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The effect of voltage transformers and capacitor Voltage Transformers (CVT) on distance protection performance

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Abstract—Distance relays rely on accurate voltage and current signals to correctly determine if a fault is within their zone of protection, as determined by the impedance reach setting. The current signal provided to the relay comes from a current transformer (CT), which is a simple device consisting of a steel core and wire wrapped around that core. At high voltage levels, the voltage signal typically comes from a capacitor voltage transformer (CVT), which is more complicated and less reliable than a CT. Although a CVT is more complex than a CT, very little additional attention is typically given to monitor the performance of a CVT. To study the effects of voltage transformer with coupled capacitor, a small network with two stations and with two switches on both sides of the communication transmission line was considered. CVT was used on the circuit breaker B1 side and VT was used on the circuit breaker B2 side. and the faults at different distances from the transmission line between two stations and in different states were modeled in PSCAD software and the output curve of the software includes voltage, current, residual current And the function of the distance relay was obtained when the fault occurred. And by comparing the results of the output curves of the software, it was concluded that by applying a slight delay in the operation of the relay zones, the distance protection operation error can be avoided due to the presence of CVT.

Keywords-component; CVT; VT; PSCAD; Distance Relay

I.Introduction

Instrument transformers perform the important function of providing windows on the power grid's electrical behaviour Protection, control, and measuring devices require these 'windows' yet they also need electrical isolation from the grid as they function at much lower voltages and currents. Instrument transformers provide the solution; they are go-betweens that provide isolation by magnetically coupling secondary monitoring and measuring devices to the grid. There are several types of instrument transformers, but one of the most common on higher voltage transmission systems is the coupling capacitor voltage transformer (CVT) "Fig. 1".

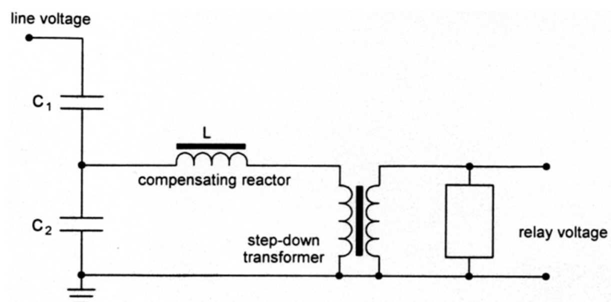

Figure 1 . coupling capacitor voltage transformer (CVT)

II. (CVT) TRANSIENT ANALYSIS

A capacitor voltage transformer (CVT) is made up of a number of capacitor units connected in series. The number of capacitor units depends on the applied primary voltage level. The (CVT) capacitance is represented by two values: one for the equivalent capacitance above the intermediate voltage point (C) and the other for the equivalent capacitance below the intermediate voltage point (CV- The Thevenin equivalent capacitance value (C1 + C2) is different from the total capacitance C1.C2/(C1 + C2) normally given by (CVT) manufacturers. C1 + C2 is approximately 100 nano-farad (nF) for the CVTs studied in this paper. Some (CVT) manufacturers differentiate CVTs as normal-, high-, or extra high-capacitance CVTs.

The high capacitance value in a (CVT) decreases the (CVT) transient in magnitude. See this by comparing the (CVT) transient plots of Figure 2 and Figure 4 for a fault initiated at a voltage zero. Figure 4 shows the transient response of a (CVT) with four times total capacitance of that shown in Figure 2.

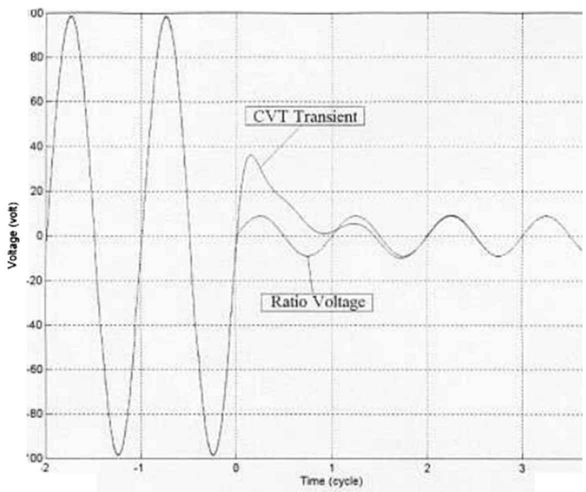

Figure 2 . (CVT) Transient with Fault at Volltage Zero

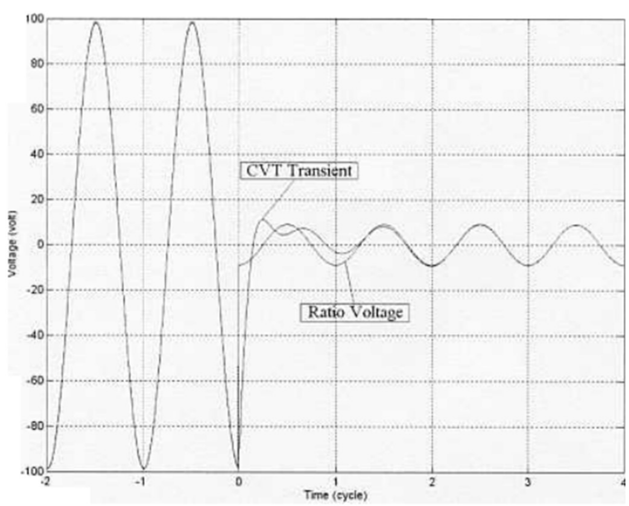

Figure 3 . (CVT) Transient with Fault at Volltage Peak

Distance elements calculate a fault apparent impedance based on the fundamental components of the fault voltage and current. The fundamental content of the (CVT) transient determines the degree of distance element overreach. Figure 5 shows the fundamental components of the same (CVT) outputs shown in Figure 2 and Figure 4. We obtained the fundamental magnitudes by filtering the (CVT) outputs using a digital band-pass filter. Notice that the fundamental component of the higher capacitance (CVT) output voltage is closer to the true fundamental magnitude than that of the lower capacitance (CVT). Therefore, any distance element overreach caused by a transient output of a higher capacitance (CVT) is much smaller than that caused by the transient output of a lower capacitance (CVT) .

Increasing the (CVT) capacitance value can increase the (CVT) cost but decreases the (CVT) transient response. Thus, protection engineers must strike a balance between (CVT) performance and (CVT) cost [1].

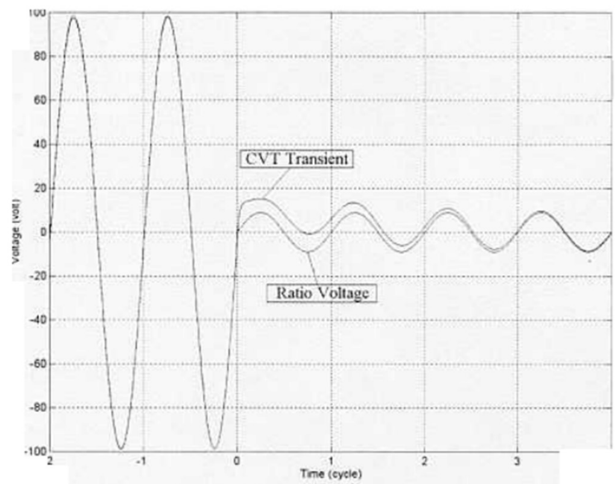

Figure 4 . Transient Response of a High-Capacitance (CVT)

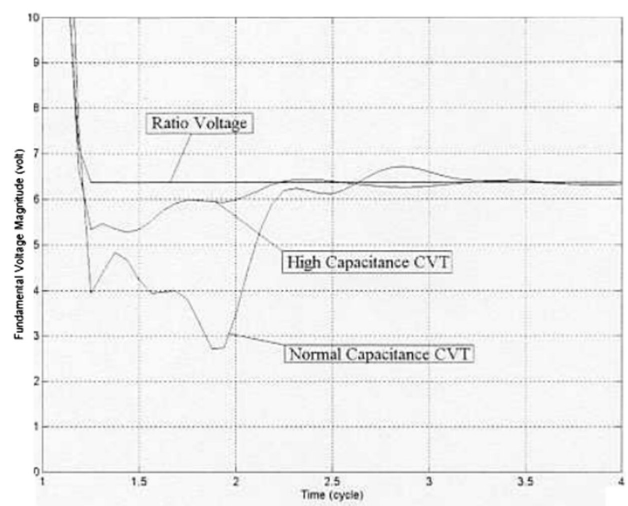

Figure 5 . High-Capacitance (CVT) Causes Less Reduction in the fundamental voltage Magnitude [1]

III. EVENT ANALYSIS

To study the effects of voltage transformer with coupled capacitor, a small network with two stations and with two switches on both sides of the communication transmission line was considered. (CVT) was used on the circuit breaker B1 side and voltage transformer (VT) was used on the circuit breaker B2 side. and the faults at different distances from the transmission line between two stations and in different states of single phase, two phase, three phase to ground and two phases together were modeled in PSCAD software and the output curve of the software includes voltage, current, residual current And the function of the distance relay was obtained when the fault occurred, which can be seen in the figures Software output.

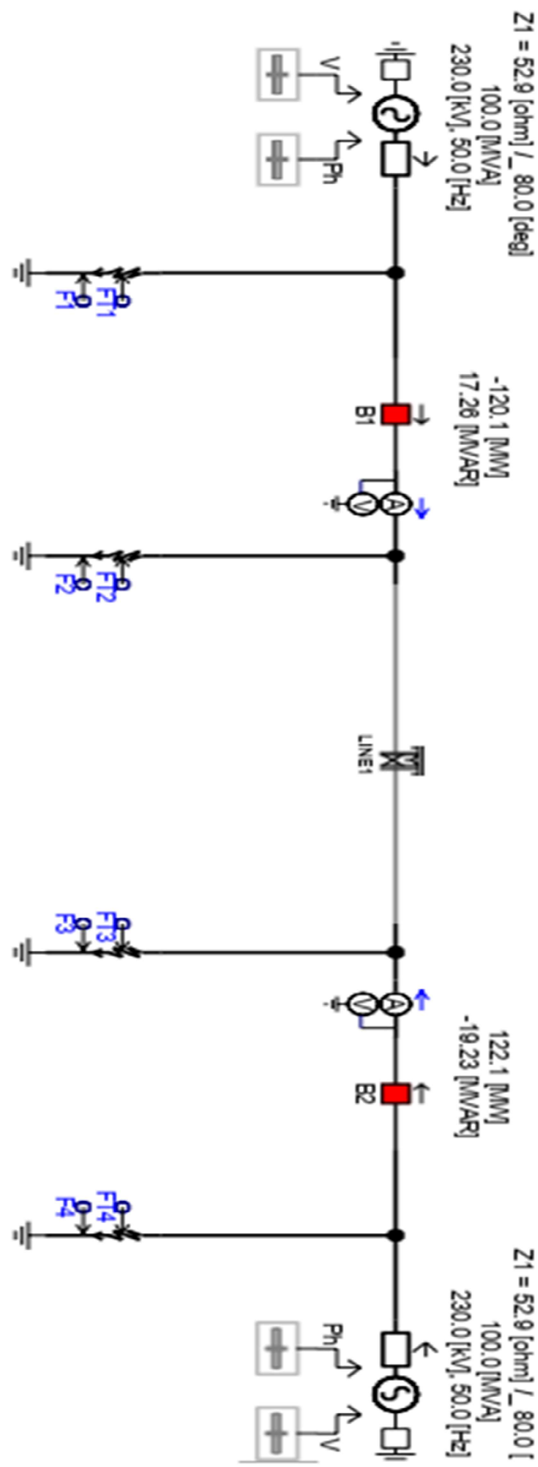

Figure 6 . The studied network with two stations and with two switches on both sides of the communication transmission line

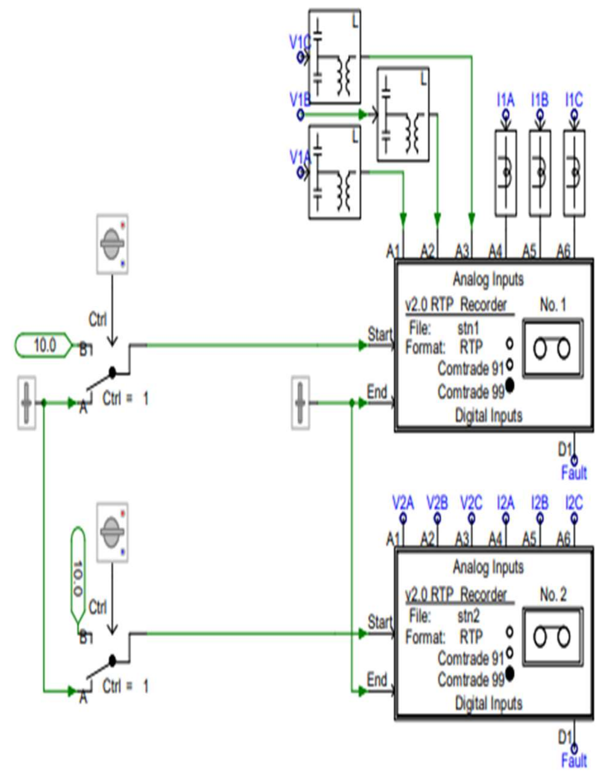

Figure 7 . Connections (CVT) , (VT) and (CT) to the relays

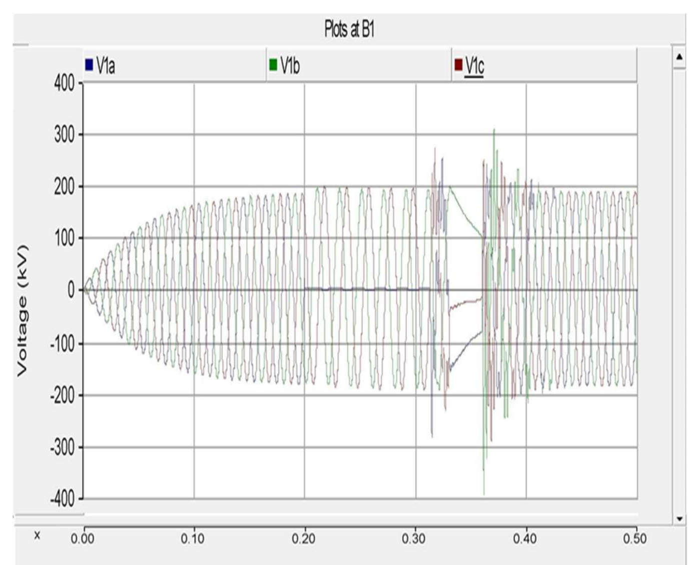

Figure 8 . Curve of voltage with single phase to ground fault at position F1 for circuit breaker B1 in the studied network

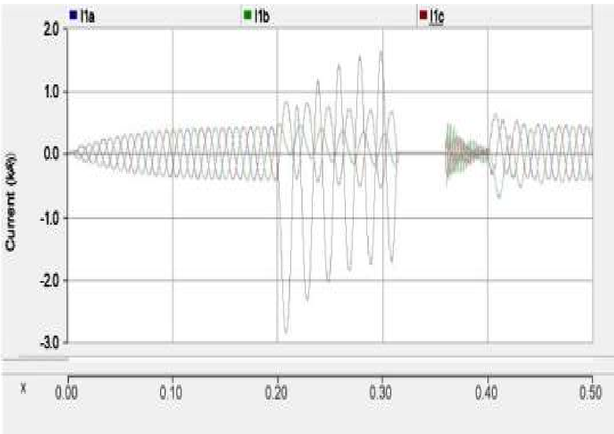

Figure 9 . Curve of current with single phase to ground fault at position F1 for circuit breaker B1 in the studied network

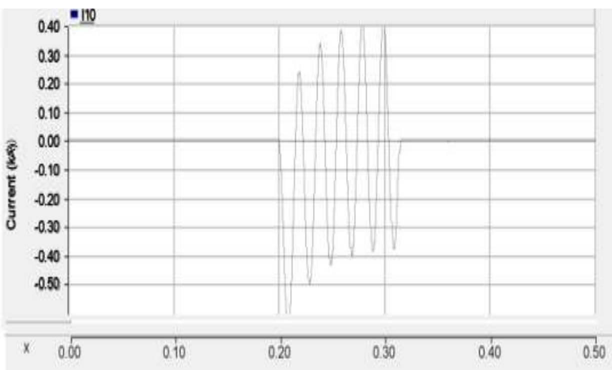

Figure 10 . Curve of residual current with single phase to ground fault at position F1 for circuit breaker B1 in the studied network

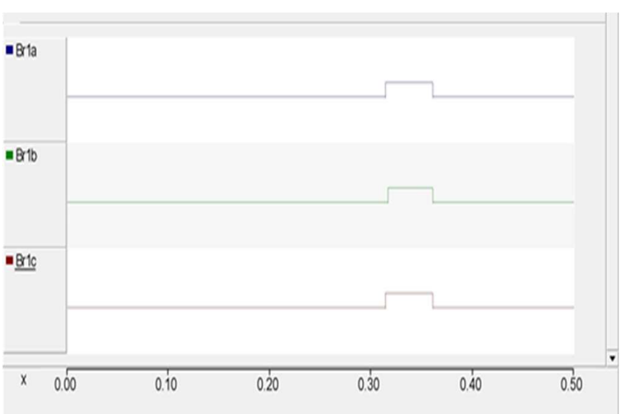

Figure 11 . Curve of relay performance with single phase to ground fault at position F1 for circuit breaker B1 in the studied network

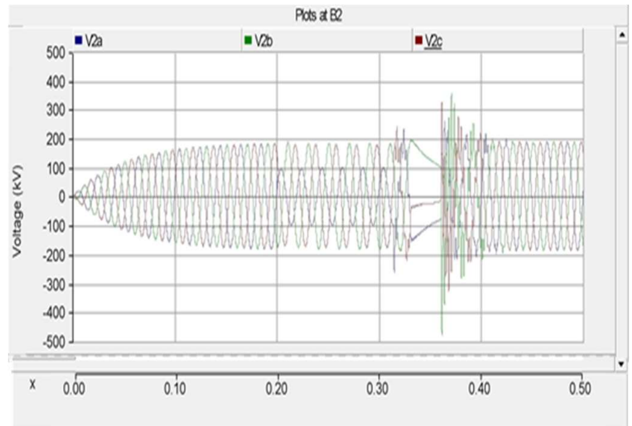

Figure 12 . Curve of voltage with single phase to ground fault at position F1 for circuit breaker B2 in the studied network

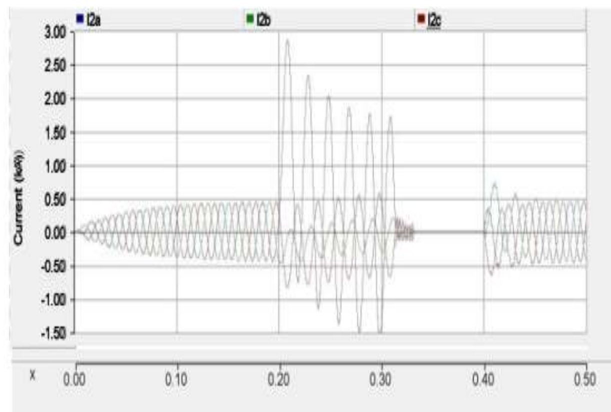

Figure 13. Curve of current with single phase to ground fault at position F1 for circuit breaker B2 in the studied network

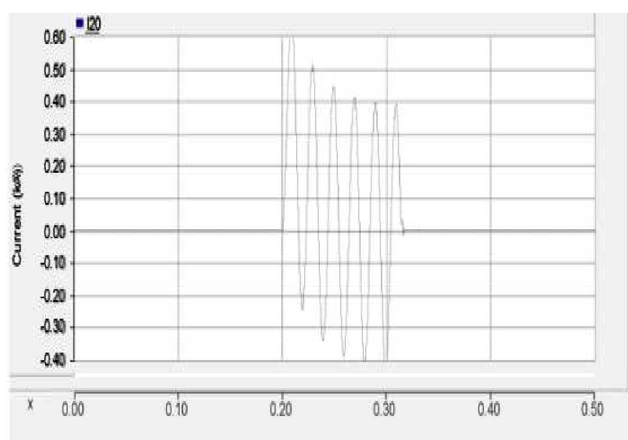

Figure 14. Curve of residual current with single phase to ground fault at position F1 for circuit breaker B2 in the studied network

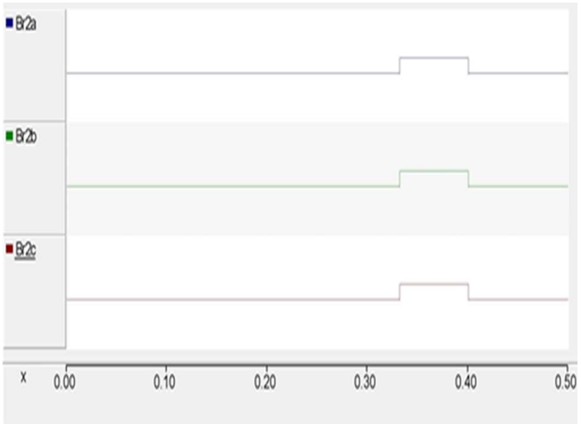

Figure 15. Curve of relay performance with single phase to ground fault at position F1 for circuit breaker B2 in the studied network

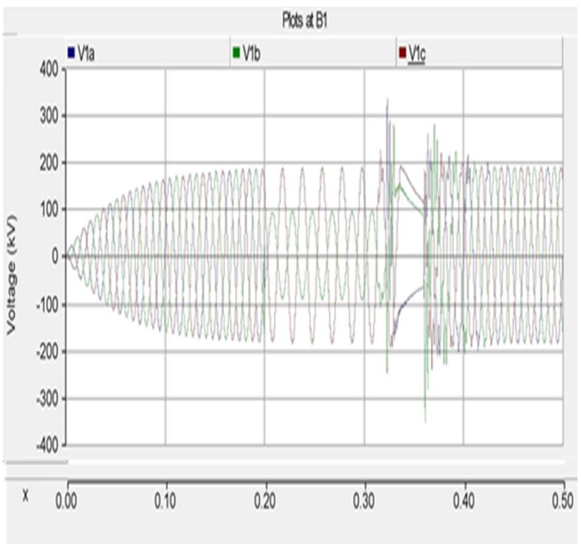

Figure 16. Curve of voltage with two phase fault at position F2 for circuit breaker B1 in the studied network

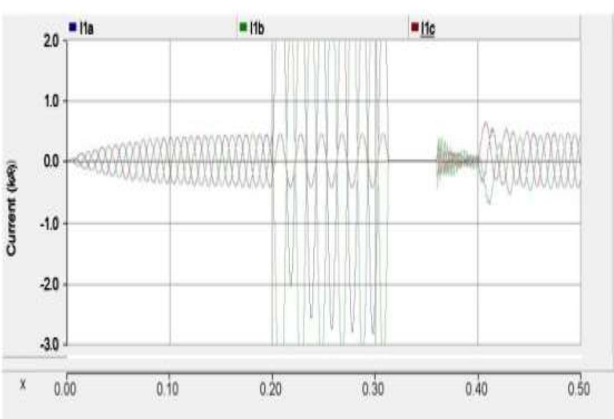

Figure 17. Curve of current with two phase fault at position F2 for circuit breaker B1 in the studied network

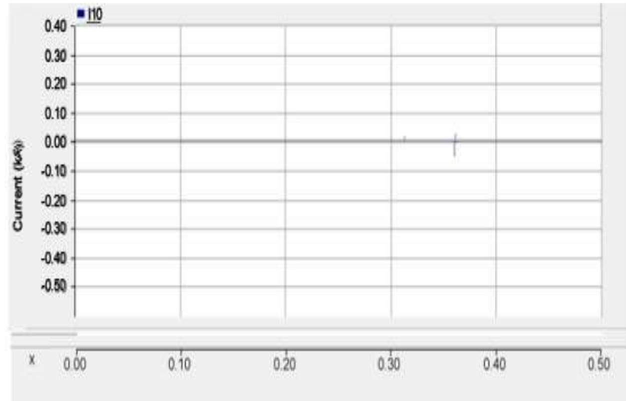

Figure18. Curve of residual current two phase fault at position F2 for circuit breaker B1 in the studied network

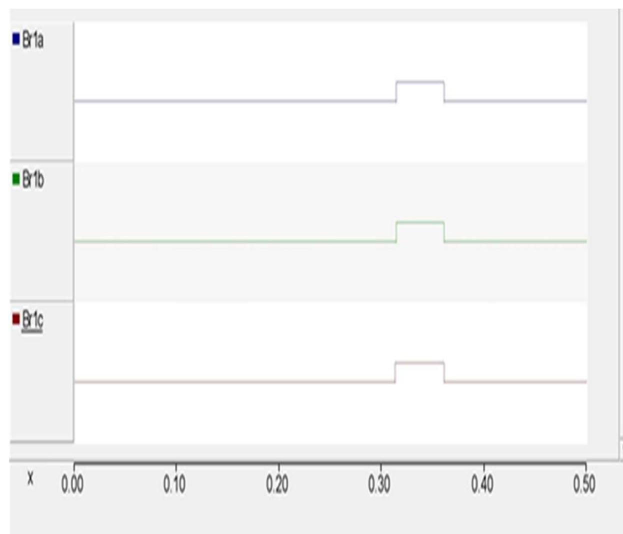

Figure 19. Curve of relay performance with two phase fault at position F2 for circuit breaker B1 in the studied network

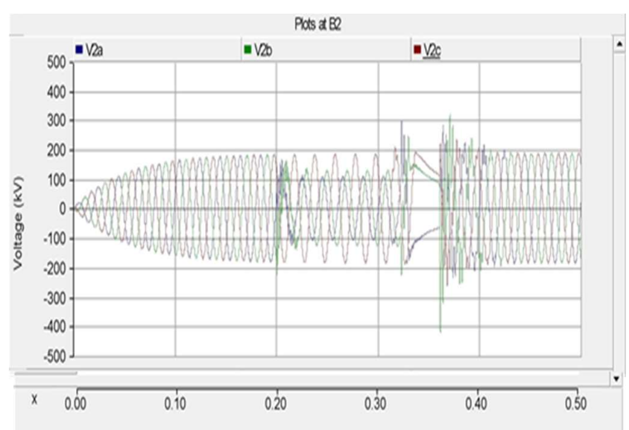

Figure 20. Curve of voltage with two phase fault at position F2 for circuit breaker B2 in the studied network

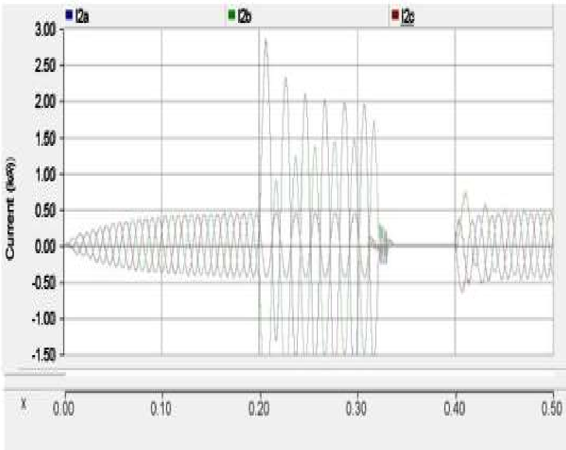

Figure 21. Curve of current with two phase fault at position F2 for circuit breaker B2 in the studied network

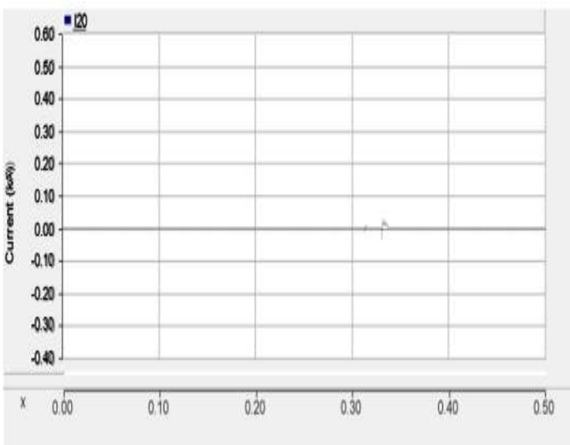

Figure 22. Curve of residual current with two phase fault at position F2 for circuit breaker B2 in the studied network

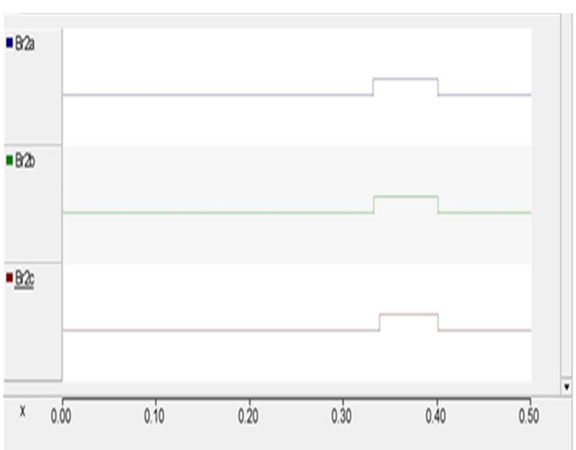

Figure 23. Curve of relay performance with two phase fault at position F2 for circuit breaker B2 in the studied network

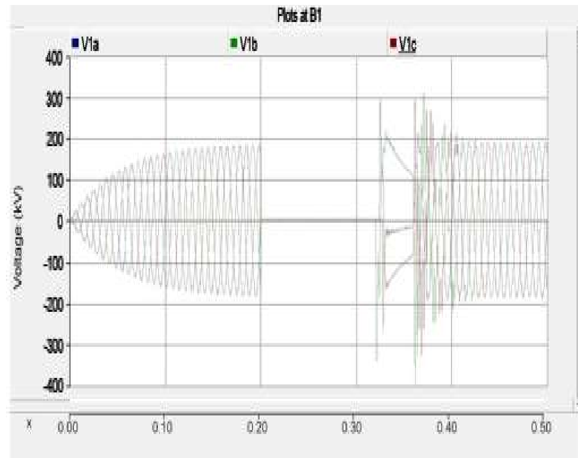

Figure 24. Curve of voltage with three phase fault at position F2 for circuit breaker B1 in the studied network

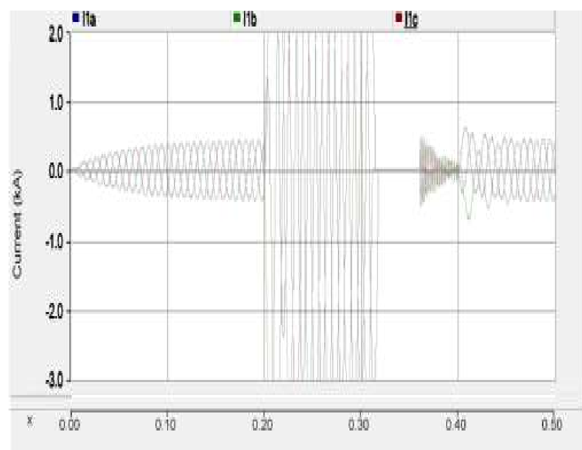

Figure 25. Curve of current with three phase fault at position F2 for circuit breaker B1 in the studied network

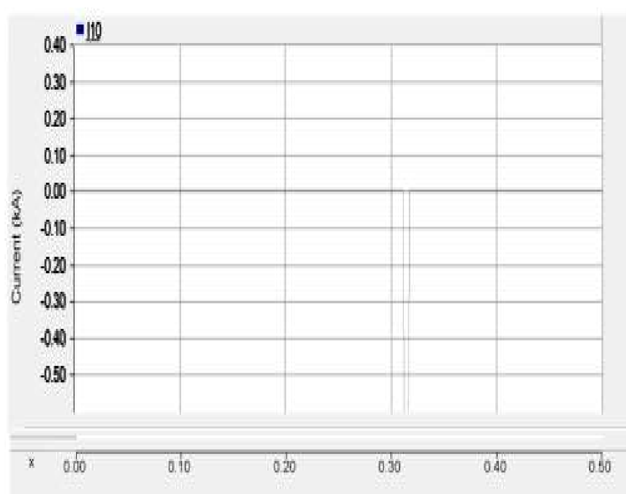

Figure 26. Curve of residual current with three phase fault at position F2 for circuit breaker B1 in the studied network

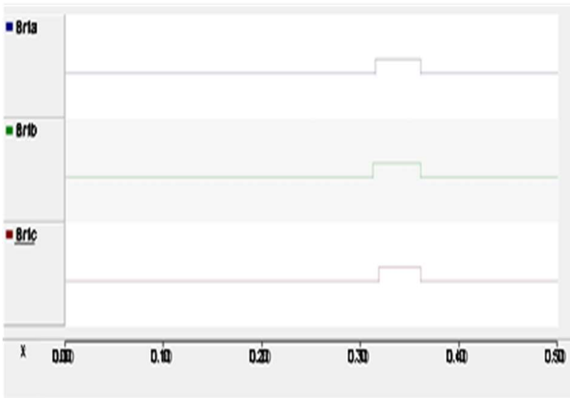

Figure 27. Curve of relay performance with three phase fault at position F2 for circuit breaker B1 in the studied network

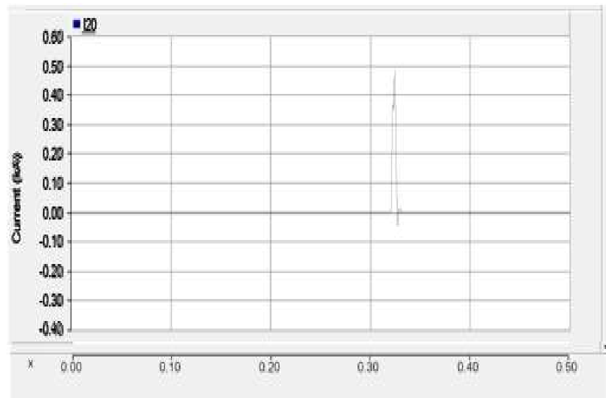

Figure 30. Curve of residual current with three phase fault at position F2 for circuit breaker B2 in the studied network

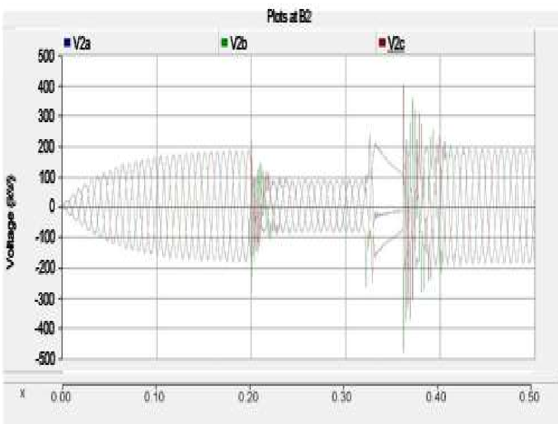

Figure 28. Curve of voltage with three phase fault at position F2 for circuit breaker B2 in the studied network

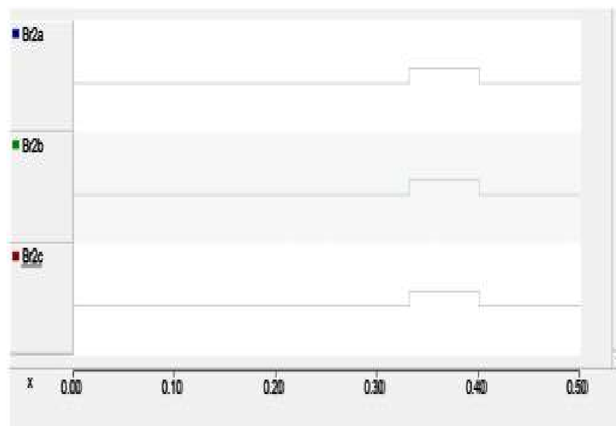

Figure 31. Curve of relay performance with three phase fault at position F2 for circuit breaker B2 in the studied network

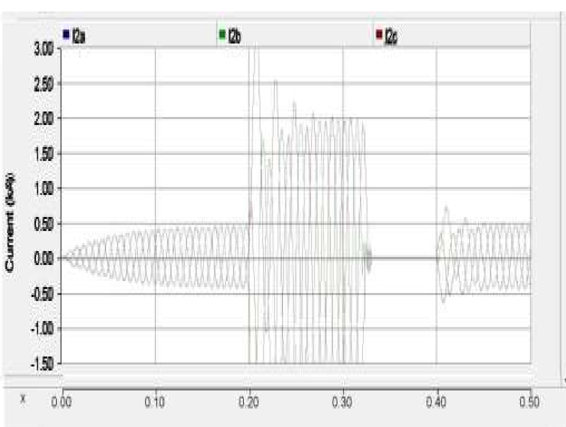

Figure 29. Curve of current with three phase fault at position F2 for circuit breaker B2 in the studied network

Examining and comparing the output curves of the software in stations 1 and 2 with the inputs of trans-voltage and trans-voltage capacitors on the sides of the transmission line “Figure 8 to 31” shows that the relays function in two stations when a single-phase to ground, two-phase and three-phase to ground fault occurs. They are the same with a slight difference. Therefore, it can be concluded that these two types of voltage transformer inputs to the relay will not cause significant performance differences.

IV. CONCLUSIONS

Preventing a misoperation with a relay setting is not the same as finding root cause. High-speed relays require properly performing CVTs. Relays should have the most recent firmware available. Relays logic is not able to detect certain CVT failures [2]; Care must be taken when setting alarm elements to balance sensitivity with the security of the alarm for normal power system unbalance.

Distance element overreach due to CVT transients is not a problem for low SIR applications.High-capacitance

CVTs reduce distance element overreach because the transients they produce have a lower magnitude as compared to lower C-ratings for CVTs [3].The proposed CVT transient detection logic is superior to past detection methods for the following reason : It does not require special user or factory settings. It introduces minimum delay for in-zone faults.

As a result, we don't need to make a special change in the distance relay logic or prepare a special method to calculate the distance relay settings.

V.References

[1] Daqing Hou and Jeff Roberts,"Capacitive Voltage Transformers: Transient Overreach Concerns and Solutions for Distance Relaying," Schweitzer Engineering Laboratories, Inc. , Revised edition released October 2010. Pullman, W A, USA.

[2] Sophie Gray, Derrick Haas and Ryan McDaniel, "CCVT Failures and Their Effects on Distance Relays," Schweitzer Engineering Laboratories, Inc. 20180307 • TP681

[3] Power System Relaying Committee, "IEEE Guide for Protective Relay Applications to Transmission Lines," IEEE Std C37.113™-2015, 3 Park Avenue, New York, NY 10016-5997 USA.