REPRINT

18TH INTERNATIONAL CONFERENCE AND EXHIBITION ON ELECTRICITY DISTRIBUTION
LINGOTTO CONFERENCE CENTRE, TURIN 6-9 JUNE 2005

THE RCC GROUND FAULT NEUTRALIZER

A NOVEL SCHEME FOR FAST EARTH-FAULT PROTECTION

Klaus Winter
Session 3 Paper 484

THE RCC GROUND FAULT NEUTRALIZER – A NOVEL SCHEME FOR FAST EARTH-FAULT PROTECTION

Klaus M. Winter
Swedish Neutral - Sweden
klaus.winter@swedishneutral.se

INTRODUCTION

The RCC (Residual Current Compensation) Ground Fault Neutralizer developed by Swedish Neutral defines new benchmarks for resonant grounded medium and high voltage grids. For the first time, safe arc extinguishing is possible also on cable faults.

*Speed is the most essential aspect of protection, trying to satisfy crucial conditions for personal safety and fire prevention. With a total response time of less than 3 cycles - independent of the actual fault location - the RCC Ground Fault Neutralizer offers a new quality in protection (***Fig. 1***).*

In many countries it has been practice to maintain full feeder operation during tracing of sustained earth-faults. Along with the increasing cabling of medium voltage networks now also the uncompensated residual has grown substantially, multiplying the risk for collateral damages during time consuming fault tracings .In order to stop this development Swedish authorities already in 1987 introduced compelling claims for feeder tripping within 5 sec.

The RCC Ground Fault Neutralizer now provides truly personal safe operation on sustained faults. Even in Sweden, being so aware of security, full-scheme protected networks are again allowed to maintain operation during fault tracing.

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 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

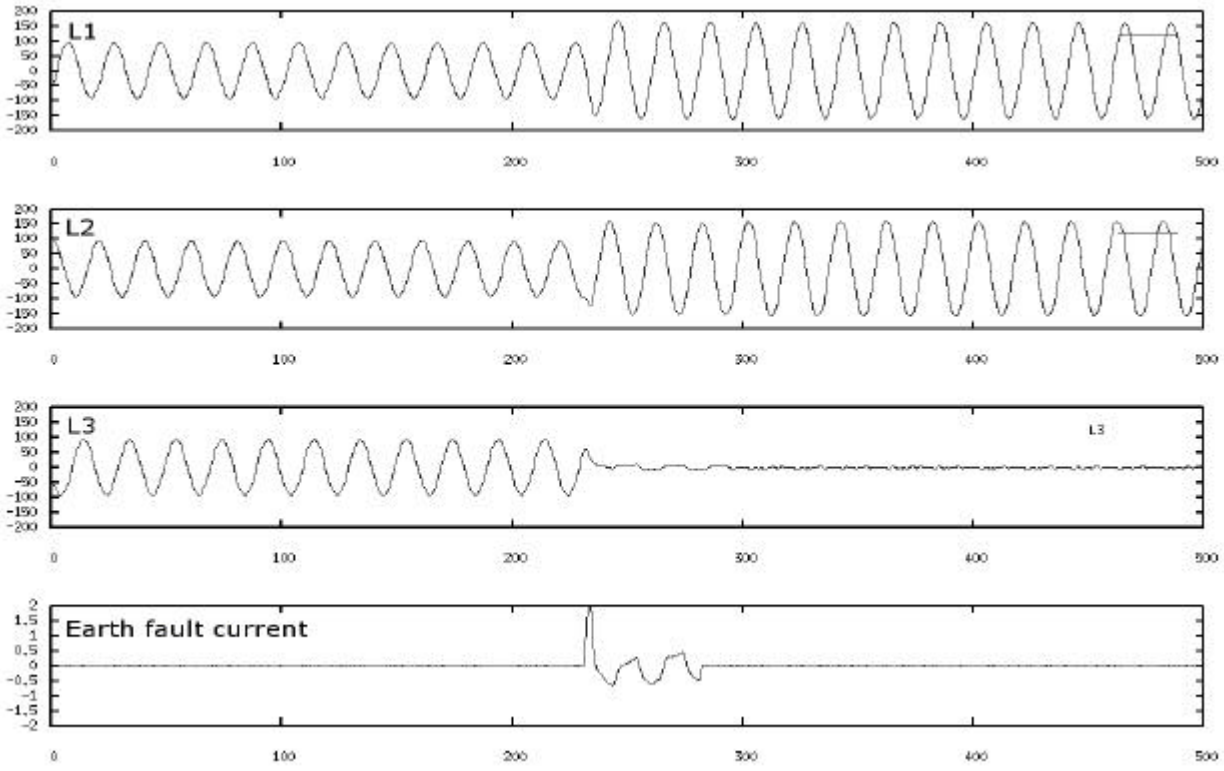

Figure 1: RCC Ground Fault Neutralizer, total response time < 3 cycles

Figure 2: 110kV / 16.7Hz, German national railway transmission system, RCC Ground Fault Neutralizer, plant overview (courtesy Deutsche Bahn)

lines by cables in medium voltage 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.

The operation of a faulty cable is virtually impossible. An unextinguished and restriking 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: 20kV twin busbar distribution, RCC Ground Fault Neutralizer, with solid-core arc suppression coils (courtesy WEMAG Vattenfall Europe)

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.

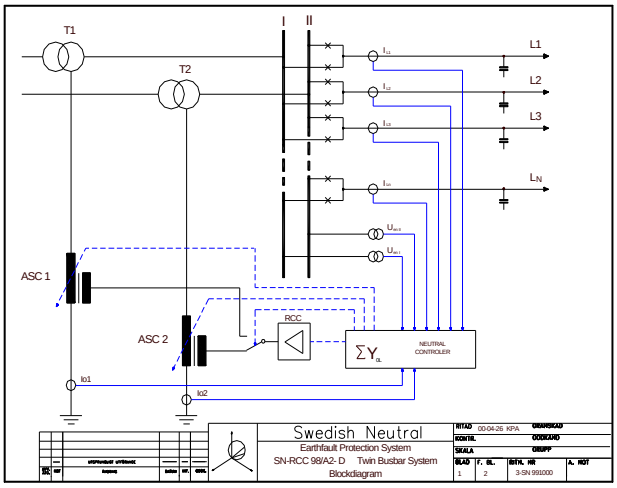

Figure 4: RCC Ground Fault Neutralizer for twin busbar, Blockdiagram

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 needs 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.

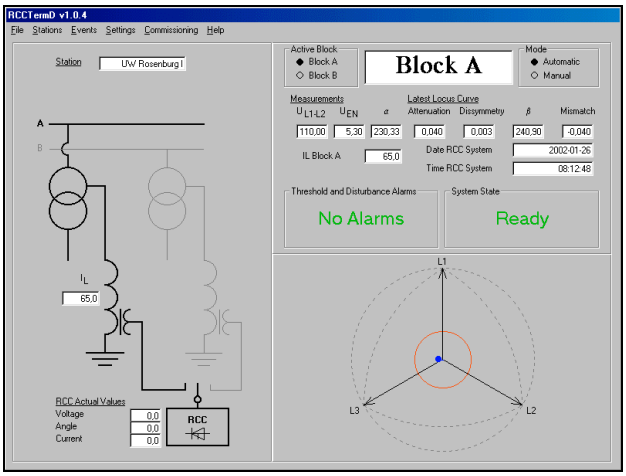

Figure 5: Operational surface for PC-terminals with MS Windows

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 overvoltage protection.

Out of good reasons, many subtransmission 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.

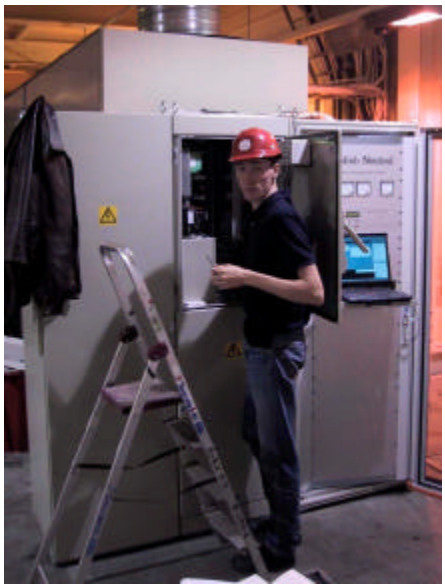

Figure 6: RCC Ground Fault Neutralizer, compact unit with integrated grounding transformer and arc suppression coil for industry applications

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 reignition process on cable faults, eventually leading to cross country faults and short circuits**.**

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 to low impedance neutral treatment.

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.

Figure 7: First RCC Ground Fault Neutralizers in Sweden, 1992

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.

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 fullscheme 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 fifty Ground Fault Neutralizers have been taken into operation, most of them in Germany, where large portions of the medium voltage 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 blockdiagram **(Fig. 4)** shows a cost-efficient solution for twin-busbar substations - only one RCC-inverter is necessary. A typical 20kV plant with 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.

Upgrading the traditional arc suppression coil to a fullscheme 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.

However, 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. 1)** - independent of the actual fault location - the latest model of the RCC Ground Fault Neutralizer has become substantially faster than traditional protection schemes.

REFERENCES

(1) *Wilheim R. and Waters M.*, "Neutral grounding in high voltage transmission" Elservier Publishing, New York 1956

(2) *Swedish Safety Regulations*, Starkströmsföreskrifter §73 ff " Published by Elsäkerhetsverket Stockholm Sweden

(3) *Winter K.* "Swedish Distribution networks – New aspects on neutral treatment", 3rd international conference on future trends in distribution switchgear, IEE conference procedure, London 1990

(4) *Winter K.* "Swedish Distribution networks – A new method for Earth-fault Protection in Cable- and Overhead systems", 5th international conference in Power System Protection, IEE conference Publication No 368, York /UK 1993

(5) *Koetzold B., Gauger V., Winter K.*, "Erdschluss-Schutzsystem mit Reststromkompensation – ein Weg zur höheren Versorgungsqualität in erdschluss-kompensierten Verteilungsnetzen" ETG-Fachbericht Nr 66, ETG/PSE Summer Meeting, Berlin 1997

(6) *Schmidt R., Krämer S., Winter K.*, "Erdschluss-Vollschutzanlage für das 110kV-Bahnstromnetz", Verlag Oldenburg, eb Elektrische Bahnen, 8/2003

Swedish Neutral

Premium Power Protection

Swedish Neutral AB Västra Rydsvägen 122 196 31 Stockholm-Kungsängen

Tel: +46 8 581 713 44 Fax: +46 8 581 759 52 Email: mail@swedishneutral.se www.swedishneutral.se