TESLA - 4000 Digital Fault Recorder

Fault Locator Function

1 Introduction

Transmission lines are a very important part of the power system, integral to reliable service from power plants to consumers. Identifying fault locations is very important to maintenance of a reliable and economical power supply [1]. In most industrial distance relays and digital fault recorders, fault distance estimation is done using the Takagi algorithm [2]. However, this task can be difficult under practical conditions such as short duration faults, high dc offset conditions, etc. [3].

This document provides the procedure for configuring the fault locator function available in the ERLPhase TESLA 4000 digital fault recoding system. Operation of the fault locator is demonstrated using the faulty waveforms generated from an electromagnetic transient (EMT) type simulation program. This simulation uses a frequency dependant transmission line and considers different types of faults (phase-to-ground, phase-to-phase, three-phase, etc.) simulated at different locations of the line with different fault inception angles.

TESLA 4000 is capable of supporting two different types of current sensors: “conventional type” and “split core type” [4]. Conventional type sensors require system interruption (as would current sensors available in the conventional relays and field installations), whereas split core type current sensors can be installed without system interruption. For this reason, split core current sensors have become popular during recent years. Application using both types of CTs is described below.

2 Test System

Fig-1 shows a 230 kV, 200 km transmission simulated in the PSCAD simulation program. The instrument transformers (CTs and PTs) were simulated, assuming a CT ratio of 600:5 and a PT ratio of 2000:1. Complete system parameters are shown in Table-1.

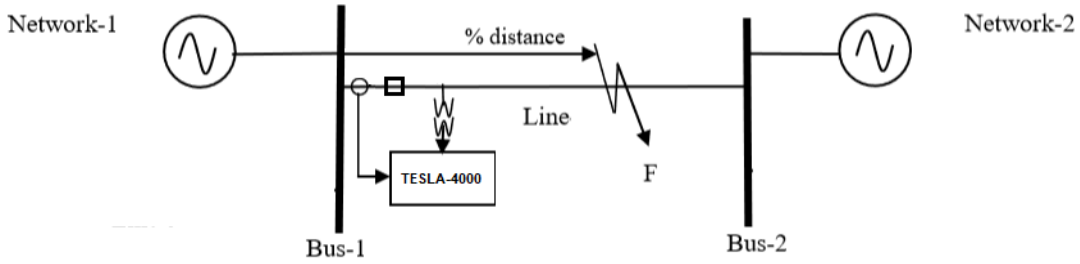

Fig-1: 230 kV, 60Hz Transmission System under Investigation

Table-1: System Parameters

Element	Network-1	Network-2	Transmission Line
Positive Seq	50.0 < 80 Ohms	50.0 < 80 Ohms	101.8 < 85.9 Ohms
Zero Seq	100.0 < 80 Ohms	70.0 < 80 Ohms	275.1 < 74.7 Ohms

3 TESLA Setting

Basic steps involved in the cofiguring of the fault locator funtion are shown in Fig-2 to Fig-7. The fault locator is set to operate for any any under voltage condtion at 85% of the nominal voltage or any zero sequence current above 20% of the nominal current.

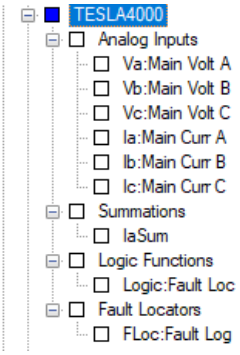

Fig-2: Overview of Fault Locator Configuration

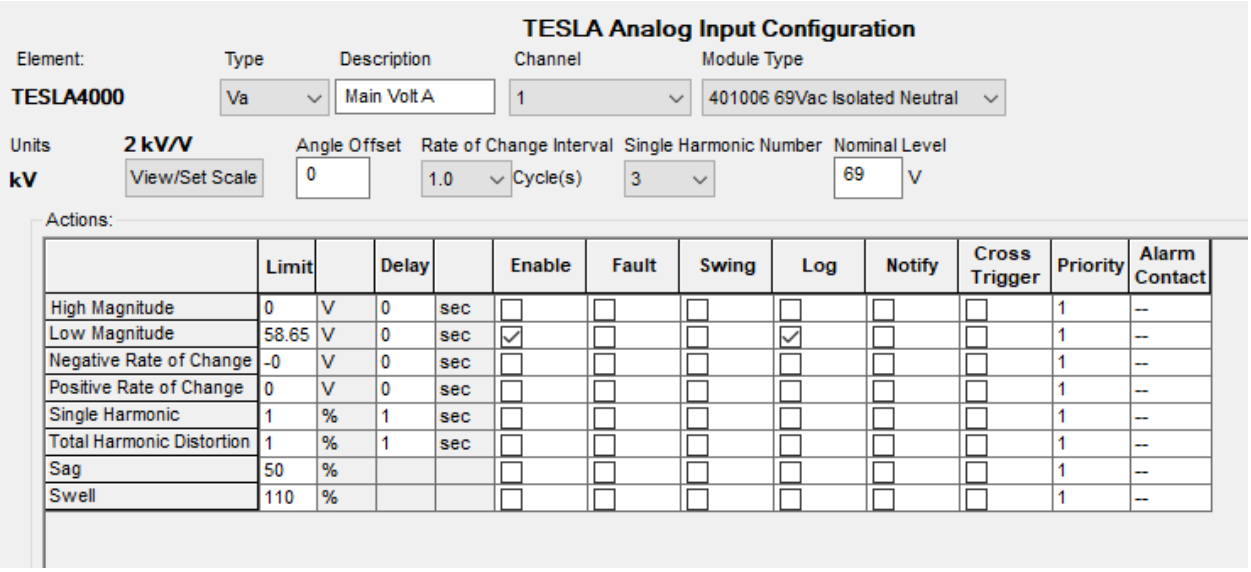

Fig-3: Voltage Channel Configuration

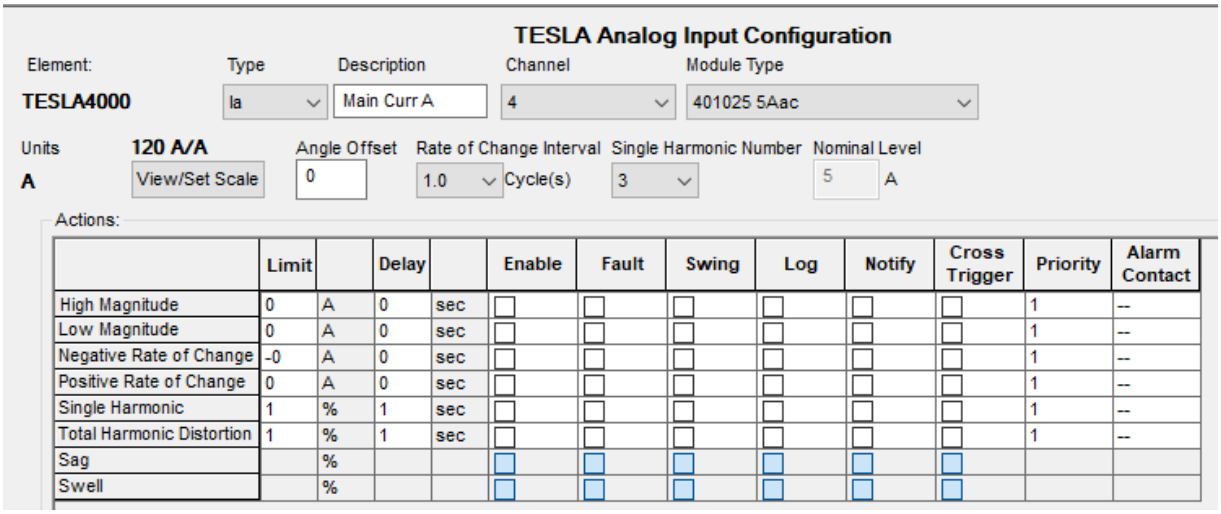

Fig-4: Current Channel Configuration

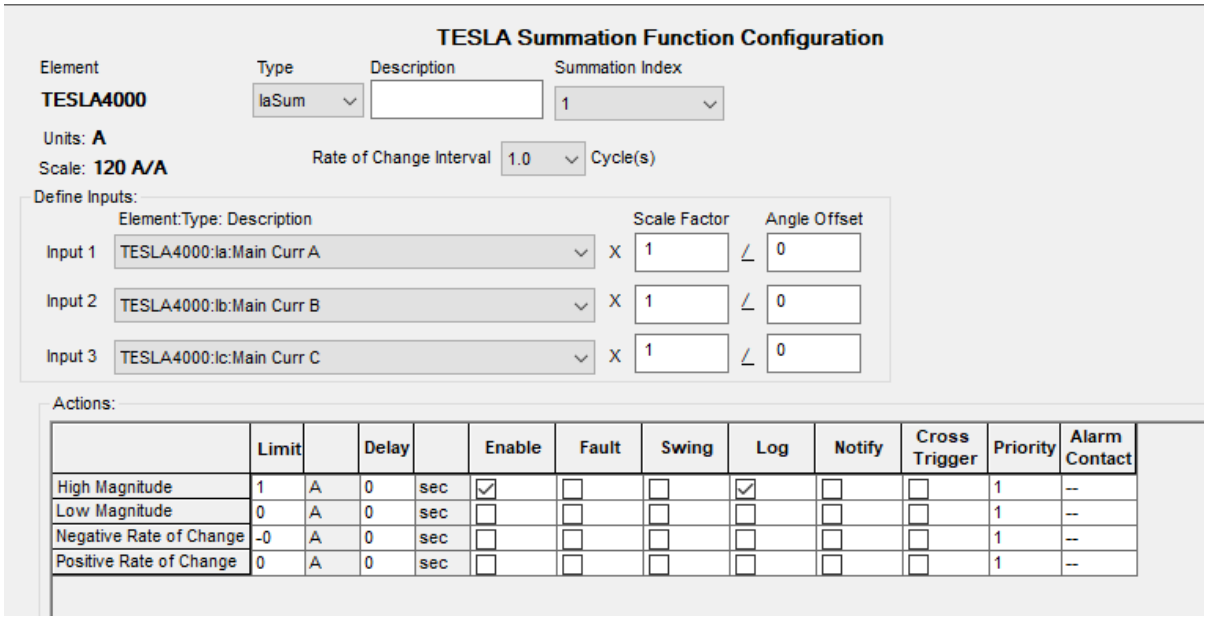

Fig-5: Summation Current Channel Configuration

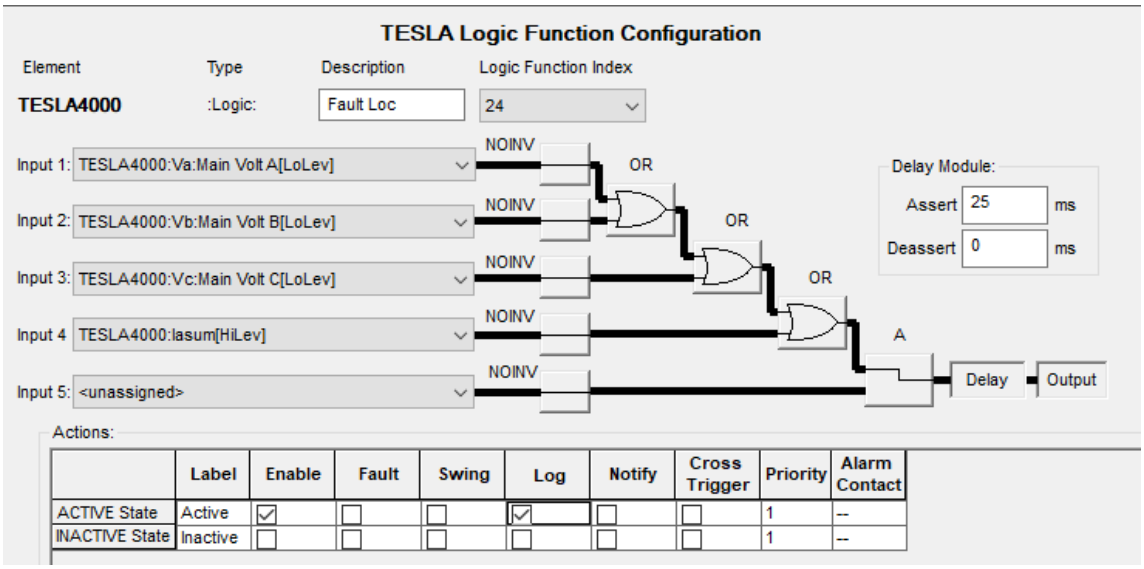

Fig-6: Fault Trigger Logic

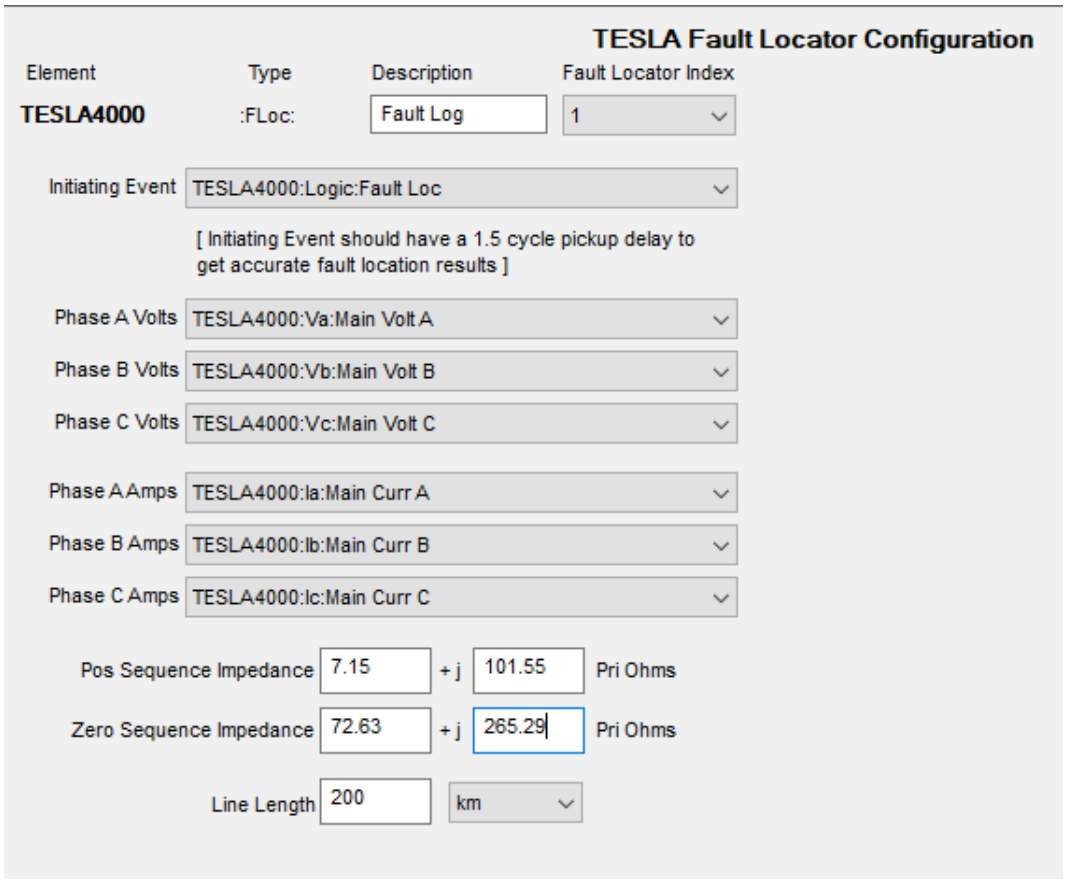

Fig-7: Fault Locator Configuration

4 Results

Fault location results obtained using different types of current sensors are presented in Table-2 and Table-3. The percentage error is calculated using the following equation:

Percentage Error = (instrument reading – exact distance to the fault) * 100 / total line length

Table-2: Fault Locator - Conventional CT Module

Fault type		Actual location (km)	Estimated location (km)	% Error
AG	1	50	49.9	0.05
	2		49.9	
	3		49.9	
BC	1	50	51.3	0.65
	2		51.3	
	3		51.3	
ABC	1	50	49.3	0.35
	2		49.3	
	3		49.3	
AG	1	100	100.8	0.4
	2		100.8	
	3		100.8	
BC	1	100	98.1	0.95
	2		98.1	
	3		98.1	
ABC	1	100	99.0	0.5
	2		99.0	
	3		99.0	
AG	1	150	152.0	1
	2		152.0	
	3		152.0	
BC	1	150	148.8	0.6
	2		148.8	
	3		148.8	
ABC	1	150	148.4	0.85
	2		148.2	
	3		148.3	

Table-3: Fault Locator - Split Core CT Modules

Fault type		Actual location (km)	Estimated location (km)	% Error
AG	1	50	49.8	0.1
	2		49.8	
	3		49.8	
BC	1	50	51.1	0.55
	2		51.1	
	3		51.1	
ABC	1	50	49.4	0.3
	2		49.4	
	3		49.4	
AG	1	100	100.6	0.3
	2		100.6	
	3		100.6	
BC	1	100	98.1	0.983
	2		98.0	
	3		98.0	
ABC	1	100	98.9	0.55
	2		98.9	
	3		98.9	
AG	1	150	151.7	0.85
	2		151.7	
	3		151.7	
BC	1	150	148.3	0.87
	2		148.2	
	3		148.3	
ABC	1	150	147.9	1.03
	2		148.0	
	3		147.9	

Table-4: Short Duration Faults - Conventional CT

Number of cycles		Actual location (km)	Estimated location (km)	% Error
~2-2.5 cycles	1	150	151.9	0.983
	2		152.0	
	3		152.0	
~2.5-3 cycles	1	150	152.0	1
	2		152.0	
	3		152.0	

Suitability of the fault locator for short duration faults was also investigated. Table-4 and Table-5 summarize the effect of fault duration on the fault locator accuracies for a single phase to ground fault simulated at 150 km tested using different types of CT modules. As it can be seen from the results, TESLA is capable of calculating the fault location for short duration faults as low as 2 to 2.5 cycles.

Table-5: Short Duration Faults - Split Core CT

Number of cycles		Actual location (km)	Estimated location (km)	% Error
~2-2.5 cycles	1	150	151.7	0.85
	2		151.7	
	3		151.7	
~2.5-3 cycles	1	150	151.7	0.85
	2		151.7	
	3		151.7	

4 Summary

Operation of the fault locator function available on the TESLA-4000 DFR was demonstrated using simulated waveforms. Applicability of different types of current sensors was also evaluated. Results showed fault estimations with approximately 1% error limit, irrespective of the type of the CT, for the simulated fault scenarios. It should be noted that for closed-in faults, fault location errors get increased due to factors such numerical issues, measurement errors and simulation errors.

5 References

[1]. IEEE Standard PC37.114, “Draft Guide for Determining Fault Location on AC Transmission and Distribution Lines,” 2004.

[2]. T. Takagi, Y. Yamakoshi, M. Yamaura, R. Kondou, and T. Matsushima, “Development of a New Type Fault Locator Using the One-Terminal Voltage and Current Data,” IEEE Transactions on Power Apparatus and Systems, vol. PAS-101, no. 8, August 1982, pp.2892-2898.

[3]. E. O. Schweitzer, III, “A Review of Impedance-Based Fault Locating Experience, Proceedings of the 15th Annual Western Protective Relay Conference, Spokane, WA, October 24-27, 1988.

[4]. TESLA 4000 User Manual: Available online at www.erlphase.com/downloads/manuals/TESLA_4000_manual.pdf.