FAULT DIAGNOSIS IN HIGH-VOLTAGE NETVORKS WITH USING MULTIPOLES

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ABSTRACT

Submitted dissertation deals with detection, identification and localization faults, which may originate on radial medium-voltage networks, with using multipole. There are described three kinds of fault, which most often appears on medium-voltage networks – line-to-ground fault, line-to-line ungrounded fault and line-to-line-to-ground fault. This algorithm for fault-location can work independently of monitoring and protecting components in network (needs only measured data) and operator offers rated data abstractedly on what finds out from protection systems. Final action depends on operator, who will make necessary steps to remove faulted part of network. Calculation probable fault location can make easy engineers fault finding on network and speeds up its removal of fault to restoration of electricity supply to the disabled areas.

After entire electric energy market liberalization, the energy supply questions will be related to all consumers of electric energy on lower voltage levels as households.

1 INTRODUCTION

More and more states lean to power market liberalization which is canned like goods, so exactly defined parameters are required. In Czech republic in the meantime entire liberalization market with power is not finished, but each supplier obliges supply electric energy in agreed quality and if possibility continually, how is embedded in appropriate contracts among him and concrete customer. If supplied energy fail to satisfy specified criteria, supplier is penalized. Except values of parameters of voltage, such as its size, frequency, voltage fluctuation etc., is for supplier important provide, preferably consecutively, supply electric power.

Different step of ensure of supply electric energy is assessed by another rate, which customer will pay as well as different height penalty for non - delivered energy according to valid contract. But faults occurs haphazardly in nets of all voltage levels and supplier have to look for compromise among expensive exchanges sections of line, expensive detecting and seeking apparatus and penalty for outage above granted limits. If it is possible to perform power supply compensation with cutoff disabled line and distribute relayed power to the other parts of system, operator cuts off faulted line and provide supply from another node, because of minimizes economic losses. Wherewith shorter is clearing time, so much better for supplier and if it is impossible to ensure supply for customers in other way, is necessary as soon as possible can find out vacancy and subsequently remove it in shortest time. For fault-location is at the present time possible to use numerical methods, built on information collected from measurements on given line. Consideration generally rests in using measuring arrangement in single nets nodes, create mathematic model corresponding real situation and by means of used computation apparatus find out information on ensue problem, if occurs. One method works with wave axiom, so derive benefit from wave's reflection at faulted point. Wave can ensue directly at fault (at point faults at moment, when voltage do not transpierce zero, or HF impulses are fed into the faulted line, but there can be distortion, or information can be wasted if the frequency of „detection wave" was unseemly selected.

There are also impedance-based methods using measured impedance of given circuit. Change of impedance references to accrued fault and its value is related to fault distance from measure-point and also to the fault resistance.

In dissertation is described control system of HV transmission lines and radial MV distribution networks in the event of established synchronous measuring. System links remote measuring systems with diagnostic apparatus able to recognize actual nets state. This system can differentiate failure state from working state, can determine fault distance and differentiate its type. Method requires measuring results of fundamental electric values (voltage and current) in each node of controlled net. Method requires measuring results of fundamental electric values (voltage and current) in each node of controlled net. Because of application proposed algorithm to each part of electric net, the computing is independent on extent of the net and computing time which increase slightly with net size.

2 CIRCUITAL MODEL

There are some numerical methods used to detection, classification and location of the fault at the present time. Using of each method depends on input data. Each of these methods uses voltages and currents measured on one end of reflected line.

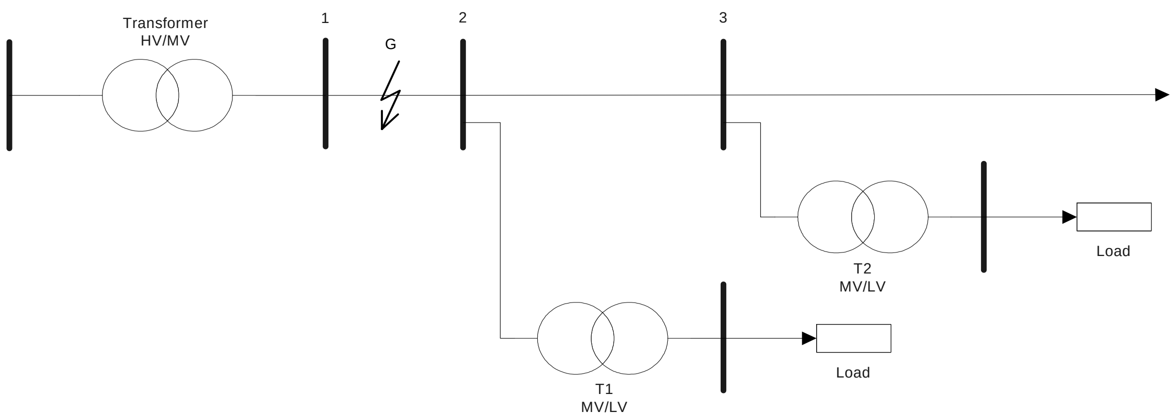

Fig. 1: *Scheme of a simple MV distribution system with fault betveen nodes 1 and 2*

The distribution systém shown in figure 1. has been used to ilustrate the circuital models of each considered component. In what follows „line“is is a part of the network between two

MV/LV substations.

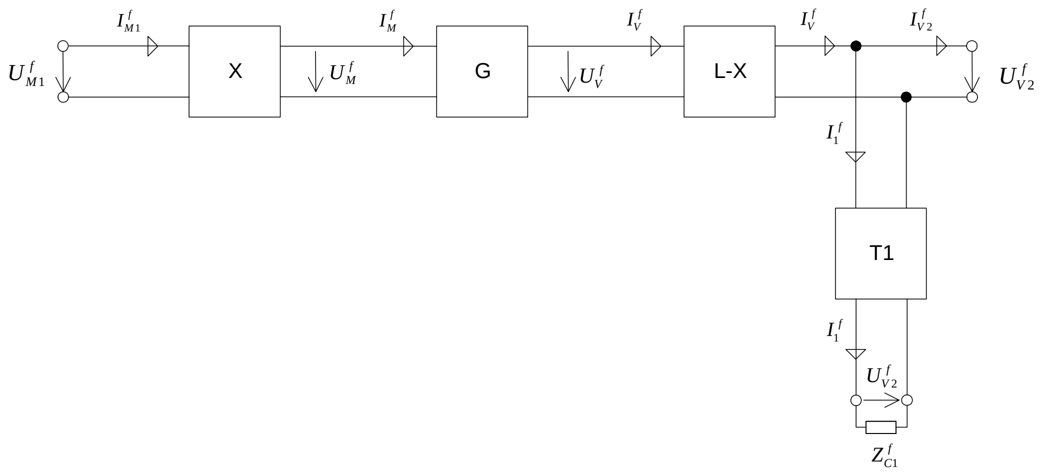

Fig. 2: *Scheme of the considered line between nodes 1-2, where f = d,i,o.*

The line can be represented by means of three equivalent quadripole, connected in cascade, as shown in Figure 2. and one shunt quadripole. The quadripole “X” represents the part of line that is upstream the fault section, quadripole “L-X” corresponds to the part of line that is downstream the fault section. Quadripole “G” represents the fault section and “T1” MV/LV transformer. Fault “G” is characteristic for each kind of fault and issues from relations between sequences - positive (d), negative (i) and zero (o).

3 SINGLE-LINE-TO-GROUUND FAULT

In this paper are presented single-line-to-ground fault, but similar algorithms are used for line-to-line ungrounded fault and line-to-line-to-ground fault. They differs only in the fault quadripole.

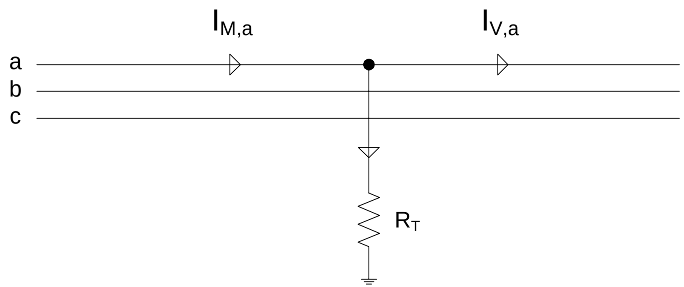

Fig. 3: *Scheme of the considered line.*

In this case, the fault can be described by six relations, four of which do not depend on the particular type of line-to-ground studied and can be expressed as follows:

$$
\begin{aligned}
U_{M,c} &= U_{V,c} \\
U_{M,b} &= U_{V,b} \\
I_{M,c} &= I_{V,c} \\
I_{M,b} &= I_{V,b}
\end{aligned} \qquad (1)
$$

Where “M” represents upstream fault section and “V” downstream fault section. Two remaining relations are characteristic of particular type of line-to-ground fault and they are related to the faulty phase:

$$
\begin{aligned}
U_{M,a} &= R_T \cdot (I_{M,a} - I_{V,a}) \\
U_{M,a} &= U_{V,a}
\end{aligned} \qquad (2)
$$

Using the symmetrical components we can write:

$$
\begin{aligned}
&\alpha U_M^d + \alpha^2 U_M^i + U_M^o = \alpha U_V^d + \alpha^2 U_V^i + U_V^o \\
&\alpha^2 U_M^d + \alpha U_M^i + U_M^o = \alpha^2 U_V^d + \alpha U_V^i + U_V^o \\
&\alpha I_M^d + \alpha^2 I_M^i + I_M^o = \alpha I_V^d + \alpha^2 I_V^i + I_V^o \\
&\alpha^2 I_M^d + \alpha I_M^i + I_M^o = \alpha^2 I_V^d + \alpha I_V^i + I_V^o \\
&U_M^d + U_M^i + U_M^o = R_T \cdot \left[\left(I_M^d + I_M^i + I_M^o \right) - \left(I_V^d + I_V^i + I_V^o \right) \right] \\
&U_M^d + U_M^i + U_M^o = U_V^d + U_V^i + U_V^o \\
&where: \quad \alpha = e^{j \cdot \frac{2}{3}\pi}
\end{aligned} \qquad (3)
$$

Grouping the variables the following matrix relation can be written:

$$
[P] \cdot \begin{bmatrix} U_M^d \\ U_M^i \\ U_M^o \\ I_M^d \\ I_M^i \\ I_M^o \end{bmatrix} = [Q] \cdot \begin{bmatrix} U_V^d \\ U_V^i \\ U_V^o \\ I_V^d \\ I_V^i \\ I_V^o \end{bmatrix}, \text{ where: } [P] = \begin{bmatrix} \alpha & \alpha^2 & 1 & 0 & 0 & 0 \\ \alpha^2 & \alpha & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \alpha & \alpha^2 & 1 \\ 0 & 0 & 0 & \alpha^2 & \alpha & 1 \\ 1 & 1 & 1 & -R_T & -R_T & -R_T \\ 1 & 1 & 1 & 0 & 0 & 0 \end{bmatrix} \text{ and } [Q] = \begin{bmatrix} \alpha & \alpha^2 & 1 & 0 & 0 & 0 \\ \alpha^2 & \alpha & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \alpha & \alpha^2 & 1 \\ 0 & 0 & 0 & \alpha^2 & \alpha & 1 \\ 0 & 0 & 0 & -R_T & -R_T & -R_T \\ 1 & 1 & 1 & 0 & 0 & 0 \end{bmatrix} \qquad (4)
$$

For this type of fault on phase “a” the matrix “G” is written:

$$
[G_a] = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ \frac{a}{R_T} & \frac{a}{R_T} & \frac{a}{R_T} & 1 & 0 & 0 \\ \frac{a}{R_T} & \frac{a}{R_T} & \frac{a}{R_T} & 0 & 1 & 0 \\ \frac{a}{R_T} & \frac{a}{R_T} & \frac{a}{R_T} & 0 & 0 & 1 \end{bmatrix} \qquad (5)
$$

Now we get non-linear system of six equations and there are two unknowns “x” and “R_T”:

$$\{H\}=\begin{cases} U_{M1}^{d}-l_1=n_1\cdot\frac{x}{R_T}+p_1\cdot\frac{x^2}{R_T}+q_1\cdot\frac{x^3}{R_T}+r_1\cdot\frac{x^4}{R_T} & (a)\\ U_{M1}^{i}-l_2=n_2\cdot\frac{x}{R_T}+p_2\cdot\frac{x^2}{R_T}+q_2\cdot\frac{x^3}{R_T}+r_2\cdot\frac{x^4}{R_T} & (b)\\ U_{M1}^{o}-l_3=n_3\cdot\frac{x}{R_T}+p_3\cdot\frac{x^2}{R_T}+q_3\cdot\frac{x^3}{R_T}+r_3\cdot\frac{x^4}{R_T} & (c)\\ I_{M1}^{d}-l_4=m_4\cdot\frac{x}{R_T}+n_4\cdot\frac{x^2}{R_T}+p_4\cdot\frac{x^3}{R_T}+q_4\cdot\frac{x^4}{R_T} & (d)\\ I_{M1}^{i}-l_5=m_5\cdot\frac{x}{R_T}+n_5\cdot\frac{x^2}{R_T}+p_5\cdot\frac{x^3}{R_T}+q_5\cdot\frac{x^4}{R_T} & (e)\\ I_{M1}^{o}-l_6=m_6\cdot\frac{x}{R_T}+n_6\cdot\frac{x^2}{R_T}+p_6\cdot\frac{x^3}{R_T}+q_6\cdot\frac{x^4}{R_T} & (f) \end{cases} \qquad (6)$$

Coupling equations a-d, b-e and c-f we can get this system of equations:

$$\begin{cases} U_{M1}^{d}-l_1=n_1\cdot\frac{x}{R_T}+p_1\cdot\frac{x^2}{R_T}+q_1\cdot\frac{x^3}{R_T}+r_1\cdot\frac{x^4}{R_T} & (a)\\ I_{M1}^{d}-l_4=m_4\cdot\frac{x}{R_T}+n_4\cdot\frac{x^2}{R_T}+p_4\cdot\frac{x^3}{R_T}+q_4\cdot\frac{x^4}{R_T} & (d) \end{cases} \qquad (7)$$

$$\begin{cases} U_{M1}^{i}-l_2=n_2\cdot\frac{x}{R_T}+p_2\cdot\frac{x^2}{R_T}+q_2\cdot\frac{x^3}{R_T}+r_2\cdot\frac{x^4}{R_T} & (b)\\ I_{M1}^{i}-l_5=m_5\cdot\frac{x}{R_T}+n_5\cdot\frac{x^2}{R_T}+p_5\cdot\frac{x^3}{R_T}+q_5\cdot\frac{x^4}{R_T} & (e) \end{cases} \qquad (8)$$

$$\begin{cases} U_{M1}^{o}-l_3=n_3\cdot\frac{x}{R_T}+p_3\cdot\frac{x^2}{R_T}+q_3\cdot\frac{x^3}{R_T}+r_3\cdot\frac{x^4}{R_T} & (c)\\ I_{M1}^{o}-l_6=m_6\cdot\frac{x}{R_T}+n_6\cdot\frac{x^2}{R_T}+p_6\cdot\frac{x^3}{R_T}+q_6\cdot\frac{x^4}{R_T} & (f) \end{cases} \qquad (9)$$

If the three obtained values of "x" and "R_T" are the same, or very close, then there is a single-line-to-ground fault on the considered phase, otherwise in the considered line there is not this type of fault.

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