MODERN REDESIGNED TIME LIMIT FUSE PROTECTION FOR MV RING MAIN UNITS

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ABSTRACT

This paper describes a new, economic and modernised version of the well known Cleveland protection / Time Limited Fuse (TLF) principle. The protection diagram has been redesigned and can now be used on all modern types of Medium Voltage Ring Main Unit switchgear with far less energy need compared to the conventional TLF scheme. The paper describes the technical background of the design and the possible applications in the network.

The idea of the TLF design is that – instead of applying a Protection Relay – a very simple circuit is used for tripping the circuit breaker. Principally, the circuit includes current transformers for the three phases connected to a set of LV fuses with a trip coil in parallel. For normal primary currents, the excited current at the secondary side of the current transformer flows through the fuse. Because of the low fuse impedance, hardly any voltage is raised in the secondary circuit and no current will flow through the trip coil. In case of over-currents, the fuse will blow and forces the secondary current to commutate to the trip coil because this is the only way left.

The design includes an innovative and compact current transformer with two tap-offs that span all current ranges specified by ENA in one single design and a third tap-off optimized to feed the trip coil. The original TLF design has been industrialized from a set of bulky components into a smart sealed design with optimal functionality.

INTRODUCTION & BACKGROUND

Already in the 1950’s Ring Main Units in the UK were fitted with HV HRC fuses sometimes fitted with a common tripping arrangement to open all three poles in the event of a single fuse operating. Both the HV fuses and the load break switches were housed in an oil filled tank with the oil used for insulation, cooling and arc quenching purposes.

Due to instances of premature fuses rupturing, cost of replacing HV fuses, cost to maintain the oil, which was done on a far more regular basis then, along with contaminated oil, alternative designs were being considered in the 1970’s. These were based on oil circuit breakers fitted with current transformers in combination with LV Time Limit Fuses (TLF’s) for protection, which would eliminate the need for holding and carrying HV fuses. This design proved expensive as well as larger than its counterpart.

In the 1980’s several manufacturers started to look at combining circuit breaker technology with TLF’s to produce a new range of Ring Main Units utilising either vacuum interrupters in SF6 or SF6 circuit breakers. Of these original manufacturers very few are left in the UK market resulting in a lack of competition.

Most UK utilities have since standardised on the use of Time Limit Fuses for protection of distribution transformers up to 1MVA. They believe that the simplicity in terms of protection settings and also construction, reliability, durability, and speed of operation has been proven over numerous years of operation. When TLF protection is used it is possible to check the continuity of the fuses. In addition they are seen as being more economical than the equivalent self-powered protection relay.

Bearing in mind that each license holder can own and operate some 20,000 number distribution substations, another advantage of TLF’s is that there is no need to specify settings, apply, record and maintain the settings of each relay.

On transformers larger than 1MVA self-powered relays have to be used since there are no Time Limit Fuses specified for protecting these higher ratings. At the higher transformer ratings greater flexibility in terms of protection settings offered by self-powered relays can be a benefit [1].

PRINCIPLE OF CLEVELAND PROTECTION

The Time Limit Fuse design is based on the Cleveland protection scheme as already developed in the 1970’s. This Cleveland protection principle is based on a trip coil with a low voltage fuse in parallel connected with a current transformer for each of the three phases. If an over current or short circuit occurs the fuse(s) will blow and as a result the trip coil will be energized. A fuse in only two poles is sufficient for all inter-phase faults. In order to protect against earth faults, an extra fuse can be placed in the scheme to the star point – see figure 1. Checking the fuse(s) indicates the reason for the trip.

The benefits of the Cleveland protection scheme are that there is no need anymore for expensive and vulnerable HV fuses. It is therefore a very simple way to protect against short circuit, over current and earth faults and that it is easy to verify what kind of fault has occurred. The drawbacks of the Cleveland protection scheme are the need for bulky current transformers, the difficulty to realize a full-range of...
protection from over-current to short circuit and, three different trip coils have to be used.

Fig. 1 Principle of the Cleveland protection scheme

A NEW MODERNIZED TLF DESIGN

As indicated, the TLF design has several benefits, i.e. no HV fuses needed anymore, very simple and robust design and the possibility to distinguish an over-current from an earth fault. Eaton has concluded that it would be desirable if it could combine the benefits of the conventional TLF design with some more modern features to come to an optimized design from a technical and economical point of view.

For this reason a desk research study has been executed to investigate the market requirements, the various technical options, to verify if there were any patents applied or pending for any improvements on the Cleveland protection principle and what the possibilities were for integration in the SF6-free Xiria Ring Main Unit.

As a next step the team has explored the application of modern components – like rectifier bridges, varistors or sidacs – to optimize the design from a technical and economical point of view and, also with the wish to apply more compact current transformers. Different schemes are possible to combine protection against short circuit, over-current and earth fault by selecting 2, 3 or 4 fuses in different configurations. The result is the new multifunctional protection scheme as shown in figure 2.

Fig. 2 The new TLF protection scheme

The principle is that for normal primary currents (normal situation) the excited secondary current can flow through the low impedance circuit with the fuse. Therefore very little voltage is raised in the secondary circuit, resulting in relatively good transfer of primary to secondary current, even with low ratio windings. In this situation almost no current will flow through the trip coil circuit. In case of over currents, one or more fuses (A, B and/or C) will interrupt the then too high secondary current. The only way for the excited secondary current left after fuse interruption is therefore through the rectifier bridge and trip coil via the specific secondary voltage winding, optimized for the trip coil specifications. In case of an earth fault, fuse E will blow and trip the circuit breaker. By selecting fuses A, B, C and E, various (optional) protection schemes can be configured with the same basic layout. Dependent on the desired protection scheme one of the three fuses A, B or C can be replaced by a solid link to minimize the number of fuses. Also fuse E can be replaced by a solid link in case no earth fault protection is required. Of course this will lead to less information in case of a fault.

Design criteria in this respect are peak current (and therefore peak voltage across components) at full rated short circuit current and thermal load of the components in case of maximum power transfer through the CT. Overvoltage protection can be realized by varistors in parallel to the CT’s. The standard CT has been designed with one secondary winding, having tap offs at 50/5 and 100/5 ratios in order to cover all required nominal primary currents [3]. The voltage needed to energize the trip coil in case of over-currents defines the full number of turns of the secondary winding. In case of high primary short-circuit currents; secondary current spikes will appear caused by saturation of the CT. For this reason a capacitor has been added. The sidac function is to block the current through the trip coil until the capacitor is charged. In this way minimum energy is dissipated, so a fast trip is possible.
Furthermore modern print design- and casting techniques have been used to make sure that the new TLF design is insensitive to severe ambient conditions and maintenance free for at least 30 years. At the same time the set up was designed in such a way that it is possible to exchange the fuses with the Xiria Ring Main Unit in service in order for alternative settings to be introduced. For this reason a temporary short-circuit connection in parallel to the fuses is provided in the terminal block.

Another design aspect was that the TLF protection unit fits in the same dimensions within the Xiria Ring Main Unit as the self-powered WIC-1 relay that is used for protection for the larger transformers [4]. This has led to the embedded design as shown in figure 3.

As this modernized TLF design is based on an old well-known protection principle but also on a new combination of several modern components and technologies, Eaton has applied for a patent at the European Patent Office, which is currently pending.

**TEST PROGRAM**

The next step in the development of the new modernized TLF design was an extensive test program. These tests were performed at the Prof. Ir. Damstra Laboratory in Hengelo, the Netherlands. This test laboratory is certified by KEMA Quality according to ISO 17025:2005 and accredited by ASTA/BEAB in Rugby, Warwickshire.

The test program was executed during the fourth quarter of 2007 and included several electrical, thermal and functional tests. The test program included (amongst others) single and three phase tripping on over-current and earth fault, maximum short circuit tests, single-phase minimum voltage tests to determine the resistance over the circuit and several tests to determine the thermal behaviour of the individual components.

The scope of the functional test program included 50/5 and 100/5 CT ratios and Time Limit Fuses with a rating of 3, 5, 7.5, 10, 12.5 and 15A. These ratings are based on the preferences of the UK market as specified by the ENA [3]. The functional tests have been executed in each design phase as well as for the industrialized version mounted in the Xiria Ring Main Unit – see figure 5.

The current TLF range for the Xiria Ring Main Unit (see figure 4) is covering transformer protection for ratings from 200kVA up to 1000kVA for application in 6.6 and 11kV networks. The TLF design complies with ENA technical specification 12-6 issue 1:1973 [3] and is currently being assessed by the ENA Protection Assessment Panel.
CONCLUSIONS & SUMMARY

Utility customers in the UK are already working since the 1970’s with TLF protection for several technical and economical reasons and are having good experience with this principle. Based on this Eaton has improved the TLF protection by developing a modern version based on state-of-the-art components, a maintenance-free and ambient proof embedded design. This design has been extensively tested and is now commercially available against lower cost than self-powered relays.

The features of this new TLF are:

- Over-current and earth fault protection
- Complete range of current settings within one standard design
- Maintenance free design with low energy need
- Only one trip coil is sufficient for the complete protection
- Application of compact CT’s
- Ergonomic access to the LV fuses on the front
- Compliance with ENA specification 12-6
- Fully tested at a KEMA certified laboratory

REFERENCES


