

Reliability of transmission by means of line impedance and k-factor measurement

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A measurement on a 400 kV overhead line with a total length of 22 km has been performed at a large utility. The reason for the test was a false trip that was subject to closer investigation. Although the single-pole error arises at a transformer at the end of the line, the distance protection relay at the other end of the line trips. Why?



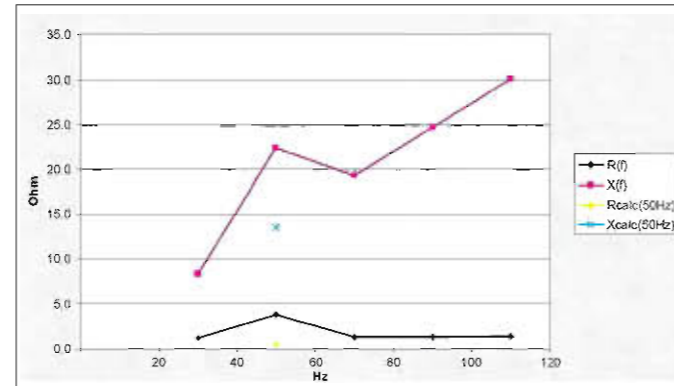
First tower of the 22 km - 400 kV line

An exact verification of the calculation of the Zero Sequence Impedance brought no solution. The utility asks OMICRON for assistance. The measurement is accomplished by means of the multifunctional primary test system CPC 100 and the coupling unit CP CU1.

The whole measurement had to be done within one hour, because the line was not available for a longer period. The measurement could be performed without problems; the chosen test current was 25 A.

The results of the measurement at different frequencies show that a measurement at 50 Hz would have needed a drastically larger test current to lift the level of the measured values over the interference level. The

reliable measurement could be achieved by the use of frequency-selective measurement with this small test current.



Measured impedance versus frequency in Hz

Most interesting was the comparison of the measured results versus the settings in the distance relay.

Settings of the relay	R[Ω]	X[Ω]	Z[Ω]	Phi(°)
Positive sequence impedance Z_1	0.542	7.019	7.04	85,58
Zero sequence impedance Z_0	6.692	23.822	24.744	74,31
Measured results	R[Ω]	X[Ω]	Z[Ω]	Phi(°)
Positive sequence impedance Z_1	0.587	7.128	7.152	85,29
Zero sequence impedance Z_0	4.623	16.067	16.718	73,95

Relay settings versus measurement results

The Positive Sequence Impedances matched perfectly, but the Zero Sequence Impedance showed a deviation of 48%. Another re-evaluation of calculation showed, that the type of the ground wires used, was not entered correctly into the companies database, once corrected the calculation matched the measurement for the zero sequence as well.

Measurement of K-Factors

Compared to the calculation the measurement of line parameters including the k-factors is nowadays relatively simple.

The test set CPC 100 and CP CU1 from OMICRON comprising a frequency variable amplifier (29 kg), a coupling unit (28 kg) and a protection device (6 kg) is all that is needed for the measurement.

The CPC 100 is a multi functional, frequency variable

test set for various tests on primary equipment. It is capable of generating currents up to 800 A or voltages up to 2000 V, with special software modules it can be used for various automated tests on CTs, VTs, power transformers or other primary equipment.

With other accessories it can also be used i.e. for tangent delta testing on power transformer bushings or windings with test voltages up to 12 kV. In the application of line impedance measurement it is used as frequency variable power generator, measurement tool and analyzer.

Due to the variable frequency generation it is possible to generate signals first under then over mains frequency. Using digital filter algorithms allows measuring frequency selective at the frequency that is currently generated, this means all other frequencies but the generated one are filtered out. Disturbances at mains frequency are thus no longer influencing the result.



OMICRON's CPC 100 and CP CU1

The coupling unit CP CU1 is used for galvanic decoupling of the generated signals in output direction and analyzed signals in input direction. The decoupling is needed mainly for safety reasons. For optimum performance there is also a range selector switch and for a quick check of induced voltages or burden a built in voltmeter.

The protection device CP GB1 is a tool for easy connection to the overhead line or power cable, existing grounding sets of the substation may be used.

In case of unexpected high voltage on the power line due to faults on a parallel system, lightning discharges or transients due to switching operations, the GB1 is capable of discharging short transients or permanently shorting fault currents of up to 30 kA for at least 100 ms. These features allow the user safe operation even in critical situations.

The measurement is performed with currents between 1 and 100 A depending on the line length. Using frequency selective measurement allows using currents in the size of a fraction of the nominal currents. Anyway higher currents mean higher accuracy therefore the biggest current possible is chosen. Measurements on lines up to 270 km have been performed so far.

Overall seven measurements per system are made, three for each combination of phase to phase loops, three for each phase against ground and one for all three phases against ground.

There is some redundancy in these measurements, allowing reliability crosschecks and calculation of individual k-factors for each phase.

The latter seems strange at a first glance, but especially for short lines often not too much care is taken having a symmetrical line, leading to quite different values for the phases. Knowing about the problem allows tending rather to smaller k-factors to avoid zone overreaches in all cases.

The results can be loaded into Microsoft Excel allowing easy post processing; the results are displayed in a format fit for direct usage for relay settings.

Conclusion

Nowadays the costs and effort for k-Factor measurements are a fraction of what they used to be. Measurements showed that for several reasons calculations often gave wrong results. Therefore, most likely measurement and calculation will be done in future. Save, selective and fast failure clearance is only possible, if all relay parameters are set properly. Line impedance and k-Factor are of highest importance for a fully operational distance protection relay.