NEUTRAL GROUNDING RESISTOR FAILURE DETECTION

Dr. Zvonko TOROŠ
Elektro Primorska – Slovenia
zvonko.toros@
elektro-primorska.si

Peter KASTELIC
Iskra Sistemi – Slovenia
peter.kastelic@
iskrasistemi.si

Tomaž KASTELIC
Elektro Primorska – Slovenia
tomaz.kastelic@
elektro-primorska.si

Silvano MALJAVAC
Iskra Sistemi – Slovenia
silvano.maljavac@
iskrasistemi.si

ABSTRACT

A resistance-grounded distribution system has a critical element that is often forgotten - the neutral-grounding resistor (NGR). During a single-phase-to-ground fault, current flows from the transformer winding through the faulted-phase conductor to the fault and to ground and then returning through the NGR back to the transformer. Operation of distribution system with an open NGR has the consequence [1] that current ground-fault protection will not properly indicate the presence of a ground fault in the system because the distribution system operated as ungrounded system and that is dangerous. A ground fault then remains on the system and might escalate to a phase-to-phase fault. Operation with reduced NGR resistance is also dangerous, because of higher fault values at the ground fault location. Because NGR's are subject to failures related to mechanical and thermal overload causes, the proper monitoring of NGR health is important as all other protections to preserve distribution system in safe state.

With several studies and field measurements we managed to establish a correlation between voltage and current on NGR during normal operation (different states of load on transformer or without load) of resistance-grounded distribution system and again on same states with faulty NGR.

Presented algorithm combines an advanced and cost-effective monitoring of NGR failure that could improve distribution system for safe and reliable operation.

INTRODUCTION

Resistance grounding has been used in three-phase distribution and industrial power system applications for many years. Properly designed resistance grounding eliminates many of the problems associated with solidly and ungrounded systems while retaining their benefits. NGR failure has influence on all ground-fault protections in the distribution system, therefore operate with damaged NGR is dangerous for human and animal health. Operation with ungrounded system can be avoided with the continuous NGR failure detection even before ground fault appears.

NGR is a mechanical component and is subject of mechanical and thermal overload failures (thermal overload, false protection operation, lightning, storms, extended service life, manufacturing defects, vibration, corrosion, improper specification or installation,...).

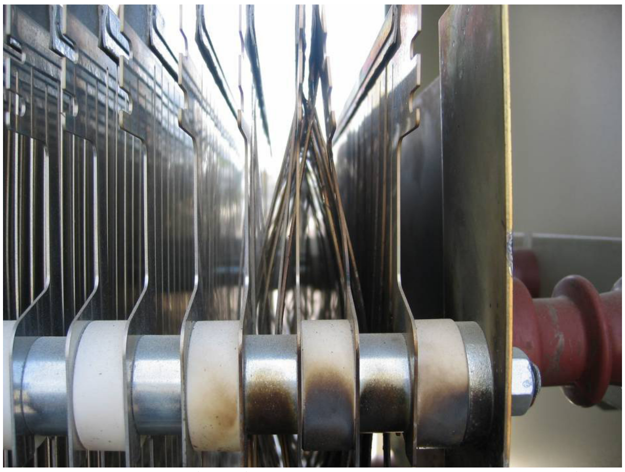

Figure 1: Partial failure of NGR components – short-circuiting parts of NGR decreases overall grounding resistance [2]

On Figure 1 is presented an example of partial failure of NGR components – short-circuiting parts of NGR decreases overall grounding resistance, which leads to further thermal overloads and finally to an open NGR – seen on Figure 2.

Figure 2: Failure of NGR caused by thermal overload [2]

Additional significant cause for failure of NGR and difficulty for safe operation in the distribution system of Elektro Primorska (Slovenia) are also increased density of lightning activities [3] and high specific impedance of terrain (Karst and rocky mountain region).

Our main goal was to discover as simple as possible solution to upgrade existing protection and control system on distribution substation that can, as reliably as it can be, report NGR failure. By the time of discovering possible algorithms to accomplish solution for detection NGR failure, we made several assumptions: cost-effective solution, no major hardware changes on substation, determine NGR failure based on existing current and voltage measurements.

On Figure 3 is shown a typical connection diagram of NGR fault detection device (with ground over-current protection) that was upgraded with NGR failure detection algorithm.

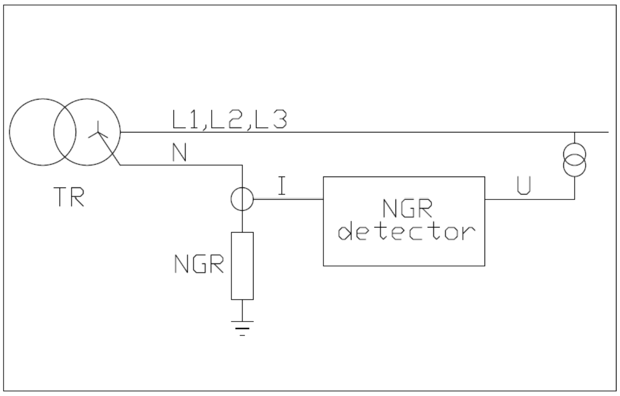

Figure 3: Connection diagram (I- current through NGR, U – residual voltage)

NGR FAILURE DETECTION ALGORITHM

Our investigation of possible NGR failure detection algorithms was focused on following situations. Normally we have NGR with nominal resistance (in Slovenian distribution system is common value 80 Ohm). Because of several possible causes it could lead to partial failure of NGR components (it depends of type of construction) – this means that NGR resistance will be reduced to lower or increased to higher values than nominal. This effect will lead to further thermal overloads and at the end it can bring to complete NGR failure. Because of these possible cases, we managed to split algorithm into three parts that are covering NGR failure detection continually or during different type of failures.

Acceptable solution for NGR failure detection was upgrade of over-current protection relay with additional sensitive ground current analog input to detect ground currents through NGR in range of few mA (primary). NGR failure detecting algorithm consists of three parts. First part continuously monitors minimal current that always flows through NGR when secondary winding of transformer has minimal load on it (even only bus-bars). In case of absence of this minimal current, algorithm reports NGR failure. Second part calculates resistance from voltage and current through NGR and reports NGR failure at deviations from nominal resistance – used as detection at ground fault. Third part of algorithm monitors maximal currents through NGR that appears for short time at ground fault and report NGR failure when current is over normal limit. All three parts of algorithm combine an advanced monitoring of NGR failure that could improve distribution system for safe and reliable operation.

Algorithm is implemented in multifunctional protection relay FPC525 produced by Iskra Sistemi d.d., Slovenia.

Part 1: Minimal current detection

First part of NGR failure detection algorithm is based on fact that in normal operation of resistance grounded distribution system through NGR is present a minimal current which is the cause of asymmetry of transformer. This current could be in range of only few mA (primary units) and is hard to detect with common solutions in over-current protection relays. Within case studies and measurements on several substations at Elektro Primorska distribution company, we discovered that with upgraded over-current protection relay (additional sensitive ground current analog input) such minimal current can be detected. One of the main questions was range of NGR current transformer on existing installations. We made intensive tests, which gave us results that existing current transformers can measure such small currents with adequate accuracy.
The absence of this minimal current is reported as NGR failure. Miss-operation because of transient effect are filtered out with buffered averaging of sensitive current measurement and with time-delayed NGR failure report. Additional input blocking signal is also preventing algorithm miss-operation due to several external reasons (equipment revision tests, if transformer is out of operation or temporary de-energized,...). Because we have to deal with such small input signals also noise could influence on miss-operation of algorithm. With proper analog channel filtering and signal processing (Fourier Transformation – algorithm uses 50Hz harmonic amplitude) algorithm is robust also to this.

Part 2: Resistance calculation

Second part of NGR failure detection algorithm is based on fact that ground faults are causing the appearance of voltage on NGR and current through NGR. The principle of this part of algorithm is to calculate resistance and compare it to nominal NGR resistance. If it is outside the settable allowed limits, algorithm reports NGR failure due to possible partial failure of NGR components. This part of algorithm is covering only situations during ground faults because accuracy depends on voltage and current levels. At that time voltage and current are high enough to provide proper calculation of resistance. Advantage of this part of algorithm is that with calculated resistance can be detected partial damages on NGR and prevent from its complete failure.

Part 3: Maximal current detection

Third part of NGR failure detection algorithm is based on fact that ground fault current through NGR is limited practically with phase voltage (maximal voltage present on NGR) and nominal NGR resistance. In case of partial NGR failure when NGR resistance is significantly reduced, we will detect higher ground fault current than it is normally expected. This part of algorithm is necessary because high currents are disconnected from other protections very fast and NGR failure detection has to report NGR failure due to possible partial failure of NGR components.

SUMMARY

Operating with damaged (changed from nominal resistance) NGR in power systems is dangerous and therefore not allowed. Power system with open NGR is subject to transient over-voltages, and so current sensing ground-fault protection will not indicate the presence of a ground fault. A ground fault then remains on the system and might escalate to a phase-to-phase fault.

An NGR failure detector provides continuous protection against NGR failures and therefore a confidence that current-sensing ground-fault protection will operate as designed at the next ground fault.

Main goal of our research was: detect NGR failures with cost-effective and most reliable solution – without installation of additional primary equipment and changing of existing wiring. And we believe we did it.

Several parts of presented algorithm were tested on four NGR’s, located in different areas in Elektro Primorska distribution system, for past few years. During these years we improved parts of algorithm for preventing NGR failure detection miss-operation.

Based on results and experience of NGR failure detector, Elektro Primorska is planning to install this detection system on all NGR locations.

With proved algorithm by multiple field installation, future plans for NGR failure detection are also extension to protection functionality, which would switch off transformer with damaged NGR.

REFERENCES

[1] D. Selkirk, M. Savostianik, K. Crawford, 2010, "The dangers of grounding resistor failure", *IEEE Industry Applications Magazine, sept. /oct. 2010*, 53-58.

[2] S. Vižintin, I.Kobal, M. Iglič, S. Rozman, Z. Toroš, 2006, "Analiza razmer ob okvari na nizkoohmskem uporu za ozemljevanje nevtralne točke 20 kV sistema transformatorja TR A v RTP Sežana", *EIMV Slovenia, study 1794*.

[3] Z. Toroš, 2009, "Hibridni kazalci kakovosti električne energije v distribucijskem elektroenergetskem sistemu", doktorska disertacija, *Univerza v Mariboru, Fakulteta za elektrotehniko, računalništvo in informatiko, Maribor 2009*, 37-41.