12th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

DISCRIMINATION BETWEEN FAULTY CONDITIONS AND POWER SWING IN DISTANCE PROTECTION.

Ladjroud Rafik
Faculty of petroleum and chemistry
University M’hamed Bougara ,
Boumerdes
Algeria

Ouahdi Dris
Faculty of petroleum and chemistry
University M’hamed Bougara,
Boumerdes
Algeria

ABSTRACT
The electrical distribution networks, for their protection against short circuits are mainly equipped with distance protection. This protection which relies upon the impedance measurement; may in some situations initiates a false interrupting signal to its controlled circuit breaker to isolate an un-faulted line; and as a result the maintain of the continuity of the service will be affected.. In This paper an approach to fault detection by the distance protection, which discriminates between the faulty conditions and the Power Fluctuation effect, has been developed. This approach which is based on the symmetrical components is taking into account the consequences of fault resistance and the power swing conditions which both have an effect upon the reliability of the protection in terms of dependability for the former and security for the latter.
Keywords: Distance Protection, Fault Detection, Negative sequence, Power swing, Transmission line.

1. INTRODUCTION
The major objective of electricity supply authority is the continuity of power supply to its customers. In order to meet this objective the protection system to which the primary requirements are reliability, high-speed tripping and selectivity must be able to distinguish between the faulty system and healthy operation conditions. Although the distance protection which is considered to be as the main protection for the transmission lines meets to a certain limit these requirements, it is still suffer from the consequences of the fault impedance and the effect of overload conditions. Under these conditions, this protection which locates a fault when it occurs on a transmission line by measurement of the impedance of the faulted conductors between the relaying location and the fault may initiate an incorrect relay operation. An approach to fault detection based on the symmetrical components; mainly the negative sequence, can be developed. This approach will improve the discrimination between the faulty conditions and the effect of overload and power swing.

2. OVERLOAD AND VOLTAGE INSTABILITY EFFECTS
The overload and voltage instability are phase symmetrical phenomena. Thus the apparent impedance Z_R as seen by a distance relay may be written as: [1]

$$\overline{Z}_r = \frac{\overline{U}_{L1}}{\overline{I}_{L1}} > \frac{\left|\overline{U}\right|^2 .(P + jQ)}{P^2 + Q^2} \quad \dots (1)$$

Where, U is the line to line voltage, P and Q are the injected active and reactive powers at the relay location.
Low system voltages and high power flow are typical cause for impedance measurement errors. It follows from (1) that these events may cause distance relays to operate. The three phase short circuit has the same characteristic as in the overload; high voltage drop and the lifting of current

measurement. In fact, the voltage drop variation $\frac{\Delta V}{\Delta t}$ in the three phase short circuit case is very significant compared to the overload case; therefore, it's appropriate to use this information as criterion for discrimination between these two states.

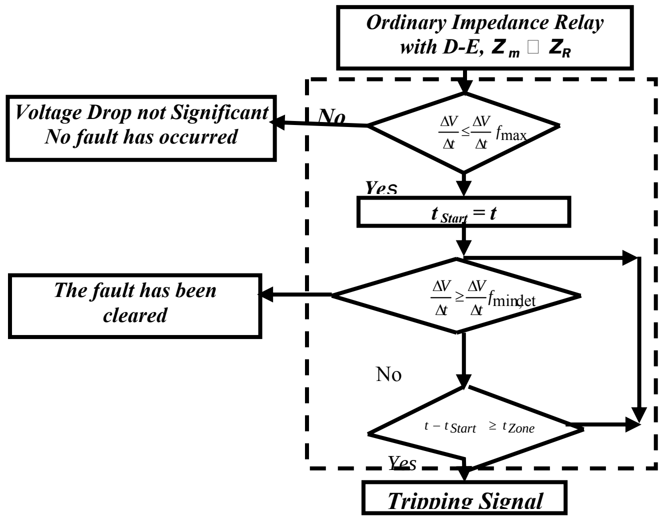

Figure 1. Symmetrical fault detection block diagram

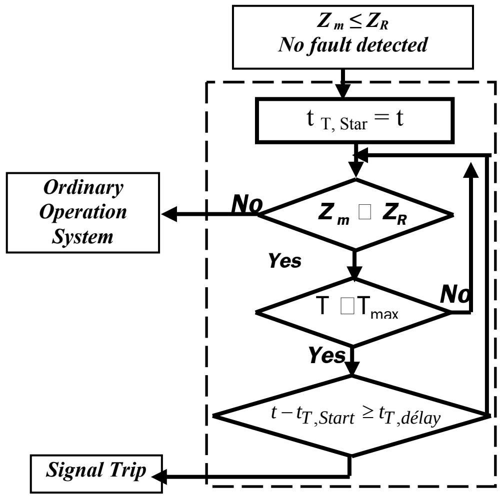

Figure 2. Overload Block Diagram

The block diagram figure 1, checks if a symmetrical short circuit fault has occurred.
When a fault occurs $\frac{\Delta V}{\Delta t}$ will have a negative value with a high magnitude.

$\frac{\Delta V}{\Delta t} \le \frac{\Delta V}{\Delta t} f_{max}$: A fault has occurred. $\frac{\Delta V}{\Delta t} > \frac{\Delta V}{\Delta t} f_{max}$: No fault has occurred.

When the fault is cleared $\frac{\Delta V}{\Delta t}$ will have a positive value with a high magnitude.

$\frac{\Delta V}{\Delta t} \ge \frac{\Delta V}{\Delta t} f_{min,det}$: The fault has been cleared. $\frac{\Delta V}{\Delta t} < \frac{\Delta V}{\Delta t} f_{min,\ det}$: The fault has not been cleared.

In order to maintain the stability of the system and in the moderate voltage drop which characterizes the overload, the relay can be equipped with an additional element that use thermal control parameter to protect the line from overheating figure 2, in which the block diagram checks if the line temperature exceeds the pre-set maximum limit.

Tmax= maximum allowed temperature in the circuit.
t: Timer is started for the thermal overload protection.
$t_{T,\ start}$ = time when the maximum allowed temperature is reached.
$t_{T,delay}$ = time delay for the thermal overload protection to operate

3. POWER SWING EFFECT AND FAULT LOCATION ESTIMATION

Transient instability in power systems generates power oscillations. These oscillations may cause unwanted tripping of distance relays. A brief analysis is exposed bellow. [2]
From (fig. 3), the current and the voltage can be given as:

$$\overline{I} = \frac{E_S\angle\delta - E_R\angle 0}{jX_S + \overline{Z_L} + jX_R} \qquad (2)$$

$$\overline{U} = E_S\angle\delta - jX_S.\overline{I} \qquad (3)$$

$$\overline{Z_S} = \frac{\overline{U}}{\overline{I}} = \frac{E_S\angle\delta}{\overline{I}} \quad jX_S \qquad (4)$$

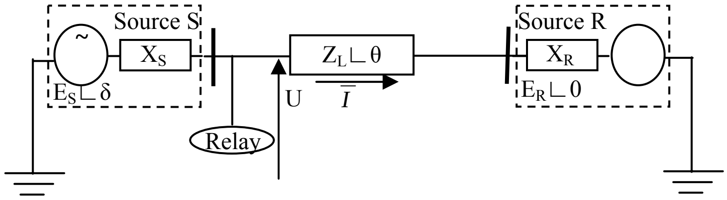

Figure 3. Two machine system

During a power swing the transfer angle δ will vary. For the transfer angle δ = 0, the current $\overline{I}$ in (4) is Zero and thus Z_S is Infinite. As δ increase, Z_S moves towards and enter into operation zone.The analysis made in [2,3,4] show that the phase angle of the voltage before and after the short circuit fault may be considered as the same. Power swings are phase symmetrical events; therefore the derivative of the current phase angle can be used as an additional criterion in a distance relay algorithm to distinguish symmetrical three phase faults from power swings.The block diagram figure 4. is an additional criterion, which decides if a short circuit fault has occurred in case of resistive fault impedance , and to distinguish between fault conditions and power swing operation.

If, $\frac{\Delta\varphi_I}{\Delta t} \geq \frac{\Delta\varphi_I}{\Delta t}_{Set}$: A fault has occurred, and if, $\frac{\Delta\varphi_I}{\Delta t} < \frac{\Delta\varphi_I}{\Delta t}_{Set}$: No fault has occurred.

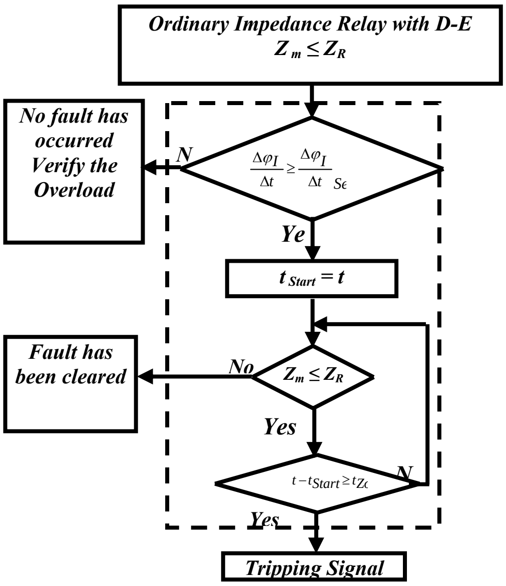

Figure 4. Power Swing Detection Block Diagram

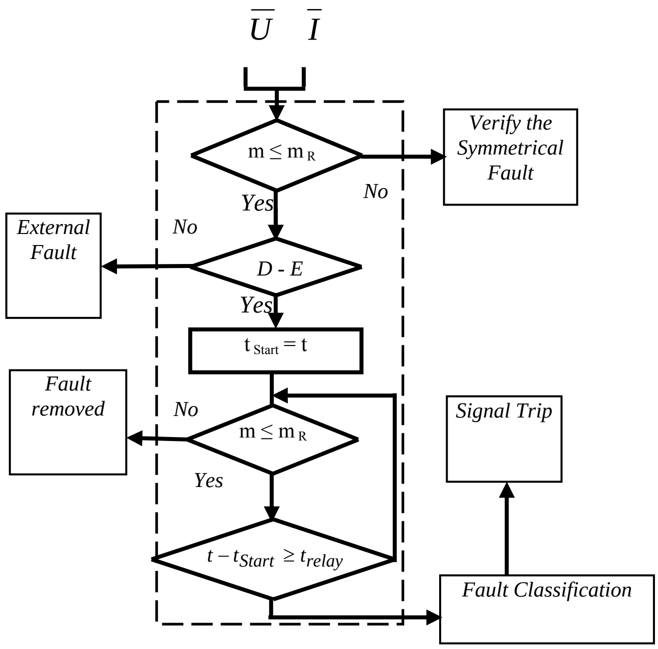

Figure 5. Unsymmetrical Fault Detection Module

The conventional approach for estimating the locations of transmission line shunt faults has been to measure the apparent impedance to the fault from a line terminal and to convert the reactive component of the impedance to line length. Several methods that use the fundamental frequency voltages and currents measured at one or both line terminals, have been proposed in the past [5,6,7,8,9].

An original methodology presented by Takagi showed a way to disregard the effects of high ground fault resistance in fault location [6]. Based on this method, several other methodologies have been suggested among theme, one modified Takagi algorithm, using negative-sequence quantities have been proposed [10].

In the case of the fault feed from both sides, the components of I_F are the fault currents contributed from Sources V_S and V_R, where: $I_F = I_{FS} + I_{FR}$

The component I_{FS} is related to the measured I_S current using the pre-fault (I_{SPF}) terminal current:

$$I_{FS} = I_S - I_{SPF}$$

The largest source of impedance error measurement comes from fault resistance, which can be eliminated if both sides of the equation are multiplied by the complex conjugate of I_{FS} to get Equation;

$$VI_{FS*} = m(Z_L I_S I_{FS*}) + R_F (I_{FS} + I_{FR}) \qquad (5)$$

If I_{FS} and I_{FR} have nearly the same phase [12], and if the small error resulting from this assumption can be neglected, then the term in the equation containing R_F is a real number. Therefore, if the imaginary components of the equation are isolated, then the distance to the fault can be determined as:

$$m = \frac{\mathrm{Im}\left\{V . I_{FS}^{*}\right\}}{\mathrm{Im}\left\{Z_L I_S I_{FS}^{*}\right\}} \qquad \ldots(6)$$

Equation (6) indicates the need to know the pre-fault current at the terminal. A modified version of this algorithm recognizes that negative-sequence currents are incremental quantities, similar to I_{FS}, where the pre-fault value is zero.

$$m = \frac{\operatorname{Im}\left\{V . I_2^*\right\}}{\operatorname{Im}\left\{Z_L I_S I_2^*\right\}} \qquad \ldots(7)$$

4. CONCLUSION

The proposed distance relay scheme for the protection of a transmission line is divided into four parts; the first is intended to protect the line from the unsymmetrical short circuit fault using the negative sequence component, and estimates the distance fault. If there is no unbalanced short circuit fault, the second block is then intended to distinguish between the symmetrical Short-circuit faults and the other operating conditions as: voltage instability, overload and power swing. For increasing degree of security, the third block is an additional criterion to reveal the symmetrical short circuit which is not detected with the voltage drop conditions, and avoids the tripping of distance protection due to the power swing. The fourth block where a second test of voltage drop checking has been introduced is an overload backup protection which is intended to prevent the operation of the relay in the overloads mode.

5. REFERENCES

[1] Vu K, Begovic M.M, Novosel D, Saha M.M, "Use of Local Measurements to Estimate Voltage-Stability Margin", IEEE Transaction on Power Systems, Vol. 14, No. 3, August 1999, pp. 1029 - 1035.

[2] Kundur P, ”Power System Stability and Control”, ISBN 0-07-035958-X, McGraw - Hill, 1994.

[3] Mechraoui A, Thomas D.W.P, ”A new distance protection scheme which can operate during fast power swings”, IEE Conference Publication No. 434, Developments in Power System Protection, March 25-27, 1997, pp 206 - 209.

[4] Ilar F, ”Innovations in the Detection of Power Swings in Electrical Networks”, Brown Boveri Review No. 68, 1981.

[5] Warrington, A.R. Van C. Protective Relays, Their Theory and Practice. Vol. I. Chapman and Hall Ltd. London, 1968.

[6] Takagi, T., Yamakoshi, Y., Yamaura, M., Kondow, R. and Matsushima. T. "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, N° 8, August 1982, pp. 2892-2898.

[7] Richards, Gill G. and Tan, Owen T. "An Accurate Fault Location Estimator for Transmission lines". IEEE Transaction on Power Apparatus and Systems. Vol. PAS-10 I, No. 4, April 1982, pp. 945-950.

[8] Srinivasan, K. and St-Jacques, A., "A New Fault Location Algorithm for Radial Transmission Line with Loads", IEEE Transactions on Power Delivery, Vol. 4, No. 3, July 1989. pp. 1676- 1682.

[9] Girgis, Adly A., Fallon, Christopher M. and Lubkeman. David L., "A Fault Location Technique for Rural Distribution Feeders". IEEE Transactions on Industry Applications. Vol. 29, No. 6. November- December 1993. pp. 1170-1175.

[10] E.O. Schweitzer III, "Evaluation and Development of Transmission Line Fault Locating Techniques Which Use Sinusoidal Steady-State Information"; Proceedings of the 9th Annual Western Protective Relay Conference, Spokane, WA, October 1982