THE DEVELOPMENT OF THE IMPEDANCE MEASURED BY DISTANCE RELAY

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Abstract: This paper explains the possibility of implementation of a model of a quadrilateral characteristic type of distance relay with the zones using MATLAB/SIMULINK package. SimPowerSystem was used to present modeling of distance relay. The quadrilateral R-jX plain was created to show the trajectory of measured impedance using the distance relay. The relay identifies the fault locations as expected. The impedance path reflects to the power system model under fault conditions. The goal of this paper is to describe the building and designing distance relay characteristic using Simulink model, inside the modeling, impedance calculation, zone coordination were designed.

Keywords: distance relay; quadrilateral characteristic; power system protection; near-to-generator short circuit; SIMULINK.

1. INTRODUCTION

Distance protection forms the basis for network protection in transmission, as well as interconnected distribution network. Distance protection is usually faster and more selective than over current protection. It is also less susceptible to changes in relative source impedances and system conditions [1]. Fully digital distance protection utilizes microprocessor technology with analogue to digital conversion of the measured values (currents and voltages) computed (numerical) distance determination and digital processing logic. For correct function of the relays there is necessary to take care about all possible states during transient phenomena in power systems. At present very useful and comfortable way of short circuit calculation technique is modeling and simulation in sophisticated mathematical tools. These techniques can be also used for power system protection setting and coordination. The example of simulation tool is MATLAB/SIMULINK which is a convenient and interactive tool for both numerous analysis and direct communications with relay's test program. Digital distance protection is a universal short-circuit protection. It's mode of operation is based on the measurement and evaluation of the short-circuit impedance, which is named by the algorithm of digital distance relay. They are used to calculate line impedance by measurement of voltages and currents on one single end. For example, for MHO and quadrilateral relay type distance relays, the relays compare the set impedance with the measured impedance to determine if the fault is inside or outside the protected zone. They immediately release a trip signal when the impedance value is inside impedance of the zone 1 of distance relay. For secure protection consideration the confirmation of a fault occurrence is not made until successive trip signals. An analysis of fault scenarios is performed for three different locations along the line. The three selected locations are the begin of the line in zone 1, line 2 (zone 2), and in line 3 (zone 3).

2. QUADRILATERAL RELAY ALGORITHM

Most relays (e.g. with MHO characteristic) were based on a balanced beam structure or induction cup unit, which generate only continuous characteristics such as a circle or a straight line. Quadrilateral characteristics are discontinuous and their characteristics cannot be generated by electro mechanical relays devices. With this type of characteristic, the tripping area can be arranged closely to enclose the desired tripping area. The ability to detect significant resistance associated with arc is important. The ability to closely enclose the desired trip area leads to more secure application. Quadrilateral elements with plain reactance affected lines can introduce error problems for resistive earth faults where the angle of total fault current is different from the angle of the current measured by the relay. This is the case where the local and remote source voltage vectors are phase shifted with respect to each other due to pre-fault power flow. This phase difference can be overcome by using a phase current for polarization of the reactance of affected line. Polygonal impedance characteristics are highly flexible in terms of fault impedance coverage for both phase and earth faults [3].

2.1. FUNCTION AND ALGORITHM

Distance relays generally requires fourteen input signals, namely, harmonic magnitude and phase of three phase voltages and phase currents signals, zero sequence magnitude and phase current to obtain phase quantities. In this work all the 14 signals are obtain from simultaneously taken samples of 6 signals namely three phase to ground voltages and three phase currents [3]. Modern distance relays offer quadrilateral characteristic, whose resistive and reactive range can be set independently. It therefore provides better resistive coverage than any mho-type characteristic for short lines. This is especially true for earth fault impedance measurement, where the arc resistance and earth resistance are contributing to the highest values of fault resistance. Polygonal impedance characteristics are highly flexible in terms of fault impedance coverage for both phase and earth faults. For this reason, most digital relays offer this form of characteristic [1]. Since utilities need to keep all the settings of the relays from different types and various manufacturers in a data base, they need to overcome these differences. Things get further complicated when the distance relays settings need to be coordinated with other relays in front or behind them or when the distance characteristics have to be tested to evaluate the relay performance or to analyze its operation. In these cases knowing the settings is not sufficient – knowledge of the behavior may be required as well [1].

2.2. SETTING OF QUADRILATERAL CHARACTERISTICS USING SIMULINK/MATLAB

Quadrilateral relay is set to three zones to protect and cover the transmission line. Three zones quadrilateral characteristics used to protect transmission line are explained in Table 1 [3]. This characteristic was designed using MATLAB /SIMULINK and was determined for three parts of line.

Relay setting			
Zone	**Setting**	**Values (Ω)**	**Time setting (S)**
Zone 1	$80\% T_{L1}$	11.5	0.15
Zone 2	$T_{L1}+60\% T_{L2}$	22.4	0.35
Zone 3	$T_{L1}+T_{L2}+60\% T_{L3}$	33.5	0.60

TABLE 1: Settings of zones of protection

3. SINGLE PHASE FAULT IN QUADRILATERAL DISTANCE RELAY

Traditionally, the distance relay zones have been set according to simple rules. The non-traditional options can be grouped according to their conceptual basics: based on expert systems, mathematical optimization, adaptive protection or probabilistic methods [3, 4].
The final stage of the model is to develop the quadrilateral characteristics of the distance relay.

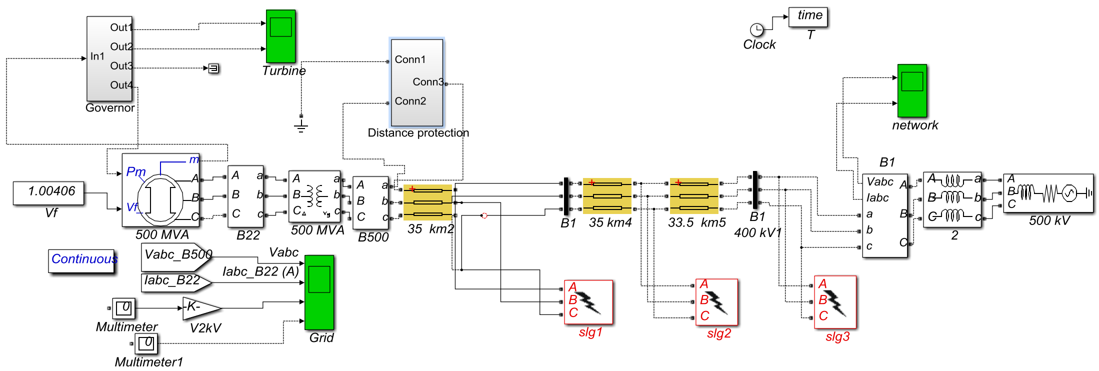

Figure 2: System model

This step helps to understand and figure out how the distance relay works. Single phase fault was set at distance 35 km, 70 km and 110 km to check the behavior of quadrilateral characteristics distance relay of this type of near-to-generator fault. The impedance trajectory seen by the quadrilateral distance relay due to this type of fault is shown in Fig. 3, 4, 5.
Quadrilateral characteristics with their availabilities to be increased only in one direction (R or X) is used to overcome the problem of high resistance fault. For each stage of distance relay the characteristics can be extended only in R direction with fixed X setting.

• C.l. Criterion used/or the reactive reach
The first criterion states that zone 1 only has to operate for faults on the line since this zone is instantaneous. Zone 1 should not operate for faults at the remote bus, by selectivity.
Zone 1 reactive reach (will be set to 80% of the reactance of the protected line) $X_{Z1} = k_Z \cdot X_{L1}$.
• C.2. Criterion used/or the resistive reach
According to the previous paragraph, zone 1 resistive reach must be set in a way that assures that the relay first zone will not trip for faults at the remote bus $X_{Z2} = k_Z \cdot (X_{L1} + k_Z \cdot X_{L2})$.
• C.3. Criterion used/or the resistive reach
According to the previous paragraph, zone 2 resistive reach must be set in a way that assures that the relay second zone will not trip for faults at the remote bus $X_{Z3} = k_Z \cdot [X_{L1} + k_Z \cdot (X_{L2} + k_Z \cdot X_{L3})]$, where $k_Z = 80\%$. Fault impedance can be calculated as

$$\overline{Z}_{slg} = \frac{\overline{V}_A}{\overline{I}_A + 3 \cdot k \cdot \overline{I}_0} \quad (1)$$

Where:

A, indicates faulty phases, g indicates ground fault. $\overline{V}_A$, $\overline{I}_A$, indicates voltage and current phases

$\overline{Z}_0$, $\overline{Z}_1$ = line zero and positive -sequence impedance

k_1 = residual compensation factor where $k_0 = (Z_0 - Z_1)/k \cdot Z_1$

k can be 1 or 3 depend on the relay design.

$I_0 = V_s/(Z_0 + 2 .Z_1)$ Where Vs is phase voltage during the phase to ground fault.

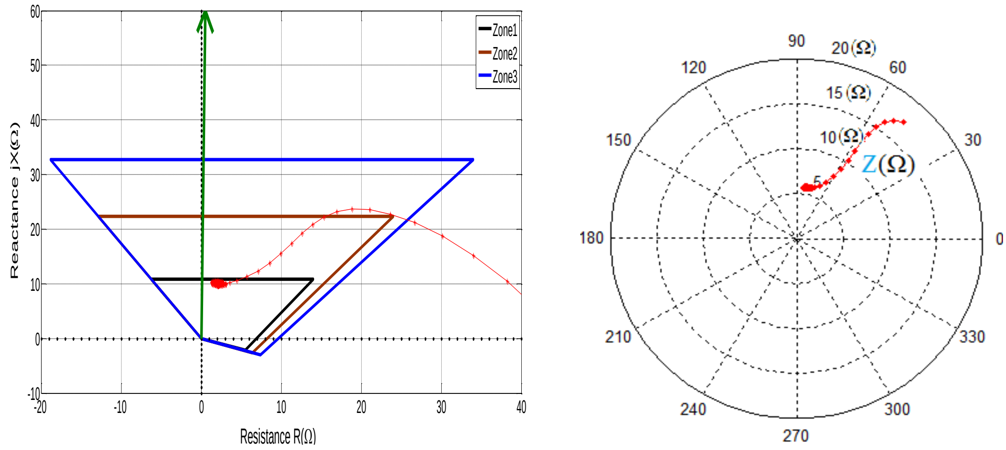

Figure 3: R-jX plot Impedance for a fault at 35 km and time development (zone 1)

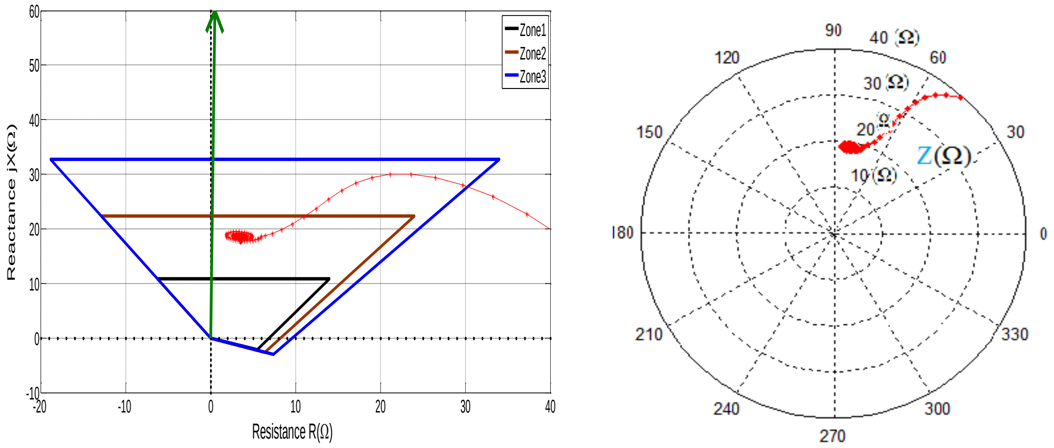

Figure 4: R-jX plot Impedance for a fault at 70 km and time development (zone 2)

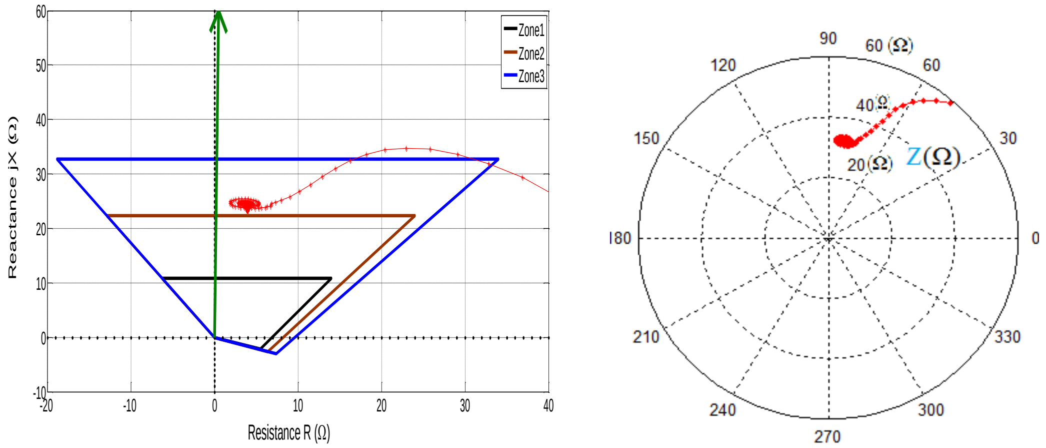

Figure 5: R-jX plot Impedance for a fault at 110 km and time development (zone 3)

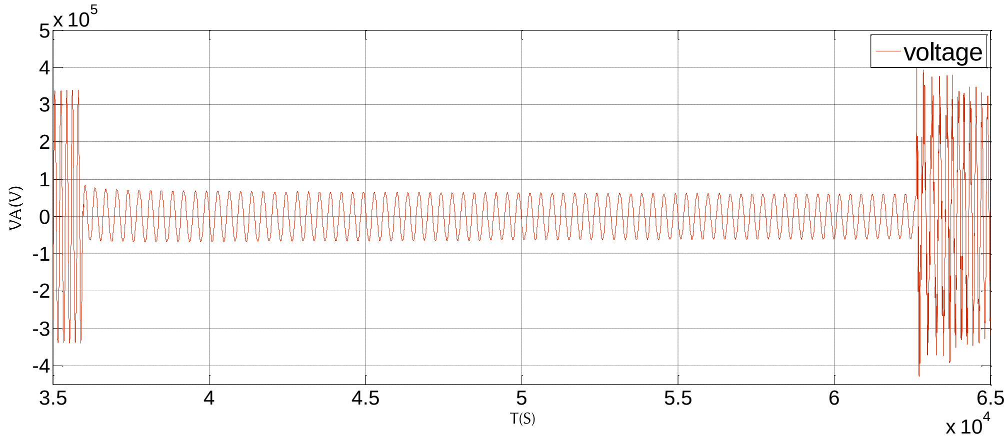

Figure 6: Fault voltage wave in generator side.

4. CONCLUSION

The paper describes introduction part of research focused on development of digital distance protection function based on standard PC platform. The research is based on quadrilateral relay From perspective impedance calculations the relay model has the ability of indicating the correct zone of operation in all cases. The relay identifiers the fault locations as expected, as the fault location is changed, the measured impedance change consequently.

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