-\mathbf{I_{R1}Z_{C1}}}{2}\exp(-\gamma_1\mathbf{D_R}\mathbf{L})\right]\mathbf{Z_{C1}^{-1}}\\&+\left[\frac{\mathbf{V_{S1}}+\mathbf{I_{S1}Z_{C1}}}{2\exp(\gamma_1\mathbf{L})}\exp(\gamma_1\mathbf{D_R}\mathbf{L})-\frac{\mathbf{V_{S1}}-\mathbf{I_{S1}Z_{C1}}}{2\exp(\gamma_1\mathbf{L})}\exp(-\gamma_1\mathbf{D_R}\mathbf{L})\right]\mathbf{Z_{C1}^{-1}}\\&=\mathrm{Re}\{\mathbf{I_{F1}}\}+j\mathrm{Im}\{\mathbf{I_{F1}}\}\end{aligned} \quad (6)$$

Thus, the relation of (1) can be rewritten as

$$\mathrm{Arg}(\mathbf{V_{F1}})=\mathrm{Arg}(\mathbf{I_{F1}}) \quad (7)$$

Using the same treatment with single-phase case, the per-unit initial fault location $\mathbf{D_R}$ can then be easily calculated by the following equation:

$$\mathrm{Re}\{\mathbf{V_{F1}}\}\times\mathrm{Im}\{\mathbf{I_{F1}}\}=\mathrm{Re}\{\mathbf{I_{F1}}\}\times\mathrm{Im}\{\mathbf{V_{F1}}\} \quad (8)$$

Correction Step

Since the right-hand side voltage $\mathbf{V_{SER}}$ of the series compensated device in Fig.1 is unknown (that is, the voltage drop of series compensated device is unknown), the shunt charging current between the series compensated device and the fault end point is also unknown. Thus, when the proposed fault location algorithm is directly applied to transmission line with shunt capacitance, the main error will be

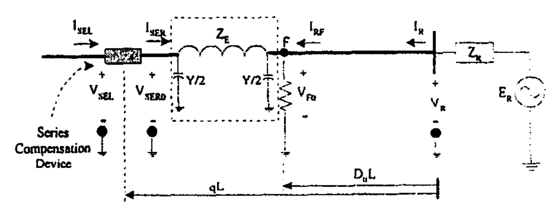


Fig.2 Two-Port circuit for correction step

induced from the unknown voltage drop of series compensation device. This subsection proposes a novel correction algorithm to adjust the pre-location result to a correct solution. Meanwhile, the voltage drop of the series compensation device also can be calculated.

Since the new unknown variable of V_{SER} is introduced in long distance lines, there need another new equation other than that used in pre-location step to calculate the new variable. Fig.2 indicates that the transmission line between series device and the fault point is modeled as a two-port hyperbolic π-model between the fault location end and the series compensated device right-hand side, i.e.

$$\mathbf{Z}_E=\mathbf{Z}_c \sinh(\gamma l)$$

$$Y/2=1/\mathbf{Z}_c \tanh(\gamma l/2) \quad (9)$$

where l = (q − $\mathbf{D}_0$)L (km) is the line length of the π-model transmission line.

Since the series compensation device does not influence the current flowing through it, the current $\mathbf{I}_{SEL}$ flow into the left-hand side of series device will equal the current $\mathbf{I}_{SER}$ flow out from the right-hand side of the series device. Thus, the two-port circuit enclosed by dashed line has two input parameters, one is the correct input current $\mathbf{I}_{SER}$ and the other is the voltage $\mathbf{V}_{F0}$ computed from the pre-location step. The basic circuit theory indicates that the input voltage $\mathbf{V}_{SER1}$ (the second iterative value) of the two-port circuit can be easily calculated as

$$\mathbf{V}_{SER1}=\mathbf{Z}_E/(1+Y/2\times\mathbf{Z}_E)(\mathbf{I}_{SER}+\mathbf{V}_{F0}/\mathbf{Z}_E) \quad (10)$$

Therefore, a new fault location problem can be constructed. The transmission line being considered is located between the two terminals of ($\mathbf{V}_{SER1}$, $\mathbf{I}_{SER}$), ($\mathbf{V}_R$, $\mathbf{I}_R$), enclosed by the dotted line in Fig.2. The line length of the new system is qL (km) and the transmission line between these two terminals has no series compensated devices.

$\mathbf{V}_S=\mathbf{V}_{SER1}$, $\mathbf{I}_S=\mathbf{I}_{SER}$ can be substituted into the pre-location algorithm proposed in previous subsection to calculate a new fault location $\mathbf{D}_1$ and fault end voltage V_{F1}. These two parameters allow the third iterative value of voltage $\mathbf{V}_{SERn}$ (i.e. $\mathbf{V}_{SER2}$) to be once again computed from the iterative formulae (9) and (10). The proposed algorithm will repeat the procedure until fault $\mathbf{D}$ is accurately located. This investigation reveals that the proposed algorithm usually takes 3~4 iterations to accurately locate a fault. Thus, the fault location for a series compensated transmission line is straightforward using the proposed algorithm and the device model is still not required. The flowchart in Fig.3 depicts the pre-location/correction two-step algorithm.

Subroutine 2 — Fault location for the left side of the series compensation device

When the fault occurs on the left side of the series devices, the reference point on x = L can be deliberately changed, substituting the following relationships:

$$\mathbf{V}_S=\mathbf{V}_R,\ \mathbf{V}_R=\mathbf{V}_S,\ \mathbf{I}_S=-\mathbf{I}_R \text{ and } \mathbf{I}_R=-\mathbf{I}_S \quad (11)$$

into the above two-step iterative formulae, and thus obtaining a new per-unit fault location (denoted as $\mathbf{D}'$) in relation to the **reference x = L**. When x = 0 is taken as the reference point, the final per-unit fault location can be computed from $\mathbf{D}_L = 1 - \mathbf{D}'$.

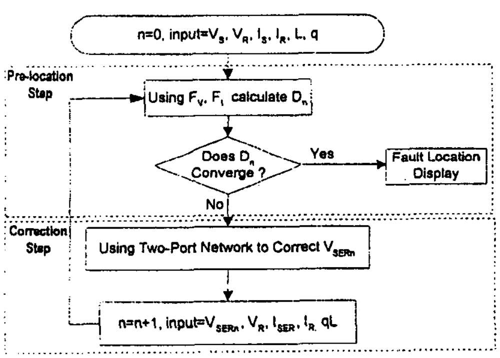


Fig.3 Flow-chart of two-steps fault location algorithm

FAULT SELECTOR

For systematically selecting the true fault location this subsection proposes a skillful selection algorithm. The proposed two-step fault location algorithm can calculate the voltage of V_{SER} in Fig.2. Additionally, the voltage $\mathbf{V}_{SEL}$ of the point just in front of the series device is also easily calculated from the transmission line equation. Thus, the voltage drop $\Delta\mathbf{V}_{SE}$ of the series compensation device can be calculated by $\mathbf{V}_{SEL}-\mathbf{V}_{SER}$. The equivalent impedance of the series compensation device can be calculated as

$$\mathbf{Z}_{SE} = \Delta\mathbf{V}_{SE}/\mathbf{I}_{SER} = \mathbf{R}_{SE} + j\mathbf{Z}_{SE} \quad (12)$$

If the estimated result of the fault location is on the correct side, the $\mathbf{R}_{SE}$ will be a positive value (obeying the law of physics). Otherwise, the $\mathbf{R}_{SE}$ will be negative (violating the law of physics) for the incorrect side estimation. For example, when b-c line-to-line fault occurs on the right side of the series device, the $\mathbf{R}_{SER}$ of b-phase and c-phase calculated from subroutine 1 will be positive. Otherwise, when using subroutine 2, the calculated $\mathbf{R}_{SEL}$ of the b and c-phases will be negative. Thus, the selecting criteria can be stated as:

The fault location of the estimated set [$\mathbf{D}_R$, $\mathbf{D}_L$] that corresponds to positive $\mathbf{R}_{SE}$ is selected as the correct solution.

III. PERFORMANCE EVALUATION

ALGORITHM TEST

This subsection evaluates the fault location algorithms proposed here using some case studies. The simulation sample considered is a 300km, 345kV transmission line compensated by thyristor controlled switched capacitance (TCSC) with a compensation degree of 70%. All the systems are modeled by EMTP. The phasors are estimated using the SDFT [11,12] filtering algorithm working at 32 samples per cycle. The total simulation time is 200 milliseconds and the error of the fault location is expressed in terms of percentage of total line length. Appendix A presents the parameters of the sample system. As is well known, the different protection function design of TCSC will introduce different type of disturbances into compensation voltage. Thus, the protection functions of TCSC must be considered when evaluating the performance of the proposed fault location algorithm. For convenience, this investigation adopts the protection functions presented in [4].

Table I. Parameters of the simulation system

System voltage 345kV	**System frequency** 60Hz
$E_S=1.0\angle 0^\circ$pu	$E_R=1.0\angle -10^\circ$pu
$Z_{SA1}=1.31+j15(\Omega)$	$Z_{SB1}=1.31+j15(\Omega)$
$Z_{SA0}=2.33+j26.6(\Omega)$	$Z_{SB0}=2.33+j26.6(\Omega)$
Transmission line parameter : length=300km	
Positive sequence:R=0.0275(Ω/km) L=0.836(mH/km) C=0.038(uF/km)	
Zero sequence : R=0.275(Ω/km) L=2.7233(mH/km) C=0.038(uF/km)	
MOV : I_{REF}=1kA, V_{REF}=140kV, Exponent=23, Ratted energy=5MJ	

<u>Case Study</u>: Large Fault Current I_F Cases

In this case, the TCSC device is installed near the midpoint at 135km (q = 0.45 p.u.) away from the receiving end of the protected

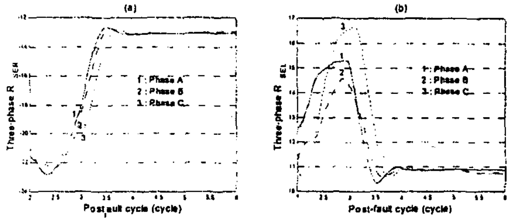


Fig.4 (a) Equivalent resistance of R_{SER}
(b) Equivalent resistance of R_{SEL}

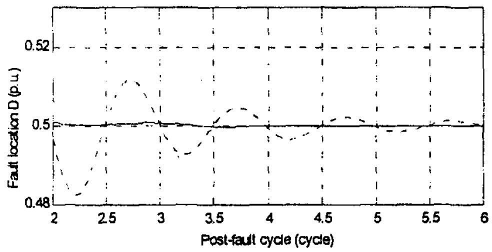


Fig.5 Fault Location Calculation by SDFT (solid line) and DFT (dotted line)

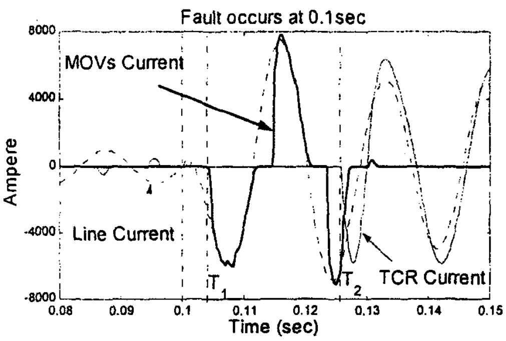


Fig.6 The Waveform of TCSC

line. Assume that a three-phase ground fault occurs at 150km (**D** = 0.5 p.u.). The fault resistance is set as 1 (Ohm).

The fault locations $\mathbf{D_R}$ and $\mathbf{D_L}$ are computed from subroutines one and two simultaneously. Meanwhile, Fig.6 plots the estimations of $\mathbf{D_R}$ and $\mathbf{D_L}$. At 2.5 cycles after fault inception, the proposed algorithms provide the following results:

$\mathbf{D_R}$= 0.3682 (p.u.), $\mathbf{D_L}$= 0.50008 (p.u.)

Obviously, the two-step iteration algorithms can provide accurate fault location in this case. The equivalent resistance of $\mathbf{R_{SEL}}$ and $\mathbf{R_{SER}}$ also shown in Fig.4(a) and Fig.4(b) respectively. Notably, that the $\mathbf{R_{SER}}$ is negative. Therefore, one can easily choose $\mathbf{D=D_L}$=0.50008 as the correct solution

Fig.5 compares fault location calculation using DFT and SDFT [13-16] filters. Obviously, the exponential decay of DC-offset in the fault current and voltage signals will markedly influence fault location when fault location is calculated by DFT. When the fault location result is calculated using SDFT, then the calculated location would not have the same slow damping as in the DFT results. Instead, the calculated fault location converges very fast and an accurate location is easily and quickly achieved.

Fig.6 presents the detailed waveform of the TCSC before and after a fault occurs. The TCR switches to the block mode and the MOV begins to bypass the fault current when the fault starts to occur at $t=T_1$, since the over-voltage condition is detected by the TCSC controller.

TABLE II . STATISTICAL TESTING OF THE ALGORITHM

[illegible]	[illegible]	Fault location error (%)				
		[illegible]	[illegible]	150km	225km	270km
[illegible]	0.1Ω	ave=0.0007 max=[illegible]	ave=0.001 max=[illegible]	ave=0.0034 max=[illegible]	ave=0.0009 max=[illegible]	ave=0.0007 max=[illegible]
	1Ω	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]
	10Ω	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]
	50Ω	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]
	100Ω	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]
[illegible]	0.1Ω	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]
	1Ω	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]
	10Ω	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]
	50Ω	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]
	100Ω	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]
[illegible]	0.1Ω	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]
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	10Ω	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]
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	100Ω	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]
[illegible]	0.1Ω	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]
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	100Ω	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]	ave=[illegible] max=[illegible]

The TCR changes to bypass mode at t = T_2, since the energy absorbs in the MOV is exceed its limitation. Notably, the proposed algorithm can still easily provide the accurate fault location result, whatever the complexity of the TCSC protection function operates.

STATISTICAL EVALUATION

This subsection evaluates the proposed fault location algorithm with over 500 test cases obtained from the EMTP simulator. It considers different fault types, resistances, locations, and inception angles as statistical tests. It uses the same transmission line and series compensation device data as the previous subsection. Table I summarizes all of these results. To save space, all of the fault location errors are calculated as the average value of five inception angles (0, 45, 90, 135, and 180 degrees in relation to the zero cross of a-phase voltage). In this table, variable **ave** is the average fault location with respect to five inception angles. For comparison, variable **max** is the maximum fault location error in five inception angles. Generally, the maximum error is 0.27% and the average error is about 0.034%. The error increases in large fault resistance cases. Additionally, if only the normal fault resistance is considered (smaller and equal 10 Ohm [7]), the maximum error can be reduced to 0.12% and the average error is only 0.0182%.

IV. CONCLUSION

This work has successfully proposed a novel fault location algorithm for series compensated lines. The proposed algorithm does not utilize the series device model and knowledge of the operation mode of series device to compute the voltage drop during fault.. Thus, the fault location errors induced from incorrect series compensation device model or inaccurate modeling of the series device protection function model can be eliminated completely. Furthermore, because the fault locator designer does not need the series compensation device model to design the fault locator, designing the proposed fault locator becomes easier than in conventional designing. Additionally, the proposed fault location algorithm can be easily applied to any other series compensated line that has no additional shunt branch or phase shift contribution on line current. To select the correct fault location with respect to the series device, this work has presented one skillful selector. The simulation results show the proposed fault location algorithm is useful and easily produces accurate fault location result.

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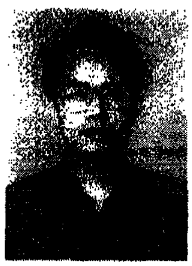

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