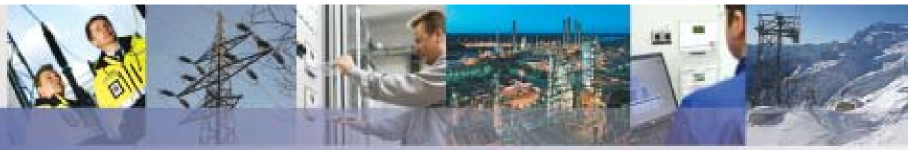

VAMP 230 and VAMP 255 Feeder Managers

Novel short-circuit fault location method used in feeder managers

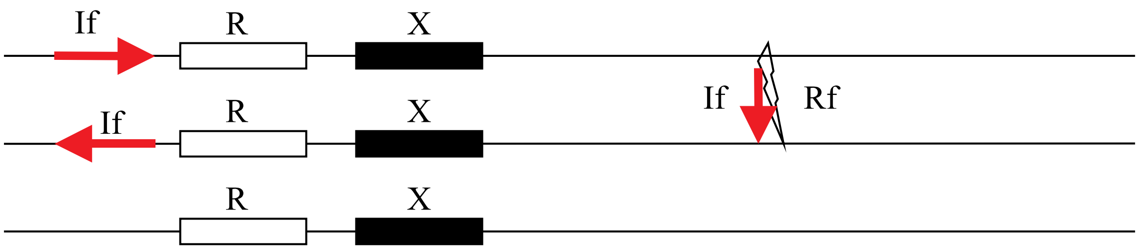

Figure 1. Two phase short-circuit.

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Electricity has become so vital that any disturbance in distribution will cause serious problems to utilities. Customers have become more demanding and therefore any kind of shortage arouses serious criticism of utility services. That's why utilities today invest in better equipment and solutions to minimise these disturbances. One way to shorten blackouts is to use fault location.

Fault location itself is not a new idea. Faults were first located manually. The circuit breaker was closed against the fault and the service personnel were nearby the line, looking for the flash caused by the fault. Then, remotely controllable disconnectors operated from the network control centre allowed separation of the faulted section from the rest of the system. The first fault location concepts were presented in the nineties. New relays with communication facilities to Scada systems enabled fault location based on fault current. The latest step is fault location based on reactance calculation.

Method

Reactance measurement is included in Vamp feeder managers that measure both currents and voltages. Compared with the fault current method, the reactance method offers several advantages. The fault current (If) depends on the fault impedance (Z). The fault impedance consists of resistance (R) and reactance (X). Since the fault resistance (Rf) varies throughout the duration of a short-circuit fault, it brings inaccuracy to the fault impedance. Furthermore, the resistance of the line changes constantly in response to temperature changes. The reactance method, however, does not utilise impedance and thus the resistance can be neglected.

$$X = U*\sin\varphi/I$$

Principle of reactance calculation.

A new idea is also to make the algorithm more accurate by compensating the load. The algorithm takes into account the pre-fault and the post-fault current.

Sometimes fault clearing takes more time.

Experiences

Finland is a rather sparsely populated country with a relatively big area. This means that utility customers are scattered. The lines are long but the loads are low. It is quite common that the medium voltage network radial feeder is tens or even a couple of hundred kilometres in length. This is why fault location is very important for fast fault recovery.

Vamp has a lot of experience about using the reactance fault location. The first installations were made in 2002. Numerous real short-circuit faults have proved that the method works and is very accurate. One example is a Finnish utility that had a two phase short-circuit in a feeder and a Vamp feeder manager for fault location. The function calculated the distance to be 70 km. When the fault place was cleared, the accurate distance from the substation, as checked from the utility data, was 70 km!

Another example is a Swiss utility that was very interested in this novel fault location. As a result, they decided to do a primary test of the function in their own network. The fault was caused by a remotely controllable switching device on a pole. The fault distance from the substation was 11.1 km (the corresponding reactance was 3.21 ohms). The function calculated the fault location within 200 meters during the test. In further tests they utilised a network simulation program to generate all kinds of networks situations and these generated signals were fed into the Vamp feeder manager. All the faults were located with an accuracy of 300 metres. Last summer the same utility closely followed the feeder manager calculation in their network. They had 24 real faults, all of which were located with an inaccuracy of 2 %.

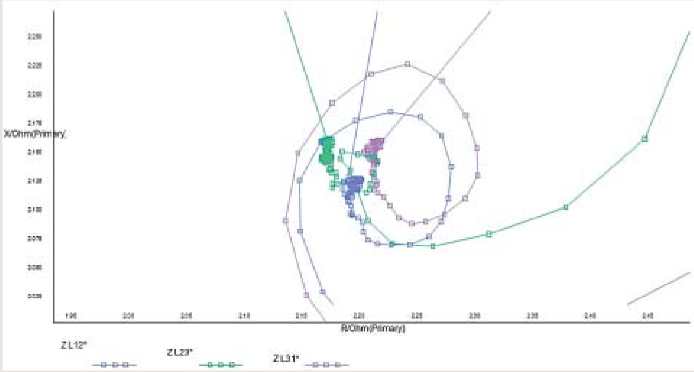

Figure 2: A real three phase short-circuit fault presented in the impedance plane.

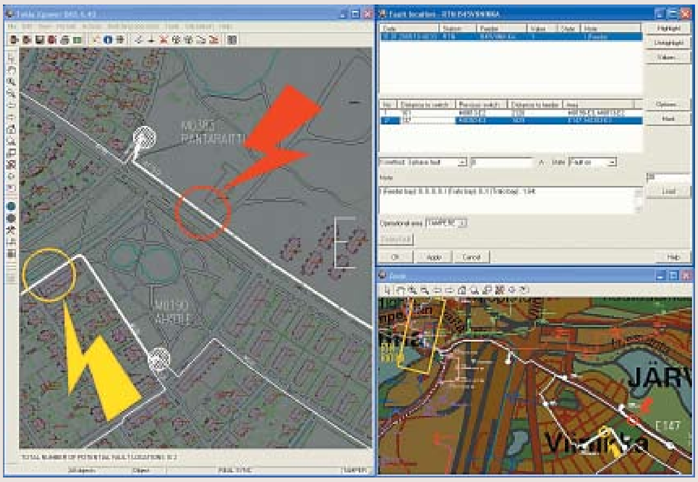

Figure 3: A view from DMS with two possible fault locations.

Application

In Vamp feeder managers the function settings are made as simple as possible. Actually, the user needs only to set the triggering condition for the function. The function can be triggered by a sudden increase in current (dI). Another possibility is to trigger it by a digital input, which could mean opening of the breaker. If all feeders are equipped with Vamp feeder managers, the dI current setting is quite simple. The maximum change of the load current ($I_{maxload}$) and the minimum fault current ($I_{minload}$) determine the triggering condition as follows:

$I_{maxload} < dI < (I_{minfault} - I_{maxload})$

If the whole substation has only one feeder manager in the incoming feeder, the sum of the maximum change in the load currents of each feeder ($I_{maxload1}+I_{maxload2}+\ldots+I_{maxloadN}$) have to take into account:

$(I_{maxload1}+I_{maxload2}+\ldots+I_{maxloadN}) < dI < (I_{minfault} - I_{maxloadtotal})$

In a typical application, the fault reactance value in ohms is transferred via a substation automation system (Scada, RTU, etc.). Then the value is entered to a

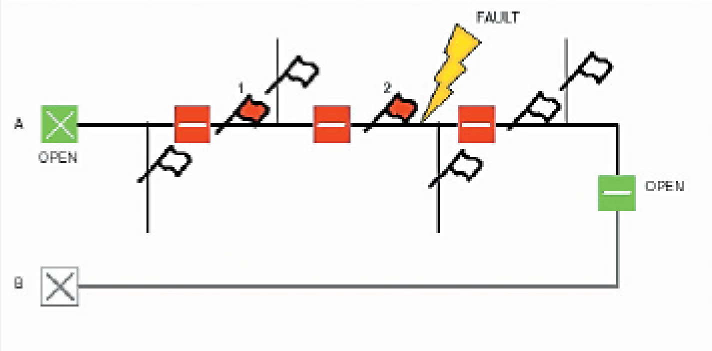

Figure 4: The idea of using fault indicators. The red flags mean that the indicators are showing fault.

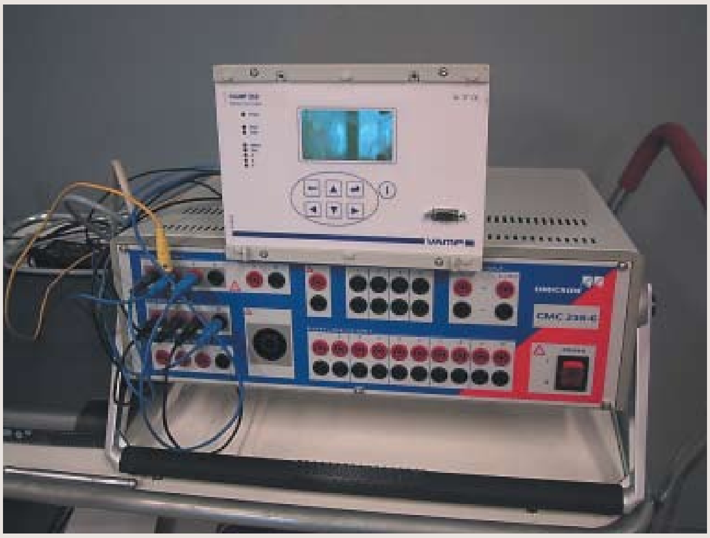

Figure 5: Vamp 255 Feeder Manager testing with Omicron CMC 256-6.

distribution management system (DMS) to see the fault location on a map.
The DMS includes all the required data of the conductor type, so the reactance value can easily be converted from ohms to kilometres. If the faulted feeder has branches, there will be several possible fault locations. Therefore, these branches should be equipped with fault indicators, which rule out the healthy branches and only one fault location is shown.

Vamp feeder managers can show the fault distance in kilometres. However, this value is only an estimate and should be used when the homogeneous conductor type applies. There is a parameter for setting the line reactance per kilometre. For example, if the line reactance is 0.3 ohms/km and the fault reactance is 6.7 ohms, the distance is 22.3 km. The line reactance is given by the manufacturer. Some examples are given in table 1.

If the feeder consists of sections of cables and overhead lines, the line reactance must be given as an average value. For example, one feeder consists of the following sections:
– 100m cable AHXAMK (Section 1)
– 5 km overhead Raven (Section 2)
– 30 km overhead Swan (Section 3)
– 200 m cable AHXAMK (Section 4)
– 10 km overhead Sparrow. (Section 5)

Line reactances for sections:
Section 1: 0.1 km x 0.123 ohms
= 0.0123 ohms
Section 2: 5 km x 0.379 ohms
= 1.895 ohms
Section 3: 30 km x 0.417 ohms
= 12.51 ohms
Section 4: 0.2 km x 0.123 ohms
= 0.0246 ohms
Section 5: 10 km x 0.398 ohms
= 3.98 ohms

Total reactance: 18.4219 ohms
Total length: 45.3 km

Average line reactance: 18.4219 ohms/ 45.3 km = 0.407 ohms/km (the setting for the feeder manager)

Type	Name	Line reactance in ohms/km (50 Hz)
Overhead conductor	AL132	0.346
Overhead conductor	Raven	0.379
Overhead conductor	Sparrow	0.398
Overhead conductor	Swan	0.417
“Overhead cable”	SAXKA 3x70	0.14
Cable	APYAKMM	0.123
Cable	AHXAMK “Wiski”	0.13

Table 1 Examples of line reactances of different types of conductors.

Testing

Modern secondary relay test equipment is very accurate and complex. Fault location testing with ready-made test models is very fast and easy. These relay testers include normally a module for testing distance relays. The same module can be used for testing the fault location, although the load compensation may cause different results. Therefore, the pre-fault currents should be zero. The signals are generated by the tester on the basis of the fault impedance given by the user. Furthermore, the fault impedance can be given as reactance and resistance. The user can then set any reactance value and inject the generated signals to the feeder manager.

If there is no distance module available, a state sequencer or even a normal injection module can be used for testing. If a sequencer is used, state 1 is the normal load condition i.e. pre-fault condition. State 2 is then the fault condition. The voltages can have the nominal amplitude and phase angle, like UL1: 100 V (0 deg), UL2: 100 V (240 deg) and UL3: 100 V (120 deg). The current should be a bit inductive, i.e. the phase difference to the corresponding voltages should be negative, say -30 degrees (the current lags the voltage). The only change needed in state 2 is the current amplitude. This change must be greater than the set dI. It is also important to note that the fault current must be greater than 30% of the nominal current.

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