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THE RCC GROUND FAULT NEUTRALIZER

A NOVEL SCHEME FOR PRE- AND POST-FAULT PROTECTION

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THE RCC GROUND FAULT NEUTRALIZER – A NOVEL SCHEME FOR PRE- AND POST-FAULT PROTECTION

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Introduction

The energy system ranks among society's most critical infrastructure and the demand for reliable electricity of highest quality is ever increasing. Deregulation among utilities and network operators, combined with elevated consciousness on matters of operational efficiency and cost-effectiveness, put intelligent means of managing plant assets into focus. Condition based maintenance (CBM), is a collection of predictive strategies and knowledge rules to target repair and refurbishment efforts onto defective system components. However, these strategies presuppose reliable ways of pinpointing where faults have an increased probability of occurring.

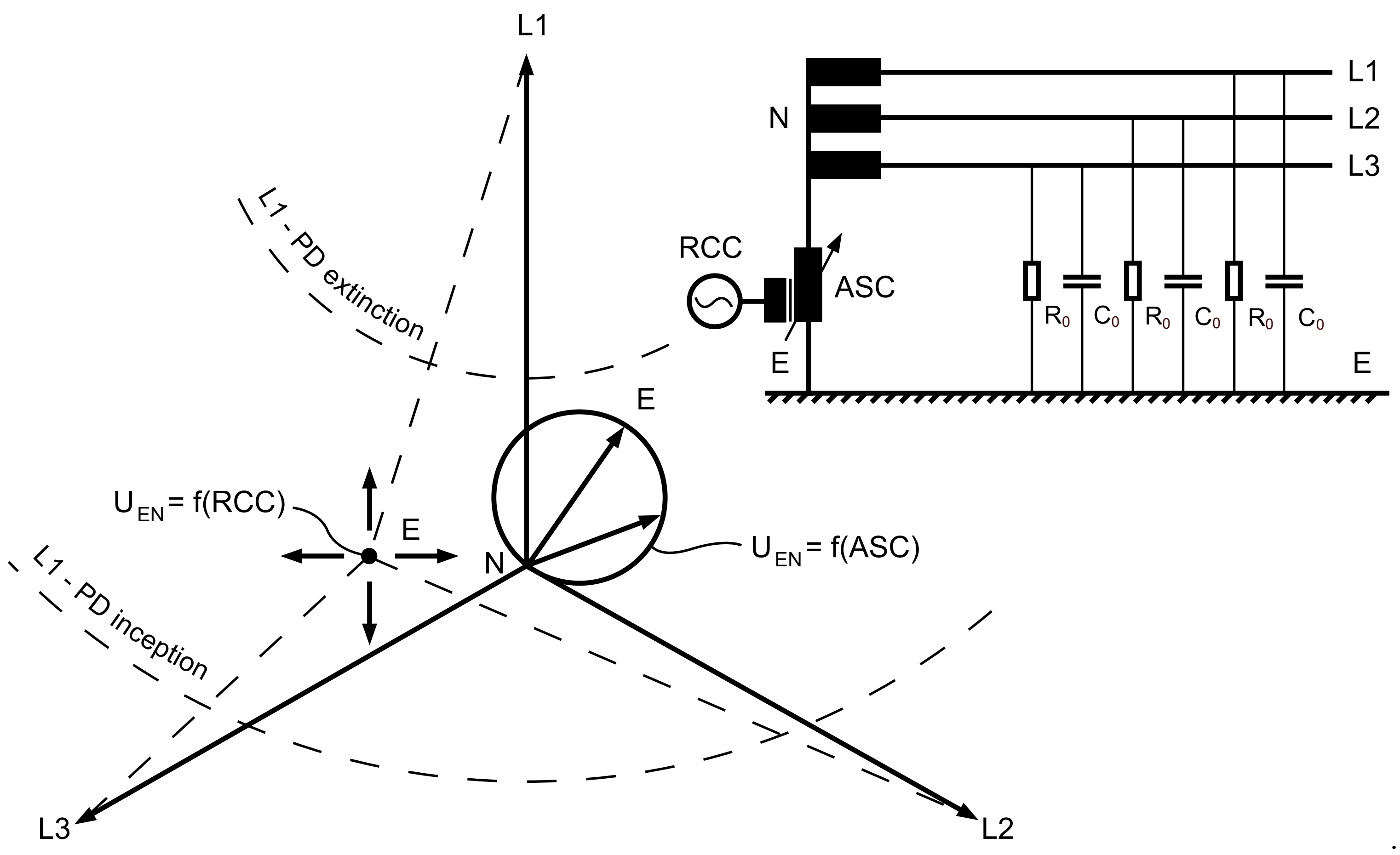
Many of the world's cable grids will soon be reaching the end of their statistical life span. However, the physical condition of an electrical cable is not always directly correlated with age. Examples can be given where cables have functioned flawlessly since their commissioning in the early years of the last century. Still, at an aggregated level, cable failures are increasing with age, and operators have a massive task at hand in responding to the degradation of their networks. A straightforward full replacement of the whole ageing cable park is neither a practically feasible, nor an economically defendable solution. Therefore, strategies and methods to identify and locate faults and failures before their occurrence become a very attractive approach to manage electrical distribution assets.

The partial discharge phenomenon (PD) has been identified as a reliable indicator of incipient dielectric collapse. PD activity can be measured offline and online, both methods offering their respective advantages but also, to date, exhibiting inherent limitations. To catch all impending insulation breakdowns, a continuous monitoring system would be necessary, but the detection of PD activity at normal operating voltages often raises the warning signal much too late. The avalanching development of partial discharge into a complete fault is in most cases only a matter of hours.

By means of voltage injection into the neutral, the RCC Ground Fault Neutralizer can immediately quench partial discharge activity and thus prevent the further development into full dielectric breakdown. Furthermore, full control of the phase-to-ground voltages also enables online PD testing at offline voltage levels and thus systematic fore-checking strategies for the early detection of defective system components - without at all affecting the power supply to end-users.

The RCC Ground Fault Neutralizer, developed originally for safe post-fault protection in resonance grounded overhead networks **(7)**, *now also generates a new option for true pre-fault detection. This in turn adds another strong argument for resonance grounding as the superior grounding concept, both for overhead as well as cable networks.*

Figure 1: RCC Ground Fault Neutralizer, PD detection and control



State of the Art in Neutral Grounding

Resonance grounding has been used in Central and Eastern Europe as well as in the Scandinavian countries for many decades. Low outage rates in these networks mirror the excellent properties of the “Petersen coil”. Single phase flashover faults on overhead lines are cleared by self-extinction without feeder tripping.

Since EdF in France and now also ENEL in Italy decided to introduce arc suppression coils in their medium voltage (MV) grids, resonance grounding has definitely become the dominating grounding concept for distribution networks in Europe.

In order to meet increasing public demands for safe and uninterrupted power supply, utilities are replacing overhead lines by cables in MV networks. This strategy is costly and not fully unproblematic. The number of weather related disturbances is reduced drastically, but localization and repair of cable faults are much more time consuming.

Figure 2: 110kV German railway transmission system, RCC Ground Fault Neutralizer, plant overview (courtesy Deutsche Bahn)

The operation of a faulty cable is virtually impossible. An un-extinguished and re-striking single phase cable fault very soon develops into a short circuit or a cross country fault. The consequences are often supply interruptions for large areas.

With the RCC Ground Fault Neutralizer, the conditions for the operation of cable grids have changed fundamentally. The fast and safe arc extinction – cable faults start in almost 100% of cases as single phase insulation breakdowns – prevents further propagation into a short circuit or cross country fault.

The Neutral – Key to the Ground Fault Problem

For a successful solution of the ground fault problem, it is fundamental to restrict the convey of electrical power to the positive and negative sequence system only.

Figure 3: Modern dry-type arc suppression coil for distribution networks

This important precondition has been kept in all European HV and MV grids from the very beginning. In contrast to the Anglo-American ”Multi-Grounded 4-Wire System”, in Europe payload is distributed exclusively between the phases.

Thus, the zero sequence system remains free for detection and disarming of single phase to ground faults. These faults are clearly dominating in almost all transmission and distribution grids. For the purpose of sensitive ground fault detection the Swede Torsten Holmgren (1874 – 1934) proposed a special CT-connection for zero-sequence measurement, already in the end of the 19th century.

The ”Holmgren connection” in turn was a precondition for Waldemar Petersen’s (1880–1946) line of thinking **(1)** : To use a tuned inductance between neutral and ground for systematic choking of the fault current – allowing the self-extinguishing of arcing faults without hindering the localization of permanent faults.

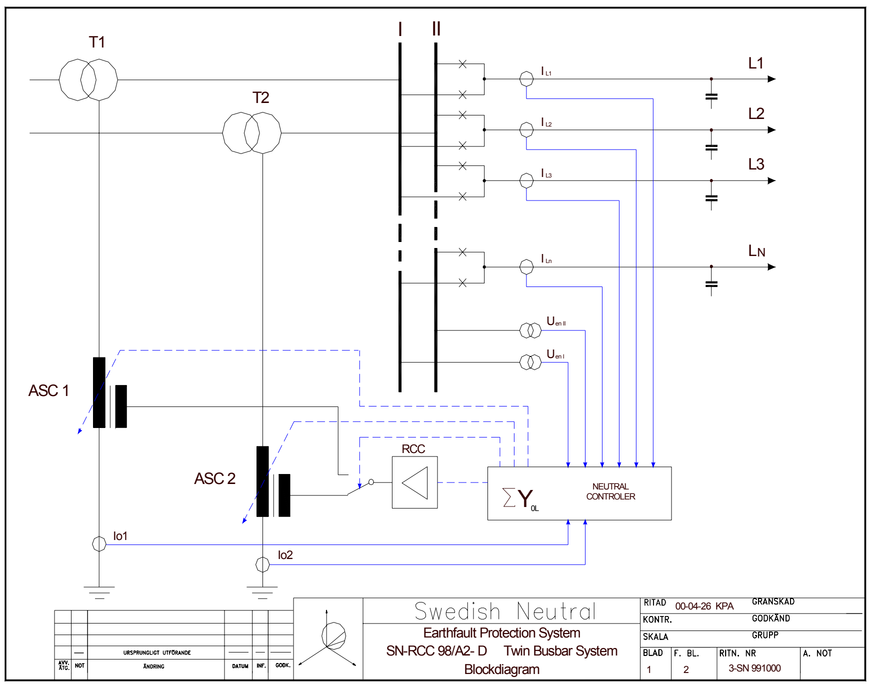


Figure 4: RCC Ground Fault Neutralizer for twin-busbar, block diagram

With the "Petersen coil", the problem of conductor ruptures due to arcing flashovers on overhead lines finally got a solution. At that time the remaining residual current was not considered as a safety problem. On the contrary, the residual was necessary to locate permanent faults. Later on a polarized Holmgren connection was introduced, further improving detecting of high impedance faults.

Emerging Need for Residual Fault Current Compensation

The Petersen coil has proved its excellent properties right from the beginning in the early twenties. Resonance grounding is now the dominating concept in most European countries. But when planning of the 400kV transmission level started in the early forties, one had to think about residual current compensation. Operational experiences with the large 220kV grids had shown that humid weather conditions with high corona losses could jeopardize safe arc extinguishing.

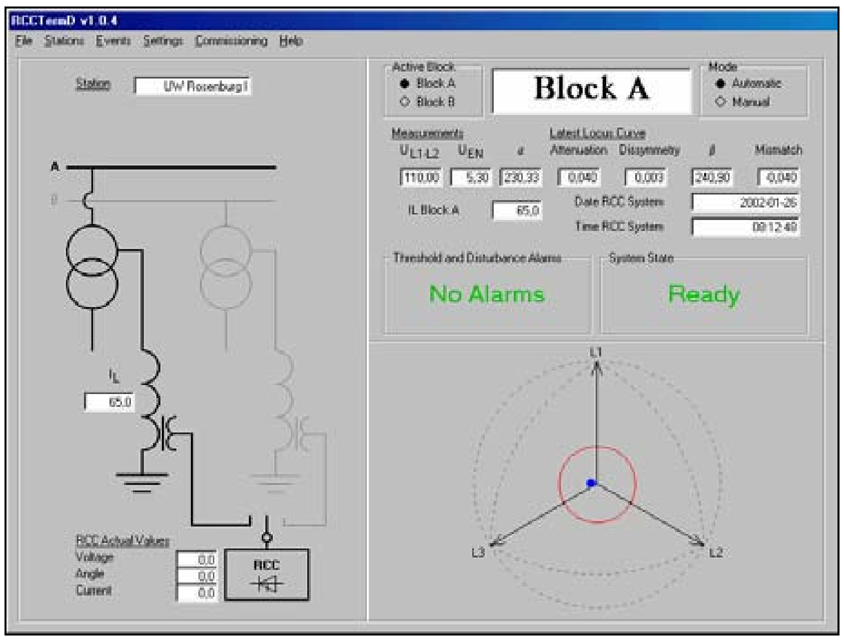


Figure 5: RCC Ground Fault Neutralizer, HMI software for MS Windows

The introduction of direct grounding on the 400 kV level and subsequent conversion of the 220 kV grids to this grounding concept in the late fifties and sixties, made this arc extinguishing problem obsolete for a time. The increasing number of short circuit stresses and voltage sacks along with direct grounding were considered to be acceptable and under control using meshed grids, broad three-safe right of ways and improved over-voltage protection.

Out of good reasons, many sub-transmission and most distribution grids are still run resonance grounded. Higher fault rates and radial structures of these grids would give rise to numerous supply interruptions when using direct grounding. On contrary, the inter-European comparison of disturbance statistics has resulted in a move from semi-direct grounding concepts to Petersen coils in countries like France, Great Britain and Italy.

Too late, one is tempted to state. Apparently, the classic arc suppression coil has lost its role as superior ground fault protection device, at least for the increasingly cabled MV grids. Instead of extinguishing the arc, the Petersen coil enhances the re-ignition process on cable faults, eventually leading to cross country faults and short circuits.

Figure 6: RCC Ground Fault Neutralizer, compact unit with integrated dry-type arc suppression coil for industry applications

In the traditional home of the Petersen coil – Central and Eastern Europe as well as Scandinavia, this apparently insolvable problem has started a reverse tendency. Pure cable grids are converted from high- to low impedance neutral grounding.

This deliberate conversion of simple ground faults with relatively low fault currents into single phase short circuits, being a fire and personal safety risk, is a matter of discussion. The costs for this suboptimized protection philosophy, causing frequent voltage sacks and supply interruptions, are mainly taken by the customers/consumers as an (avoidable) quality reduction of their electricity supply.

Figure 7: One of the first RCC Ground Fault Neutralizers in Sweden, 1992

The Development of the Modern Ground Fault Neutralizer

The increasing cabling of MV grids had side effects on the remaining overhead part. The specific capacitive ground fault current for a cable is about thirty times its value for an overhead line. In proportion, also the uncompensated residual current increases, thus increasing hazard potentials on the remaining overhead lines.

In order to stop this development, Swedish authorities already in 1987 introduced compelling claims for immediate disconnection also in resonance grounded networks **(2)**. At the same time, an improved detection of high impedance faults was introduced. Ground faults with up to 20 kOhm fault impedance are to be detected safely today. The mandatory limit for line disconnection is 5 kOhm in Sweden.

These new Swedish regulations initialized the development of the modern Ground Fault Neutralizer with fast tuning solid core arc suppression coils, residual current compensation and computer-aided adaptive zero sequence measuring for detection of high impedance ground faults **(3).**

The first of these new full-scheme protection units developed by Swedish Neutral was commissioned in 1992 on the Swedish island Gotland (**Fig. 7)**. The first results of this pilot installation were presented to a larger public one year later at the IEE 5th International Conference in Power System Protection **(4)**.

By now more than seventy Ground Fault Neutralizers have been taken into operation, most of them in Germany where large portions of the MV network are underground. In addition to reduced accident potentials on remaining overhead lines, the unique arc extinguishing features on cable faults were the main argument for decision **(5)**.

The block diagram **(Fig. 4)** shows a cost-efficient solution for twin-busbar substations - only one RCC-inverter is necessary. A modern solid core arc suppression coils is shown on **(Fig. 3)**. The largest RCC Ground Fault Neutralizer so far installed is shown on **(Fig. 2)**. Further details of this 5.5MVA 110kV-plant are given in **(6)**. Finally **(Fig. 6)** shows a typical 6kVcompact unit for industry applications.

Conclusions

Upgrading the traditional arc suppression coil to a full-scheme Ground Fault Neutralizer means that Waldemar Petersen's superior protection concept of resonance grounding will survive the ongoing cabling in MV grids. The Ground Fault Neutralizer also provides for the first time truly fire and personal safe operation of sustained faults.

As many injury-files clearly indicate, speed is still the most essential aspect of protection. With a total response time of less than 3 cycles **(Fig. 8)** - independent of the actual fault location - the RCC Ground Fault Neutralizer has become substantially faster than traditional protection schemes.

Finally, the possibility to convert already existing PD online detection methods into true "Early Warning Systems" adds another strong argument for resonance grounding as the superior grounding concept.

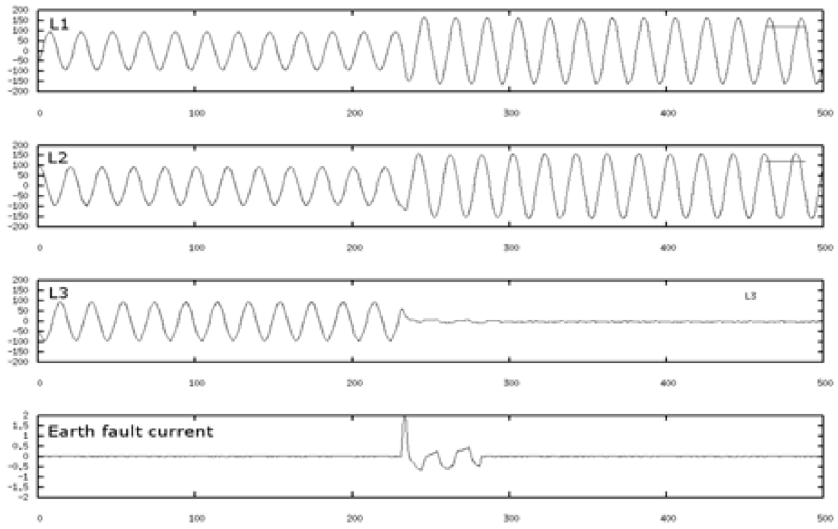


Figure 8: RCC Ground Fault Neutralizer, fault extinction time < 3 cycles

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