Investigation of Transient Recovery Voltage on Circuit Breaker

Omar Abdullh, Bidemi Awogbemi **Advisor: Michael Omidiora**
Department of Electrical Engineering
University of Bridgeport, Bridgeport, CT

Abstract

For technically adequate interruptive performance, circuit breaker (CB) must be able to sufficiently interrupt current and voltage transients in power system network. Transient recovery voltage (TRV), an overvoltage transient resulting from the initiation, or interruption of current greatly affects breaking capacity of breakers. This work investigates TRV across circuit breaker and presents an effective method of limiting it. EMTP-ATP software was used to create the model and simulation.

Introduction

Transient recovery voltage (TRV) occurring following current interruption, must be properly evaluated before selecting any interruptive device, including a circuit breaker, an automatic recloser, a fuse or a load breaking switch. TRV is the voltage that appears across the pole contacts of circuit breaker during current zero interruption. TRV peak and its rate of rise depend on the inherent properties of the CB and the characteristics of the surrounding network. In this paper, EMTP-ATP software was used to model and analyze line-to-ground short-circuit of terminal and short line faults (SLF) for a 28.169 kV(L-G) medium voltage substation. Terminal fault (Fig. 2) is a fault where the short circuit occurs at, or very near the terminals of the circuit breaker (see Fig. 3); while short line fault (Fig. 4) is a fault where the short-circuit occurs at a relatively short distance downstream from the circuit breaker on its load side (see Fig. 5).

Single Line Diagram Representation

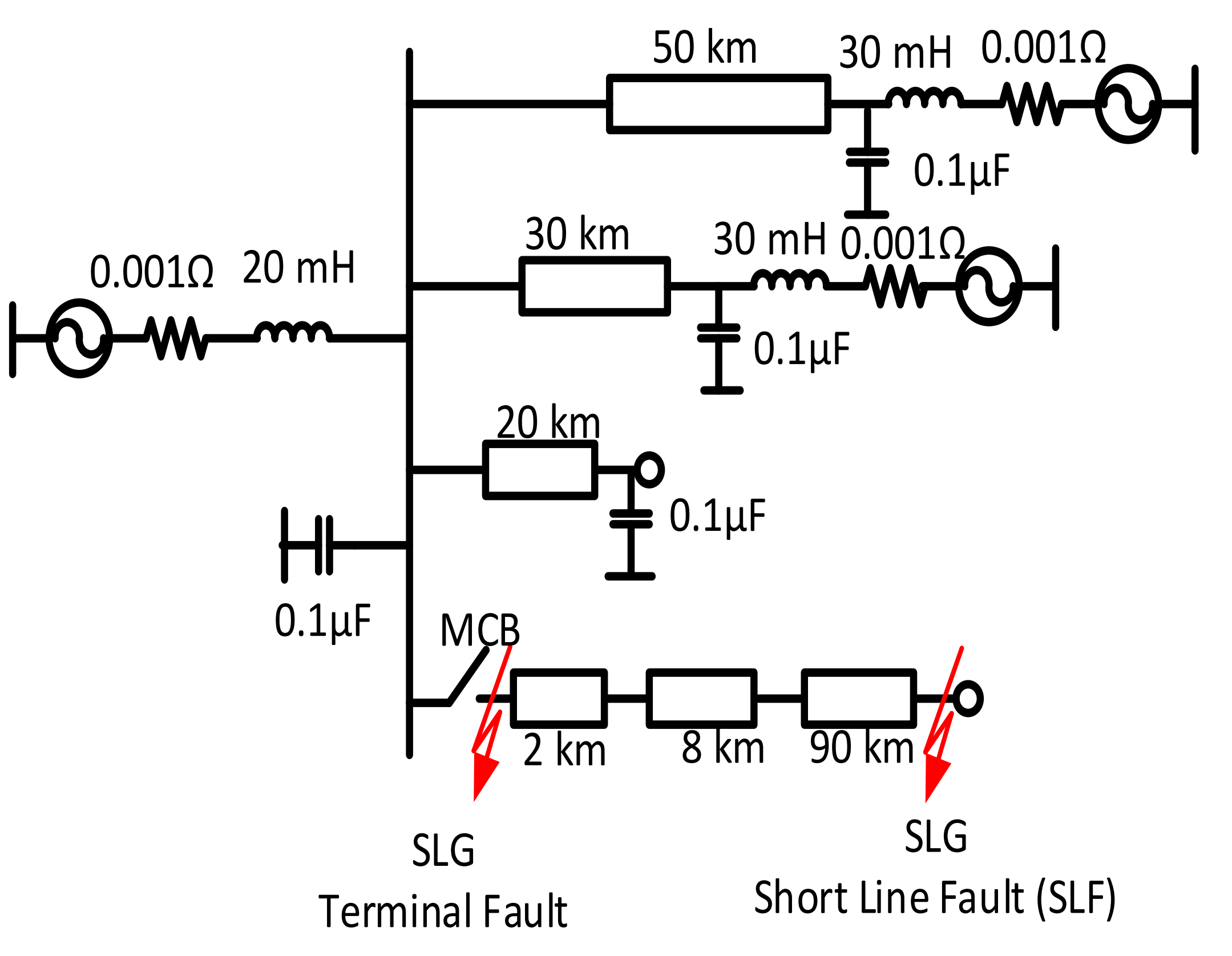

Fig.1: A single line representation of a 345 kV substation to analyze

Line Parameters

Phase Conductors Parameters:

DC Resistance = 5.85 $*10^{-5}$ Ω/m

Outside Diameter = 3.105 $*10^{-2}$ m

Tube inner radius = 5.5 $*10^{-3}$ m

Soil resistivity = 0.20 Ωm

Conductor separation in the bundle = 0.6 m

Auto bundling option is enabled to simplify the data entry for the 4 conductor per phase

TRV on Circuit Breaker (with JMarti Line Model)

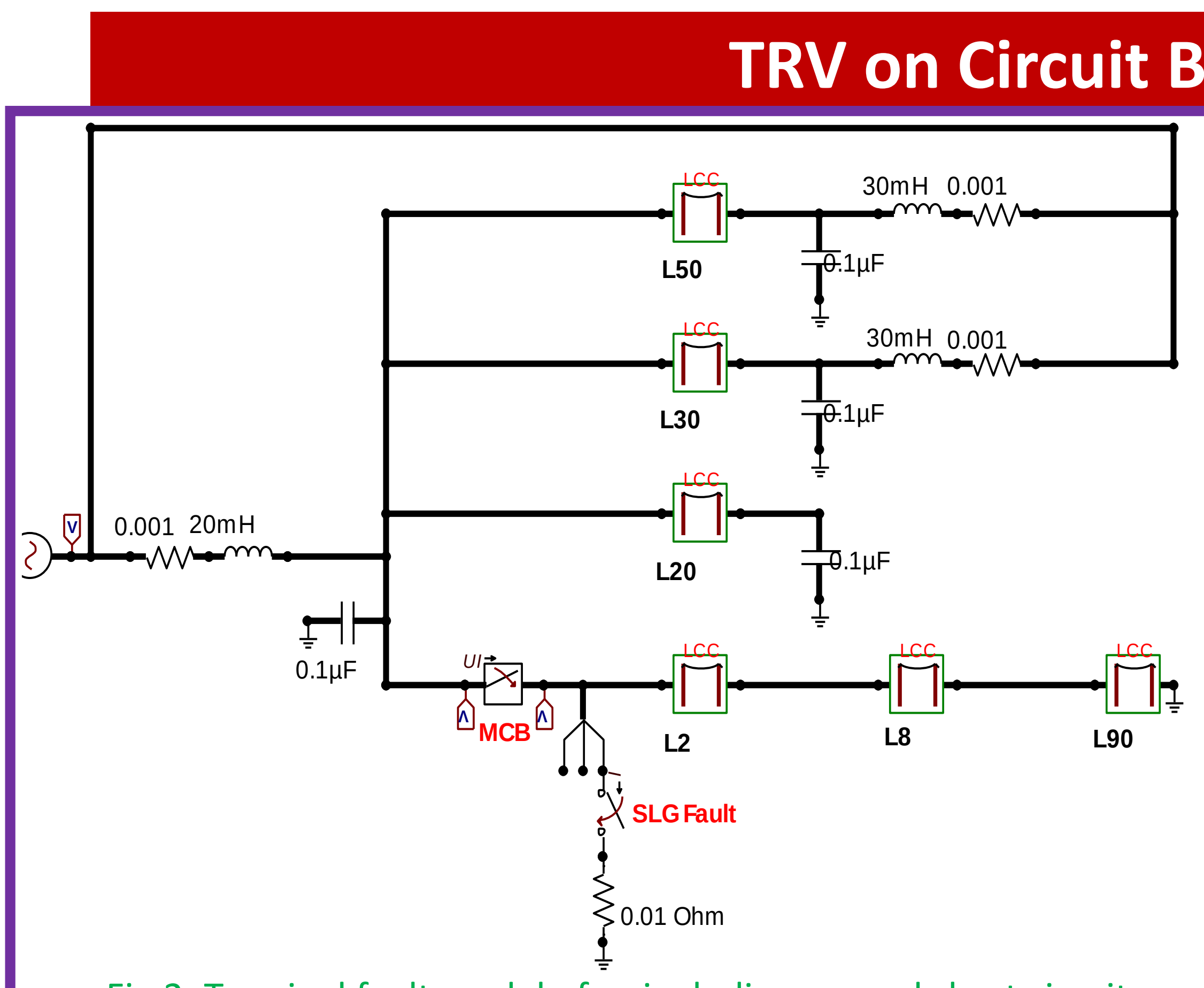

Fig.2: Terminal fault model of a single-line ground short circuit

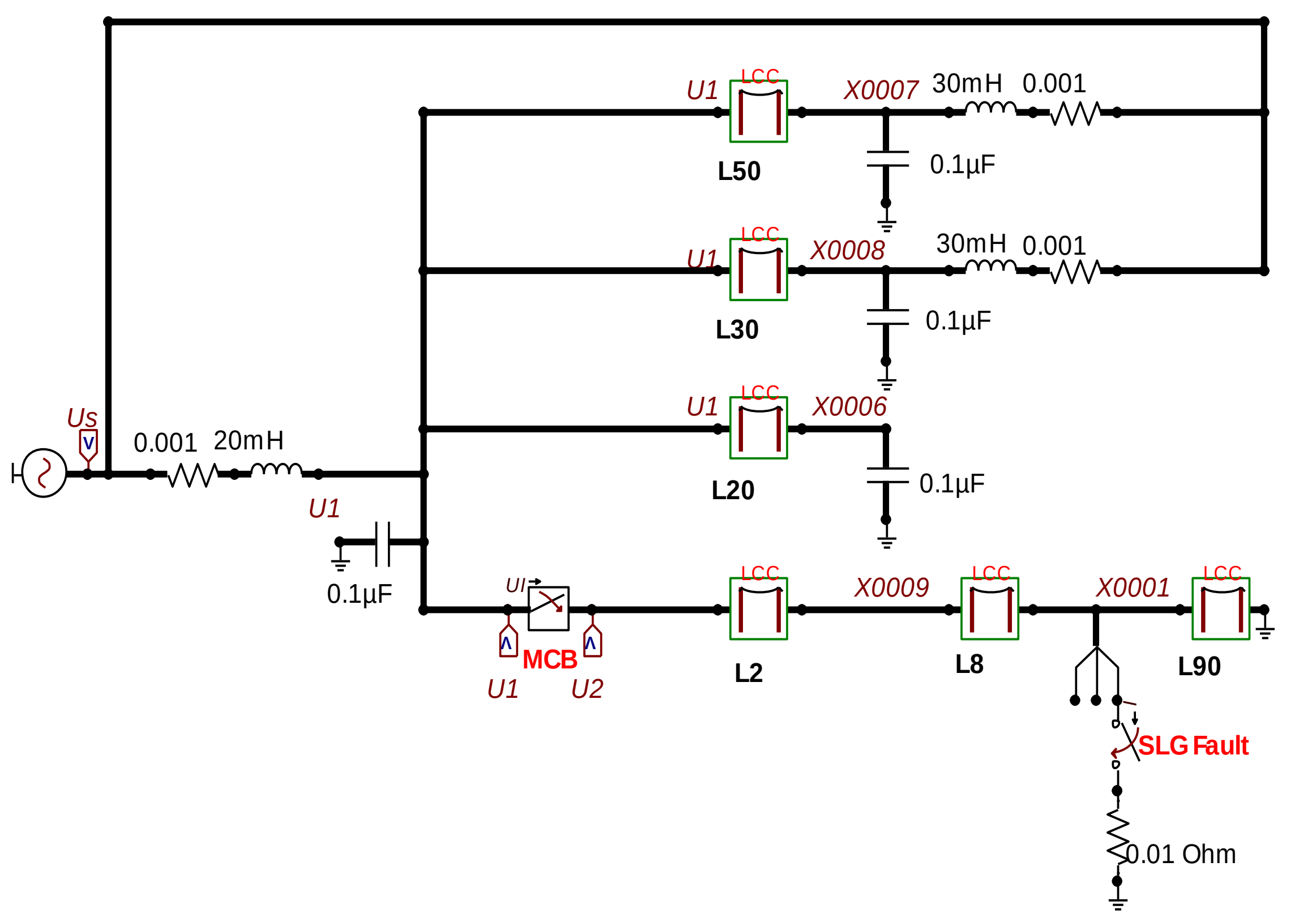

Fig.4: Short line fault (SLF) model of a single-line ground short circuit

Simulation Results

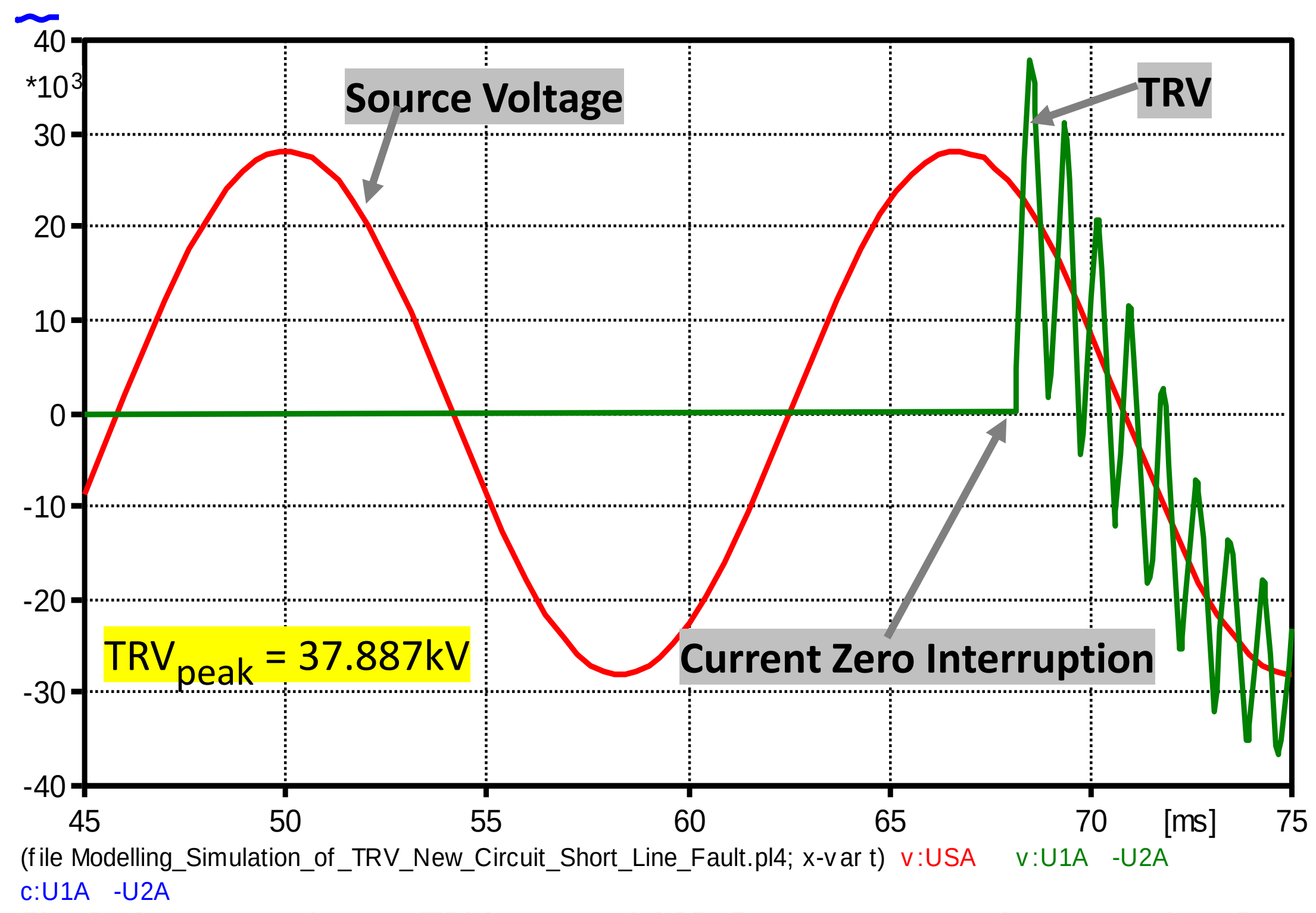

Fig.3: Source voltage, TRV across MCB & current zero interruption for terminal fault

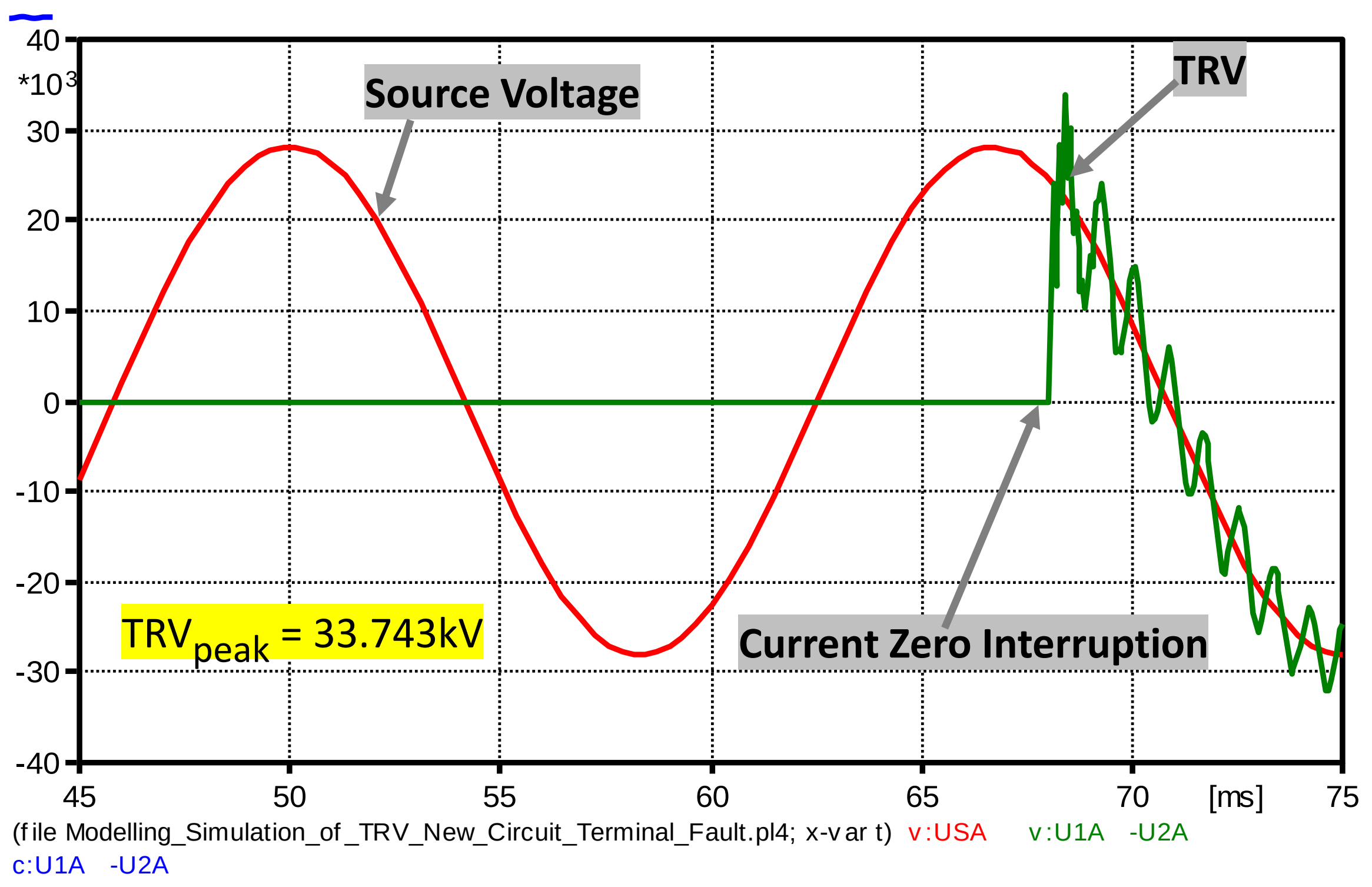

Fig.5: Source voltage, TRV across MCB & current zero interruption for short line fault (SLF)

Mitigation with Pre-insertion Resistor

The circuit breaker employed for mitigation has two contacts per pole: auxiliary contact, **A** and main contact, **M**. During short circuit, auxiliary contact switches resistor into the circuit, after few seconds, main contact is switched-in. In this work, the 3-phase model of Fig. 6 and simulation results of Figs. 7 & 8 are used to present TRV reduction with a 400 Ω resistor switched into the circuit via auxiliary contact at 0.01 s, thereafter, main contact switched into the circuit at 0.04 s

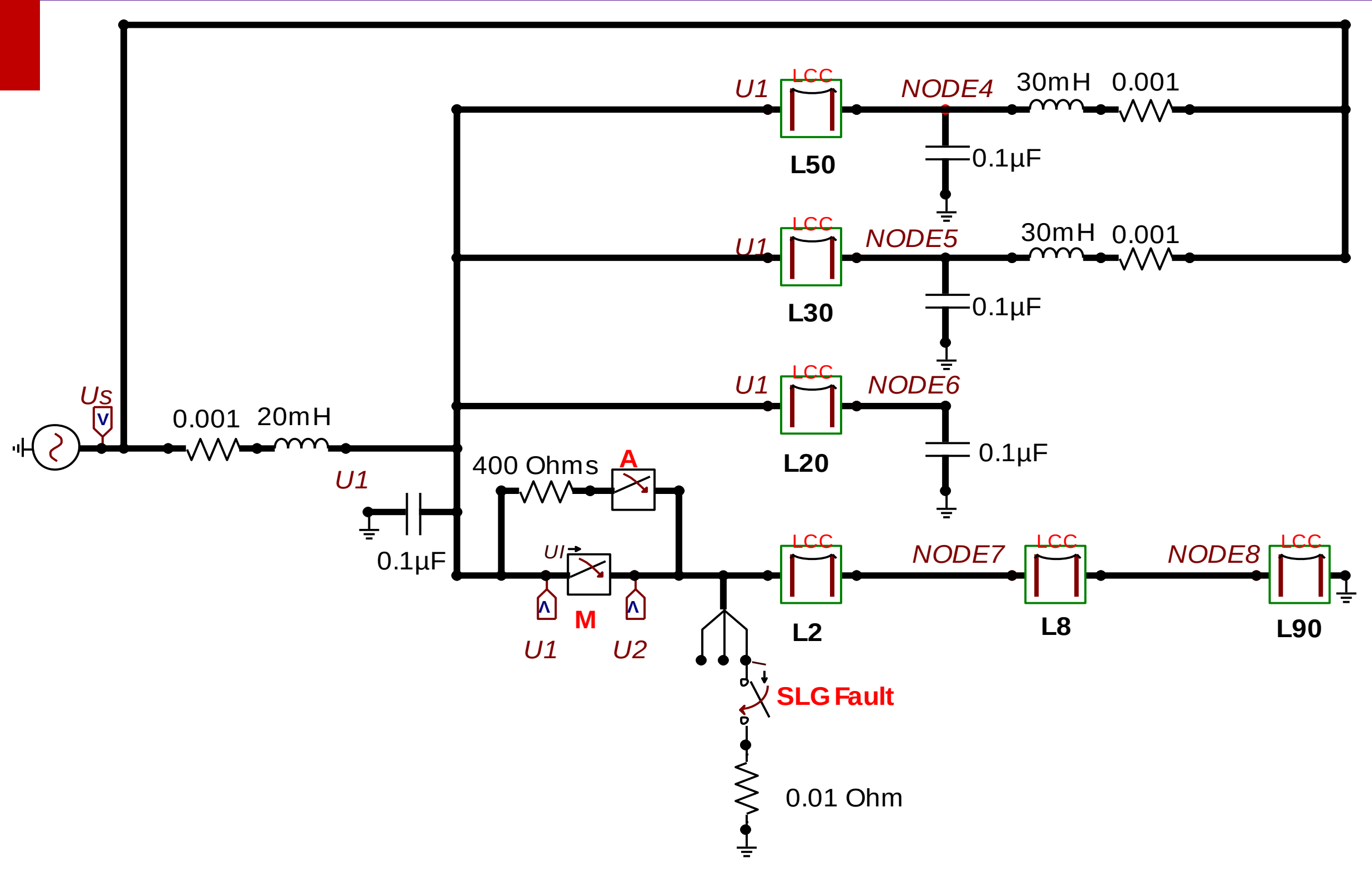

Fig.6: Resistive switching to mitigate TRV due to terminal fault

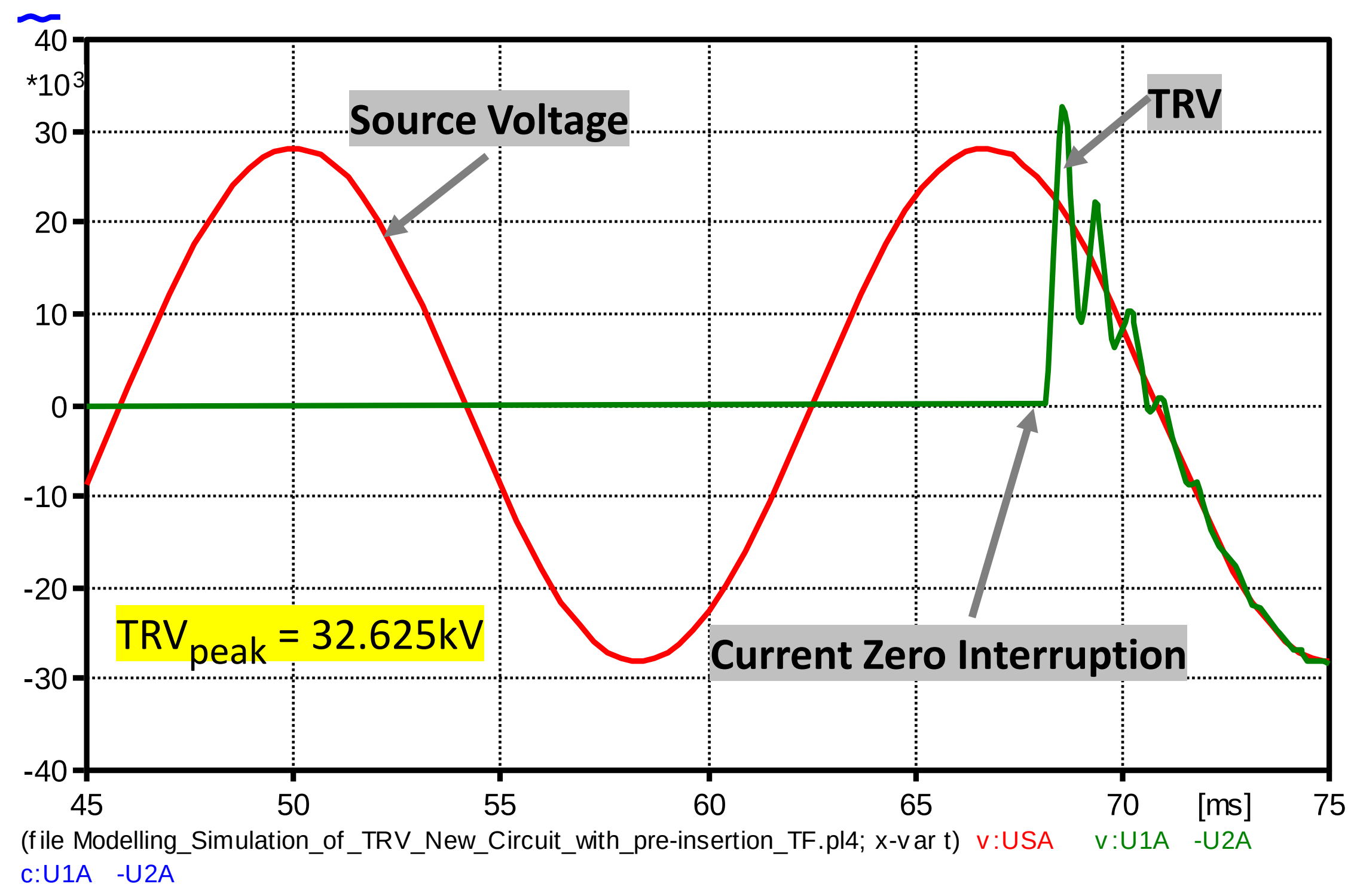

Fig.7: Source voltage, TRV across MCB and current zero interruption for terminal fault with resistive switching

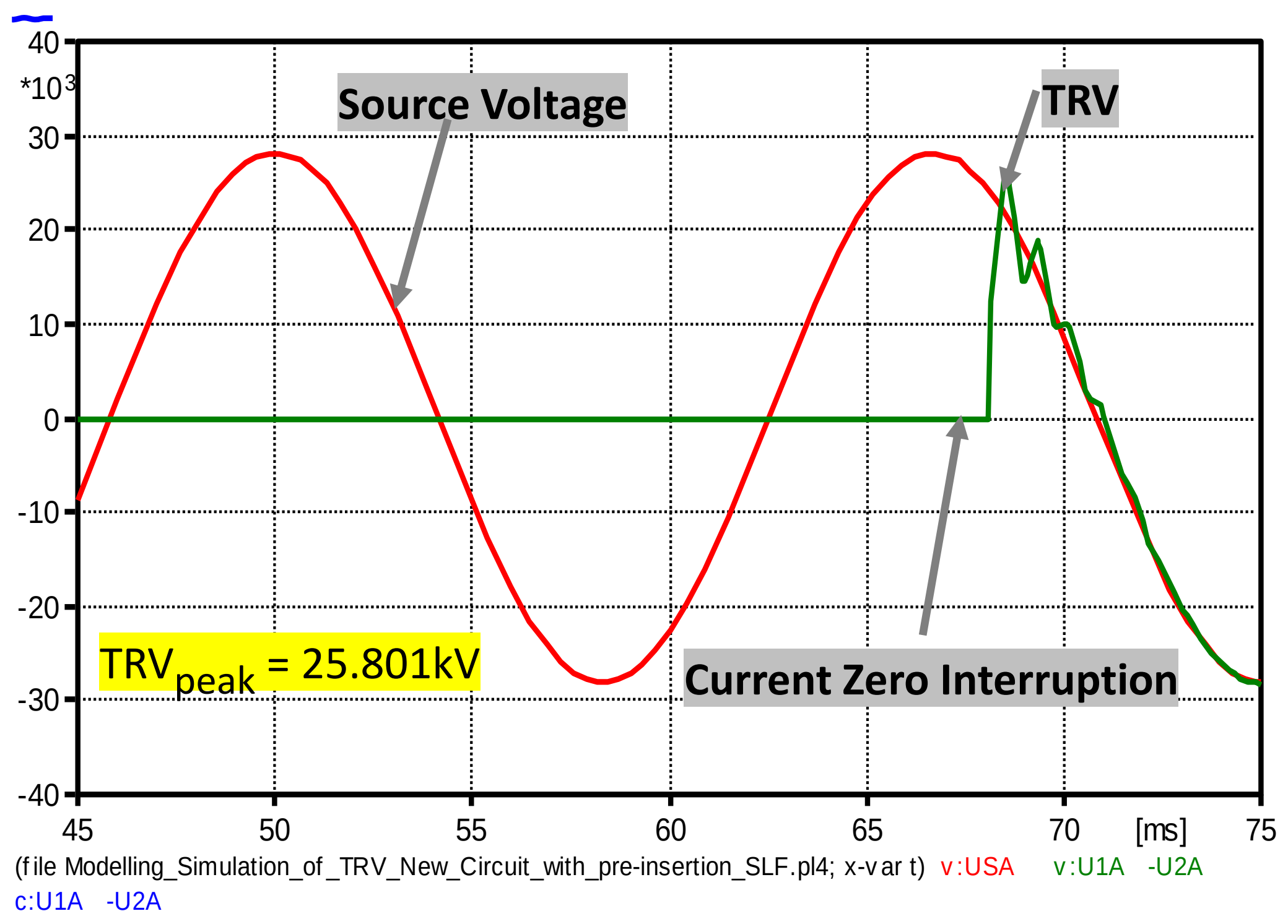

Fig.8: Source voltage, TRV across MCB & current zero interruption for short line fault (SLF) with resistive switching

Conclusion

The work takes medium voltage substation as research project to investigate TRV across CB under two fault scenarios. Line parameters and components were selected for modeling according to line structure. TRV associated with terminal fault was found to be higher than TRV associated with short line fault. To mitigate TRV across CB, resistive switching was effectively used and this reduced TRV across CB during both fault scenarios.

References

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[2] Ezra P.A Van Lanen, Marjan Popov, Lou Van Der Sluis and Rene P.P Smeets "Vacuum Circuit Breaker Current-Zero Phenomena "IEEE Trans. On Plasmas Science, Vol. 33, No5, October, 2005 Power & Energy Society, April 2011.

[3] R. W. Alexander, D. Dufournet, Transient Recovery Voltage for High-Voltage Circuit Breakers, Tutorial IEEE Switchgear Committee, FL, USA, May 2003.