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Conference Paper

Prevention of Cascaded Events of Distance Relay Zone Three Using Logic Controls

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This paper presents a new method to prevent cascaded events caused by zone 3 elements of distance relays due to transmission line overload by using logic controls. A proposed adaptive distance relay algorithm provides a new concept to distinguish between actual faults and flow transfers and secures time to perform remedial controls by a defense system during cascaded events. Maloperation of distance relay is a very critical situation, leading to more operation of other distance relays and finally partial or total blackout. Logic controls are used to insure the operating decision through observing the system parameters and compare it with a setting already being input to the system. When distance relay is activated and the logic controls find that the system is healthy (unfaulted) and that the activation resulted from transmission line overload not real fault, the operation signal will be blocked to protect the system from maloperation.

1. Introduction

Transmission lines are a vital part of the electrical distribution system , as they provide the path to transfer power between generation and load. Transmission lines operate at voltage levels from 66 kV to 765 kV and are ideally tightly interconnected for reliable operation.

Factors like deregulated market environment, economics, right of way clearance, and environmental requirements have pushed utilities to operate transmission lines close to their operating limits. Any fault, if not detected and isolated quickly will cascade into a system-wide disturbance causing widespread outages for a tightly interconnected system operating close to its limits. Transmission protection systems are designed to identify the location of faults and isolate only the faulted section. The key challenge to the transmission line protection lies in reliably detecting and isolating faults compromising the security of the system [1].

The effects of a major blackout have become more serious as a result of the wide area interconnections. Due to the lack of transmission enhancement during the last decades and the resulting low security margins, the risk of major outages for the power grid has also increased [1].

Distance protection is the most widely used method to protect transmission lines. The fundamental principle of distance relaying is based on the local measurement of voltages and currents, where the relay responds to the impedance between relay terminal and the fault location. As compared to differential protection, distance protection can operate properly without a communication device. This aspect is attractive from both a reliability and an economical point of view. However, in some applications, communication links are used as a supplement to speed up the fault clearing time [2, 3].

In usual practice, distance relays are constructed to give three zones protection in forward direction and one zone in reverse each zone has different time delaying. Faults occurring within those zones are cleared by circuit breakers [4].

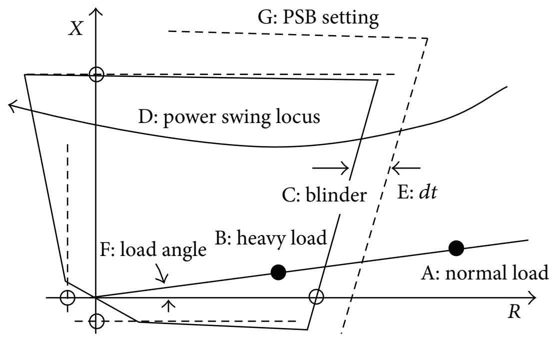


Figure 1: Characteristics of a distance relay.

Table 1: Line impedances of the six-bus system.

Line	Z (ohm)	Y (mho)
L1	26.6 + J105.8	J3.8E − 5
L2	26.6 + J105.8	J3.8E − 8
L3	42.3 + J158.7	J5.7E − 5
L4	26.34 + J52.9	J1.89E − 5
L5	52.9 + J158.7	J3.8E − 5
L6	37 + J105.8	J3.8E − 8
L7	26.5 + J52.9	J5.7E − 5
L8	26.5 + J52.9	J1.89E − 5

Power swing, over load, transient periods, or current in feed may cause maloperation of distance relay for zone 3, because the value of the impedance may move and locate in zone 3 activation zone Figure 1. So, the distance relay will be activated, although the network is healthy. As a result of this operation, the flow of the disconnected line will flow in the rest lines causing more overloading on it, leading to more operation of other distance relays and finally partial or total blackout. So, the tripping signal must be blocked in this case to prevent undesirable operation [5–7].

Logic controls are used to insure the operating decision through observing the system parameters and compare it with a setting already being input to the system. So, when the distance relay is activated the logic controls can send the operation signal or block it depending on the observing system parameters and the input setting. When distance relay is activated and the logic controls find that the system is healthy and the activation resulted from transmission line overload not real fault, the operation signal will be blocked to protect the system from maloperation. If the overload increases, the program will take another action like load shedding.

2. Flow Chart of the Logic Control Characteristic

Distance protection can operate without communication links (*nonpilot distance relay*) or with communication links (*pilot distance relay*).

2.1. Nonpilot Distance Relay. In nonpilot distance relays, program takes local measurements for currents and voltages and calculates the impedance of the line; *nonpilot* means no communication system between distance relays in different buses. When the calculated impedance of the line reduces and locates in zone 3 activation zone, the program will compare the value of voltage with a setting value already being input in the program and the same in the current. When the program finds that the values of voltage and current are within acceptable range, the program will block the trip signal for zone 3, or it will send load shedding signal to disconnect some of the loads to recover the stability to the network. The following flow charts are for logic control characteristic in distance protective relay in case of being without load shedding and with load shedding Figures 2 and 3.

Figures 4 and 5 show the logic control of distance protective relay in case of being without load shedding and with load shedding. In case of being without load shedding, when the three parameters of (Z, V, and I) were achieved, the logic control would delay the trip signal with setting of zone 3 delayed time; after this time, if the parameters are still in activation zones, the logic control will send trip signal to the line breaker. In case of with load shedding, when the three parameters of (Z, V, and I) were achieved, the logic control would delay load shedding signal with time delay that is less enough for zone 3 delayed time; after this time, if the parameters are still in activation zones, the logic control will send load shedding signal. If the parameters are still in activation zones, the logic control will send a trip signal to the line breaker.

Setting of voltage depending on the acceptable dipping level allowable was according to North of American Reliability Corporation (NERC), automatic load shedding was set blow 0.9 P.U. with time delay from 3.5 sec to 8 sec, and the setting of generation unit under voltage was set at 0.8 P.U.; so, the setting of voltage must be set higher enough for generation unit trip setting. Setting of voltage was put at 0.85 P.U., and setting of current was put lower enough from the physical limit of the transmission line.

3. Case Study

In order to study the feasibility of the proposed algorithm, computer simulations have been performed for a simple six-bus system. Figure 6 shows a system that consists of six buses including three generators, three loads, and eight lines. The generations, loads, and the corresponding MW power on the buses in a normal operation state are given in Figure 6.

Table 1 gives the impedances and admittances of the eight transmission lines. Table 2 provides the settings of blinder elements for the distance relays on each line of the six-bus system. The settings are calculated by the authors according to the setting guideline of Korean Electric Power Cooperation (KEPCO) [1].

The MATLAB Power System Tool Box is used to simulate this case.

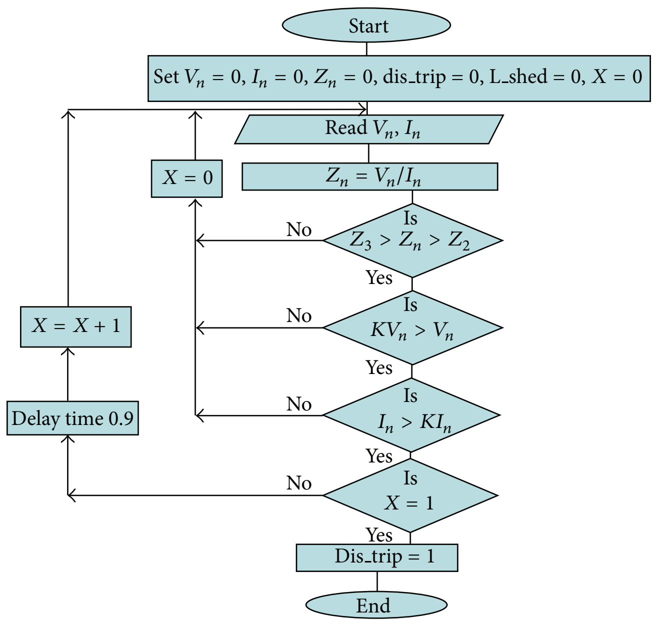


Figure 2: Flow chart of logic control characteristic of nonpilot distance relay in case without load shedding.

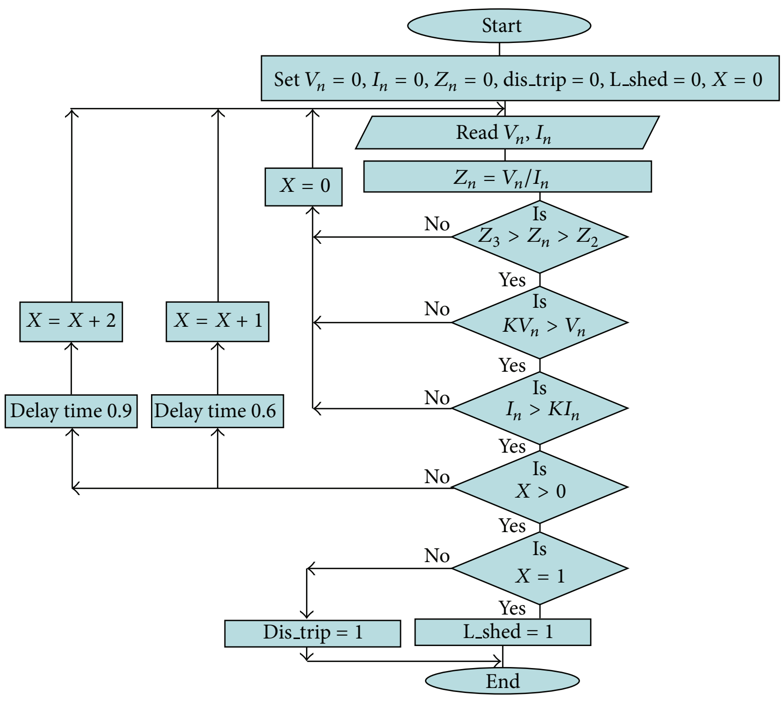


Figure 3: Flow chart of logic control characteristic of nonpilot distance relay in case with load shedding.

4. Simulation and Results

The system under study was simulated to find out the feasibility of the purposed system. The system under study was tested in normal operation, overloaded operation, cascaded events operation, using logic control operation without load shedding, and using logic control operation with load shedding.

Table 3 shows the impedances of all lines in the system seen to the distance relays under normal operation, overloaded operation, and in case of tripping of line 7 leading to cascaded events.

As shown in Table 3, when the system was overloaded with excess 40 MW which might be an acceptable level and line 7 was tripped for any reason, the distance relays were supposed to be in healthy status, and all voltage ranges for

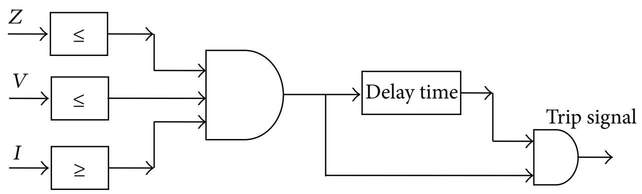


Figure 4: Logic control diagram of nonpilot distance relay in case of without load shedding.

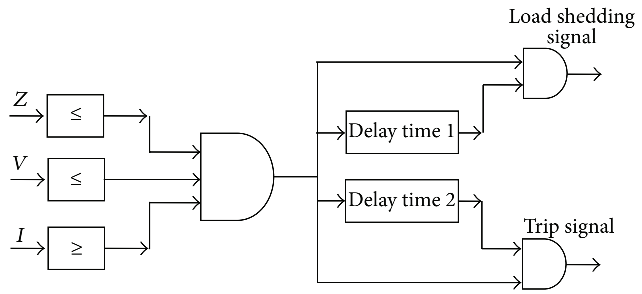


Figure 5: Logic control diagram of nonpilot distance relay in case of with load shedding.

Table 2: Blinder element setting in the six-bus system.

Bus	Line	Setting (ohm)
B1	L1	576.6
B1	L2	576.6
B1	L3	433.7
B2	L4	692.9
B2	L5	692.9
B2	L6	576.6
B3	L7	491.9
B3	L8	491.9
B4	L1	576.6
B4	L2	576.6
B4	L4	692.9
B5	L3	433.7
B5	L5	692.9
B5	L7	491.9
B6	L6	576.6
B6	L8	491.9

all buses were in acceptable levels. But the impedance of some lines moved and located in zone 3, activation zone, and consequently, the second line was tripped. When the second line was tripped, power flowed in the other rest lines that made another distance relay of another line activated and tripped. Another line was the same, which led the system to cascaded events, and finally; the system was divided into two sections; in the first section, the voltage dropped to about 0.30 P.U., and in the second section, the voltage rose to about 2 P.U., and finally, the enter system collapsed.

By observing the system parameters the voltages and the currents shown in Figures 7, 8, 9, 10, 11, 12, 13, and 14, the voltages and the currents were in an acceptable ranges at all buses before tripping the second line by distance relay.

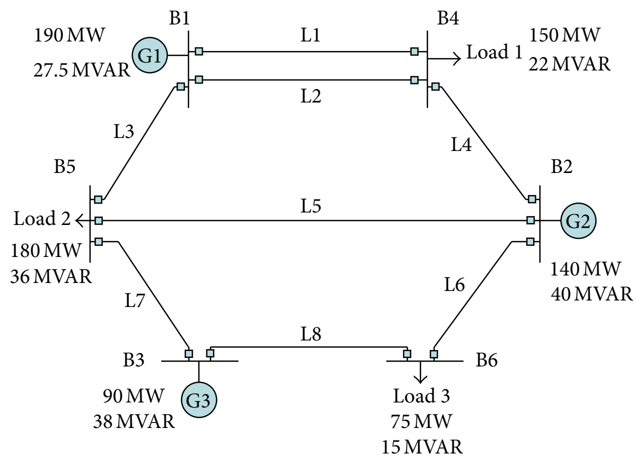


Figure 6: Six-bus system in normal operation condition.

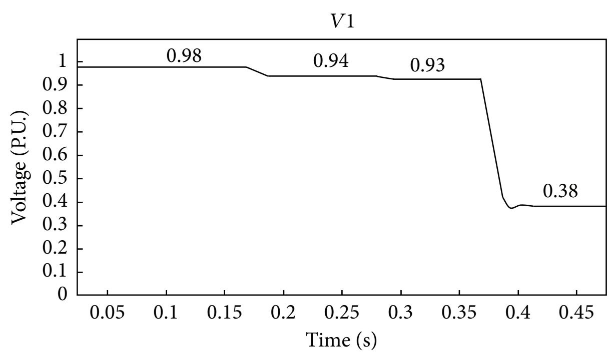


Figure 7: Voltage at bus 1 during cascaded events.

From the previous observing parameters for voltages and currents, it is found that all voltages at all buses were at normal ranges or with acceptable ranges and currents also, until the second line tripped by maloperating of distance relay and the cascaded system collapsed and finally total blackout. This blackout caused by maloperation of the distance relays.

After using logic controls, the system was secured and became more reliable. When the impedance moved and located in activation zone for zone 3, the program would have checked on voltage and current levels for this line and compared these values with input values set on the program. When the program found that the values were within ranges, it blocked the trip signal to protect the enter system from cascaded events.

In the previous case, when line 7 was tripped for any reason, the current of line 5 rose to about 2.2 times of the operation value, and the value of voltage dropped to about 0.87 P.U.; those values activated distance relay and tripped the line leading the enter system to total blackout, although the transmission line was working far of its physical limits, and the dropping of the voltage was not very high. Logic controls observed and analysed these parameters and blocked the trip signal to protect the system from collapsing.

Table 3: Cascaded events leading to a system collapse.

Line	Normal	Overloaded	Trip line 7	2nd line trip	3rd line trip	System is landing
1	3405	3450	9060	2060	1550	
2	3405	3450	9060	2060	1550	
3	2615	1421	890	452	450	
4	1455	1477	961	*522*	**Trip**	System was divided into two sections, and the voltage dropped to 0.3 P.U. in the 1st section and rose to 2 P.U. in the 2nd section.
5	2340	1252	*657*	**Trip**	**Open**	
6	2614	1891	1835	2445	2718	
7	1346	1020	**Trip**	**Open**	**Open**	
8	3812	9948	881	1118	3573	

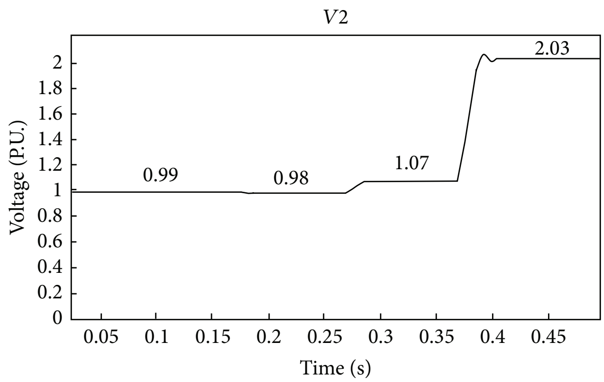


Figure 8: Voltage at bus 2 during cascaded events.

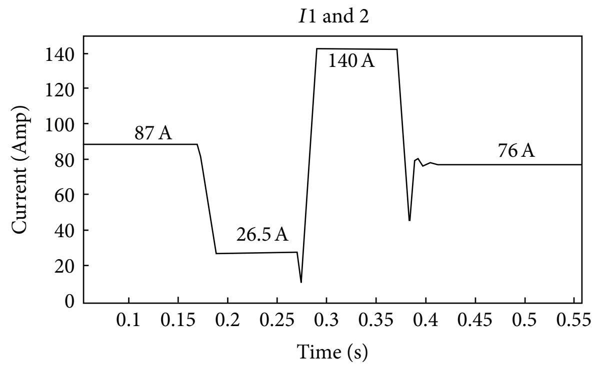


Figure 11: Current in line 1 and 2 during cascaded events.

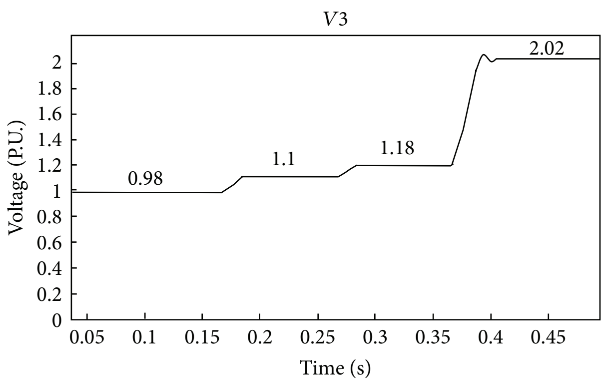


Figure 9: Voltage at bus 3 during cascaded events.

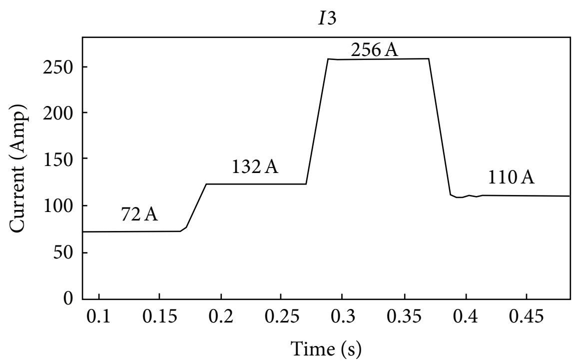


Figure 12: Current in line 3 during cascaded events.

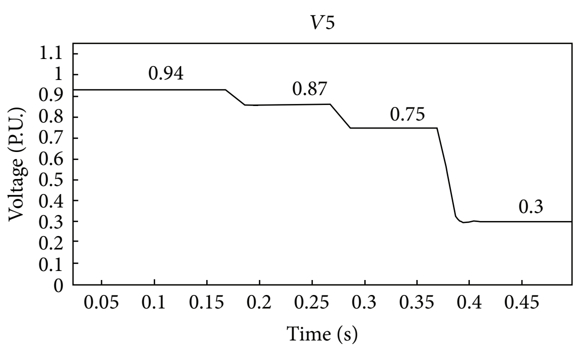


Figure 10: Voltage at bus 5 during cascaded events.

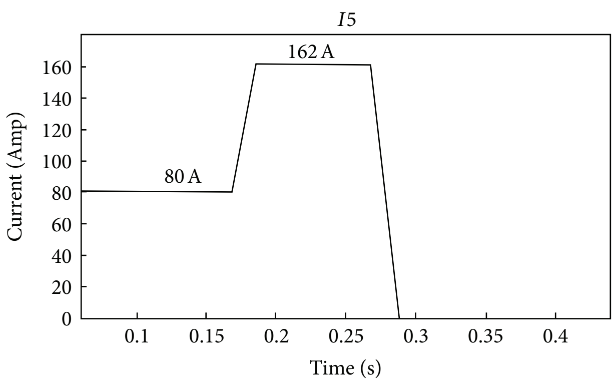


Figure 13: Current in line 5 during cascaded events.

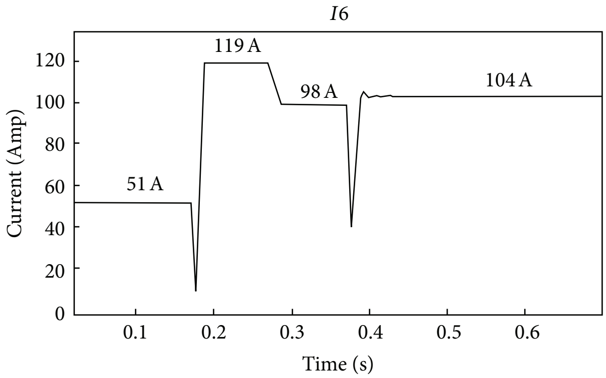


Figure 14: Current in line 6 during cascaded events.

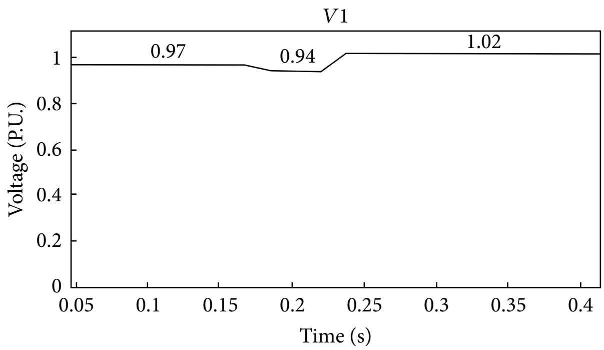


Figure 15: Voltage at bus 1 using load shedding.

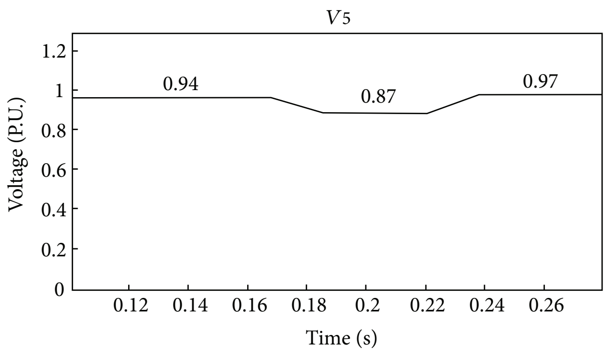


Figure 16: Voltage at bus 5 using load shedding.

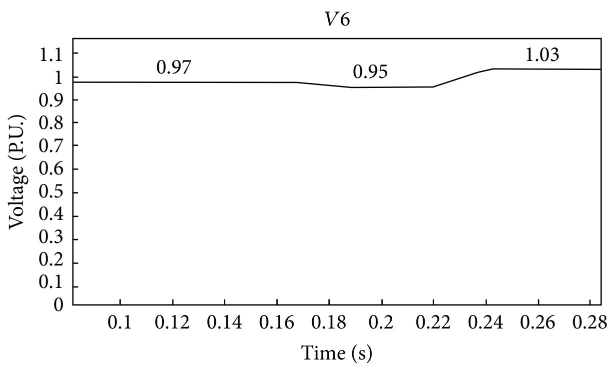


Figure 17: Voltage at bus 6 using load shedding.

Table 4: Cascaded events prevented by using load shedding.

Line	Normal	Overloaded	Trip line 7	After load shedding
1	3405	3450	9060	8580
2	3405	3450	9060	8580
3	2615	1421	890	1165
4	1455	1477	961	963
5	2340	1252	*657*	848
6	2614	1891	1835	1593
7	1346	1020	**Trip**	**Open**
8	3812	9948	881	792

Italic and bold font: abnormal values (faulted values).

Logic control could take remedial controls like load shedding to help system to reach now equilibrium operation point [8]. Amount of load shedding predefined depending on load demand, generation capacity, and may be put in several stages. Location of load to be shed also predefined depending on load center and type of load. Table 4 shows impedances of all lines in the system under normal operation, overloaded operation, and tripping of line 7 in case of using logic control to shed part of the load at bus 5 at about 40 MW to return the system stability. As shown in Table 4, the impedances of all lines after using load shedding moved and located out of activation zone of distance relay zone 3. So, the system was secured against cascaded events that led to total blackout. Time delay of zone 3 is about 900 ms, this is enough time to do the remedial control of load shedding.

Figures 15, 16, and 17 show the voltage at several buses in the system and show the advantage of using logic control.

5. Conclusion

Many factors have pushed utilities to operate transmission lines close to their operating limits, and the utilities must be able to work under such situations with high efficiency. Overloading on the transmission lines became often matters. Maloperation of distance relays is a very critical situation, leading to more operation of other distance relays and finally partial or total blackout. As shown in this paper, the use of logic controls with distance protection relays secures the utilities and makes it more reliable in many critical cases. In addition to adding a great advantage to the system by distinguishing between actual faults and flow transfers or overloading and securing time to perform remedial controls like load shedding during cascaded events, logic controls are used to insure the tripping decision through observing and analyzing system parameters.

References

[1] S. I. Lim, C. C. Liu, S. J. Lee, M. S. Choi, and S. J. Rim, "Blocking of zone 3 relays to prevent cascaded events," *IEEE Transactions on Power Systems*, vol. 23, no. 2, pp. 747–754, 2008.

[2] M. Jonsson, *Line Protection and Power System Collapse*, Department of Electric Power Engineering, Chalmers University of Technology, Gothenburg, Sweden, 2001.

[3] T. Manokaran and V. Karpagam, "Performance of distance relay estimation in transmission line with UPFC," *International Journal of Computer and Electrical Engineering*, vol. 2, no. 1, pp. 158–161, 2010.

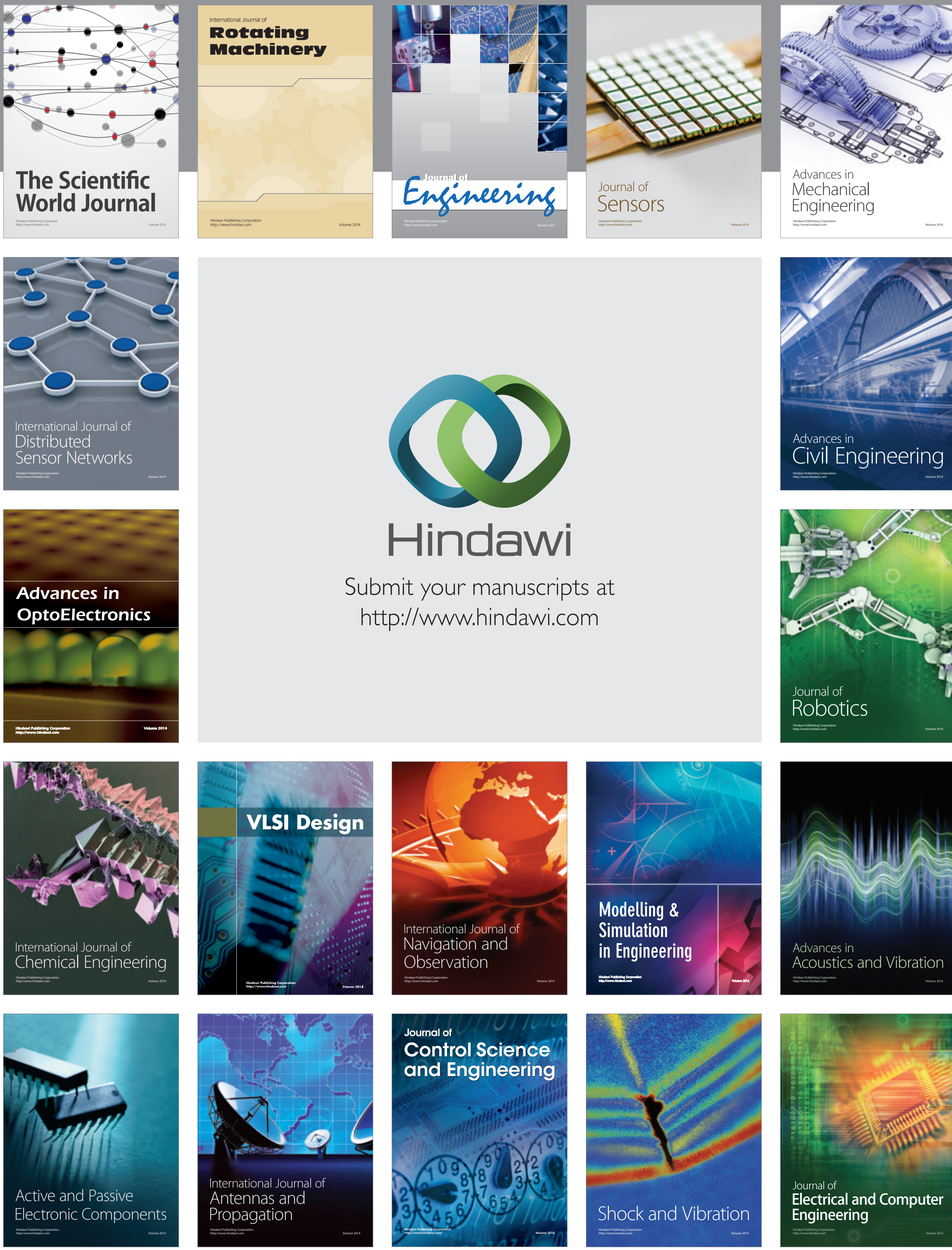
[4] C. J. Mozina, M. Reichard, Z. Bukhala et al., "Coordination of generator protection with generator excitation control and generator capability," in *Proceedings of the IEEE Power Engineering Society General Meeting (PES '07)*, June 2007, paper no. 1-4244-1298-6/07.

[5] J. G. Andrichak and G. E. Alexander, "Distance Relays Fundamentals," GE Power Management, General Electric Co. Malvern, PA, GER-3966.

[6] N. Zhang and M. Kezunovic, *Verifying the Protection System Operation Using an Advanced Fault Analysis Tool Combined with the Event Tree Analysis*, Department of Electrical Engineering, Texas A&M University, College Station, Tex, USA, 2004.

[7] M. Jonsson, J. Daalder, and K. Walve, "An emergency strategy scheme based on conventional distance protection to avoid complete system collapse," in *Proceedings of the IEEE PES Transmission and Distribution Conference and Exposition*, pp. 315–319, September 2003.

[8] Undervoltage Load Shedding Task Force (UVLSTF), *Undervoltage Load Shedding Guideline*, Technical Studies Subcommittee, Western Systems Coordinating Council, 1999.



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