NEUTRAL GROUNDING RESISTOR FAILURE DETECTION VERIFICATION

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ABSTRACT

A resistance-grounded distribution system has a critical element that is often forgotten - the neutral-grounding resistor (NGR). Because NGR's are subject to failures [1] related to thermal overload, lightning, storms, extended service life, manufacturing faults, vibration, corrosion, and improper specification or installation, 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. NGR failure detecting algorithm [2] is divided in several stages. First stage continuously monitors minimal current that always flows through NGR. Second stage calculates resistance from current and voltage through NGR and reports deviations from normal resistance. Third stage monitors higher currents through NGR and indicate that NGR could be partially damaged. This functional algorithm with specially developed hardware combines an advanced monitoring of NGR failure detection that could improve distribution system safe operation.

During two years operation supervision of implemented detections on several NGR's in distribution company of Elektro Primorska d.d. and field testing we manage to confirm proper operation of NGR failure detection. With some improvements of algorithm also verification results [3] are presented in this paper.

INTRODUCTION

Operation with damaged NGR (changed resistance or even total breaking failure) can be avoided with the continuous NGR failure detection. In past years several faults of NGR appears in the distribution system of Elektro Primorska d.d. (Slovenia) [4], mostly because of increased density of lightning activities [5] and high specific impedance of terrain (Karst and rocky mountain region).

In the year of 2011 Elektro Primorska d.d. distribution company started to upgrade existing protection and control system on distribution substations with additional function of NGR failure detection. Basic connection diagram of NGR failure detection is presented on Figure 1.

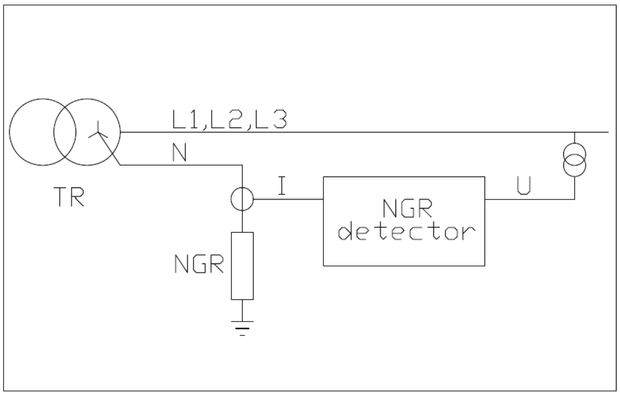

Figure 1: Connection diagram (I- current through NGR, U – residual voltage)

NGR FAILURE DETECTION ALGORITHM

An NGR failure detection algorithm is focused on following situations. Normally an NGR with nominal resistance is installed (common value of 80 Ω in Slovenian distribution system). Because of several possible causes it could lead to partial failure of NGR components when resistance is reduced to lower or increased to higher values than nominal. This effect could 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 NGR failure detection algorithm [2] into three parts that are covering detection continually or during different type of failures.

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 even only at minimal load on secondary winding of the power transformer. The absence of this minimal current is reported as NGR failure.

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. This part of algorithm calculates resistance and compares it to nominal NGR resistance. Deviation of settable allowed limits are reported as NGR failure due to possible partial failure of NGR components.

Third part of NGR failure detection algorithm is based on fact when NGR resistance is significantly reduced and very high ground fault currents are detected. This part of algorithm is necessary because high currents are disconnected by protections very fast and NGR failure detection has to report NGR failure before the ground fault is switched off.

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

VERIFICATION FIELD TEST

Once again NGR failure detection verification field tests were taken on transformer station RTP Sežana (Figure 2) with cooperation of distribution company Elektro Primorska d.d., relay manufacturer Iskra Sistemi, d.d. and independent institute Elektroinštitut Milan Vidmar. Testing were conducted on NGR with nominal resistance of 80 Ω installed on power transformer 110/20 kV. Measurement plan was covering different possible operational cases of NGR, but main focus was to achieve total failure of NGR (operation with isolated network) and performing a ground fault at changed resistance of NGR. Performing a ground fault with partially reduced NGR resistance was not allowed because of dangerous operation in case a real ground fault occurs on the network – all tests were performed in real transformer station operation with normal load. In both cases NGR failure detection alarm report were expected. All measurements were performed on primary side of NGR (with proper measuring equipment) and secondary side of NGR via CT and VT.

Figure 2: Field test site with existing NGR and additional NGR of 80 Ω resistance

NGR breaking failure test

Breaking-disconnecting test of NGR has been performed during normal operation of 20 kV distribution network which temporary operated with isolated neutral ground point. Voltage and current diagram during test is presented on Figure 3. Current through NGR dropped to zero and voltage increased slightly. After adjusted operation delay the detection First part of NGR failure algorithm accurately reported alarm.

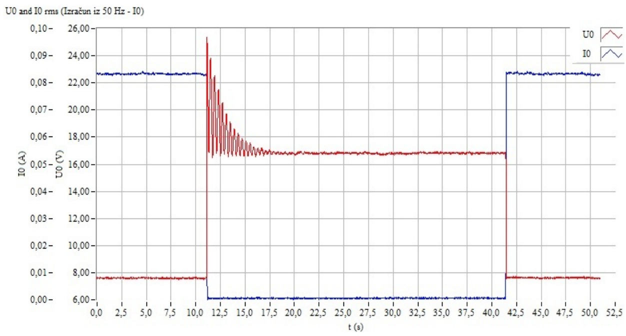

Figure 3: Recording of current and voltage measurement at breaking of NGR

Ground fault at increased resistance of NGR test

Additional NGR was installed in serial to existed NGR to achieve increased NGR resistance of totally 160 Ω. During this abnormal operation of the distribution network, ground faults were performed. Voltage, current and alarm trigger diagram during test is presented on Figure 4. Current of only 75 A has been detected through both resistors which is half of nominal current at normal operation. Second stage of NGR failure algorithm accurately reported alarm.

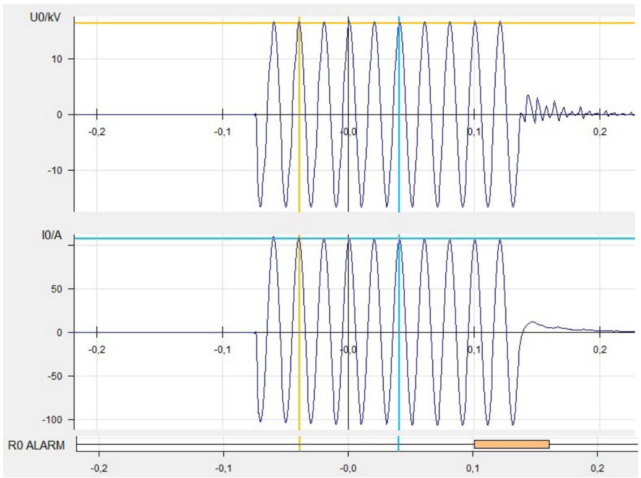

Figure 4: Recording of current and voltage measurement and alarm trigger at ground fault by higher resistance of 160 Ω

SUMMARY

Operating with damaged (changed from nominal resistance) NGR in power system networks is dangerous and not allowed.

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 ground faults.

During five years of developing and testing NGR failure detection we improved parts of algorithm for preventing detection miss-operation. Presented failure detection were tested on several NGR's, located in different areas in Elektro Primorska d.d. distribution system, for past two years.

Based on results and experience of NGR failure detector, Elektro Primorska d.d. is extending installation of this detection systems on all NGR locations. With proved algorithm by multiple field installations and performed field tests, future plans for NGR failure detection are also extension to protection functionality, which will switch off power transformer with damaged NGR.

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

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