THE SMARTER SINGLE BREAKER RMU. A FUSE-LESS, SINGLE BREAKER, AUTO-LOOP-SECTIONALIZING RMU

Stylianos NIKITAKIS
emac ltd – Greece
s.nikitakis.emac@gmail.com

Georges ARGYRIOU
emac ltd-Greece
g.argyriou.emac@gmail.com

ABSTRACT

Cost efficient Cable Distribution Grids currently and to a greater extend in the future, must meet the following Smart-Grid requirements:

1. *High performance and reliability (Self-Healing)*
2. *Integration and control of Distributed Generation (Islanding) and e-car charging.*
3. *Reduction of power losses (Congestion Management resulting in "Green Smart Grid")*

The only point in the network where these requirements can be addressed is the Ring Main Unit. It is therefore evident that a "Smart-Grid" must rely on a "Smart RMU".
Already several major Distribution Utilities and RMU manufacturers are in the process of developing the "Smart RMU" by applying telecoms and sensors, as well as motorizing or replacing the LBFM Switches and the HRC fuses with vacuum breakers. It is now widely accepted that in the ideal maintenance-free "Smart RMU" the LBFM Switches and the HRC Fuses should be completely eliminated and replaced with three vacuum breakers.
The ***"Smart Three-Breaker RMU"*** *as shown in Figure 1, is clearly the ideal component of the smart-grid secondary substation. The only disadvantage being its* ***high cost*** *as a result of utilising three vacuum breakers.*
In this paper we will present the "Smarter Single Breaker RMU" which has all the advantages of the Smart Three-Breaker RMU as well as being considerably more cost-efficient. Furthermore, it offers the possibility of modernizing old generation RMUs in a cost-effective way.

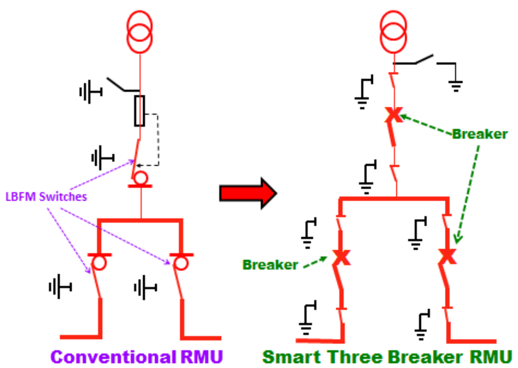

Figure 1. Single Line Diagrams of a Conventional RMU with 3-LBFM Switches c/w HRC Fuses and the Smart Three-Breaker RMU.

INTRODUCTION

The rate of urbanization is accelerating globally, consequently the demand for high performance Medium Voltage Cable Networks adhering to the Smart-Grid requirements is on the rise. Until recently, the performance of urban networks using current technologies has been satisfactory because power flow was largely uni-directional from the HV/MV power substation source to the load points via Normally Open Rings (Passive Grids). There is an increasing need for bi-directional and active operational functionality of Medium Voltage Cable Networks with the ability to be "Self-Healing", reduce losses and handle multiple variable current source points. This major shift in requirements renders the use of "Smart Grids" concepts a necessity. Bearing in mind that the majority of the network is buried cable, it is clear that the key location for the implementation of the "Smart Grid" principles is the RMU. Minimizing the need for human intervention in dealing with the Distribution Grid operation and malfunctions is an important feature of modern cost efficient networks. The "Smart Grid" concept emphasizes automation through DMS (Distribution Management Systems) delivering the following:

1. Self-Healing.
2. Reduction of power losses (Congestion Management)
3. Integration and control of Distributed Generation (Islanding, Micro-Grid operation) and e-car charging.

In order to apply successfully the DMS and accomplish above objectives the following conditions need to be fulfilled:

A. Real time continuous **data monitoring and recording** of multiple grid parameters in multiple points of the Grid, using sensors located in the Smart RMU (KV, Amps, KVA, KVAR, KW, KWh, Power Factor, Harmonics, oscillography, Low Voltage feeder monitoring, Transformer dielectric temperature, pressure etc.).
B. **Instant intervention** capability which can only be accomplished by the application of loop and transformer vacuum breakers.

The cost and importance of distribution transformers is on the rise as amorphous or special reduced losses designs are increasingly being required (Green Grid) in order to minimize power losses and improve performance. This further reinforces the need for a significantly improved distribution transformer monitoring and protection system including transformer sensors for temperature, pressure, oil-level, vibrations, internal arc and gas generation DGA, which can identify transformer malfunctions at a very early stage and schedule for transformer service accordingly and minimize transformer damages.

In a Medium Voltage Cable Grid, approximately 85% of the Faults are caused by cable/sleeve connections and 15% are Transformer or Transformer HRC Fuse failures. Of these, 70% are erratic HRC Fuse operations, and only 30% are Transformer failures out of which only 4% are Phase-to Phase Transformer Faults. This represents a mere 0.018% overall, of Phase-to-Phase Transformer Faults for the Medium Voltage Grid.

For all isolated or Petersen grounded networks and lower Earth-faults in resistance-earthed systems, the HRC fuse is of almost no use, as it is only in the extremely rare cases of high amperage faults, that it would operate.

These reasons, as well as the handling of Distributed Generation located in the low voltage, e-car charging and the need to address the islanding phenomenon, reinforce the already established practice of the use of a Breaker for the Transformer protection [1].

All of the above requirements combined with expectation of a modern RMU to perform completely maintenance-free for more than 50 years, reinforce the notion that an ideal "Smart RMU" should utilize three vacuum breakers.

ADVANTAGES OF THE THREE-BREAKER RMU

By replacing the three LBFM switches and the fuses with secondary vacuum-breakers, the "Smart Three-Breaker RMU" allows the application of DMS accomplishing the following:

1. Instant Automatic Bi-directional Loop Intervention Capability with Auto-Loop-Sectionalisation Breakers (Self-Healing).
2. Extended maintenance-free operational life by eliminating the problematic LBFM switches. (Reduced fault making duty, lack of fault interruption capabilities, low electrical and mechanical endurance, making them inadequate for frequent maintenance-free automatic operations).
3. Integration and operation control of the medium and low voltage Distributed Generation (Islanding, Micro-grids, e-car charging).
4. Elimination of problematic fusing (not remotely resettable transformer protection, spurious fuse operations, heat energy losses, cost of spare parts inventory, high maintenance, poor harsh climate durability).
5. Improved protection performance for transformer internal zero sequence earth-faults and lower magnitude phase faults.
6. Improved transformer protection by the application of advanced sensing providing early stage warning of transformer malfunctions (temperature, pressure, oil-level, vibrations, internal arc and gas generation DGA).

1. Provision of Medium voltage Loop-cable, transformer and low voltage feeders readings and recordings of: KV, Amps, KVA, KW, KVAR, power factor, harmonics and oscillography.
2. Monitoring of Low Voltage Feeders of specific interest (With Distributed Generation, e-car charging, or any other special application.)

The Smart Three-Breaker RMU is clearly the ideal component of the Smart-Grid Secondary Substation. The main disadvantages are its **high cost** and **bulky dimensions**, largely owing to the need for **three vacuum breakers.**

THE "SMARTER RMU"

Figure 2 shows the single line diagram of the "Smarter RMU". The bi-directional single breaker performs exactly the same feeder protection and automatic loop sectionalisation function of the two breakers located in the loop of the conventional "Three Breaker RMU". The transformer is always protected by the same single Breaker because it is connected at the load side of this breaker through the use of the 3-position transformer load-current switch controlled by the microprocessor.

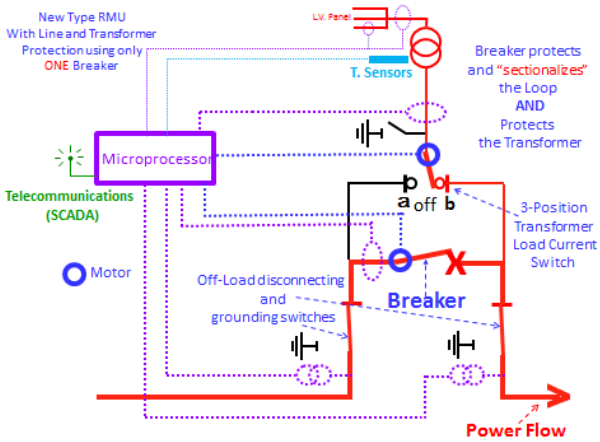

Figure 2. Single Line Diagram of "Smarter RMU"

Transformer Faults in the "Smarter RMU" Distribution Substation.

The vast majority of the Transformer faults are low amperage zero sequence or inter-winding faults.

The Smarter RMU microprocessor will identify them at their very early stage and either alarm for a scheduled maintenance or actuate the 3-Position switch in the open position isolating the damaged transformer within 200-300

msec as shown in Figure 3 and Figure 4, (provided the current is within the interrupting capacity of the 3-p switch).
In the rare case of a higher amplitude of the 3-position switch interrupting capacity, such as phase-phase fault in any system (0.018% probability), or earth-fault in the earthed system, the microprocessor will instantly actuate the Breaker and immediately following the fault clearance, the 3-Position switch will flip in the open position, isolating the damaged transformer. The Breaker will then reclose, establishing the power supply in the downstream network within 500 msec.

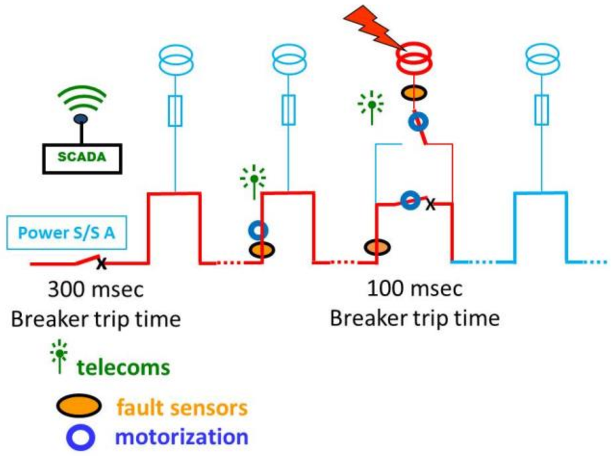

Figure 3. Zero Sequence Fault in the Transformer

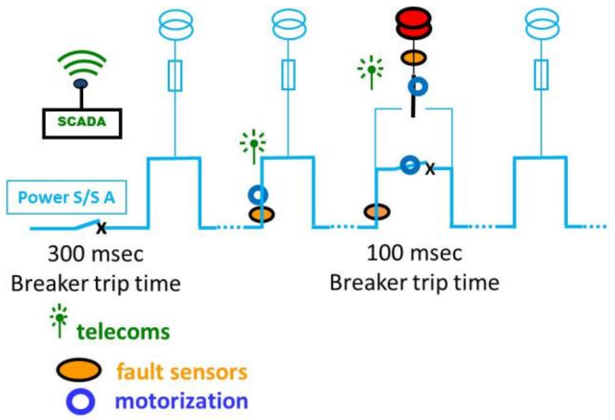

Figure 4. Damaged Transformer isolated.

Cost Structure of the "Smarter RMU"
Already the elimination of the HRC Fuses and the use of a Vacuum Breaker for the Transformer protection is an established practice with several electrical utilities and this type of RMU is readily produced by several manufacturers [1].
The application of replacing one of LBFM Loop-Switches with a Breaker is already an established practice by one of the biggest European electrical utilities. It is produced by several RMU manufacturers and the same utility recently introduced the concept of replacing both LBFM Loop-Switches with Breakers in SF6 insulation [2][3][4].
Hong-Kong, several Chinese utilities and some Swedish Municipalities are already using the 3-Breaker RMU.
Table 1 compares the cost of the "Smarter RMU" with alternative RMU designs. It is apparent that the "Smarter RMU" meets all the Smart Grid requirements at a fraction of the cost of all other Smart RMU designs.

	Basic RMU	RMU with XRMR Breaker	RMU with 1-loop Breaker	RMU with 2-loop Breakers	RMU with 3 Breakers	Smarter RMU
Breakers	0	1	1	2	3	1
LBFM – Switch	3	2	2	1	0	1
LBFM –Switch Motor	1	1	0	0	0	1
HRC Fuses	1	0	1	1	0	0
Earthing Switch	1	2	3	5	6	3

Table1. Cost Comparison of RMU Designs

Old RMU Refurbishment
By utilizing the Breaker and the 3-Position Switch packaged in a compact module as shown in Figure 5, any existing old RMU (including the old wall-mounted hook-stick operated units) can be modernized and can be made to operate maintenance free for more than 50 years, since the existing loop LBFM Switches will perform only an Off-Load Disconnect and Grounding function.

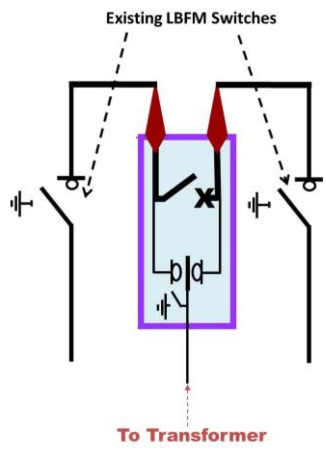

Figure 5. Refurbishment of conventional RMU

The Dielectric of the "Smarter RMU"
Urban Secondary Substations need to be extremely compact (due to high real estate cost in urban areas), reliable, safe, flood-proof, environmentally friendly and cost-effective. This was partially achieved through the use of SF6 as an interrupting and/or dielectric medium. The Kyoto protocol however imposes the reduction and ultimately, if possible, the elimination of SF6.

In the "Smarter RMU", there are only two active components (the Breaker and the 3-Position Switch) which significantly reduce the spatial requirements. This means that in addition to SF6, different dielectrics can be used such as dry air, nitrogen, solid insulation or esters in flood and pollution proof sealed mild steel or galvanized tanks of a smaller size than conventional breathing tanks.
In the case that the dielectric to be used is ester, a simple cost efficient concept can be utilized in order to meet the internal-arc requirements as shown in Figures 6 and 7.

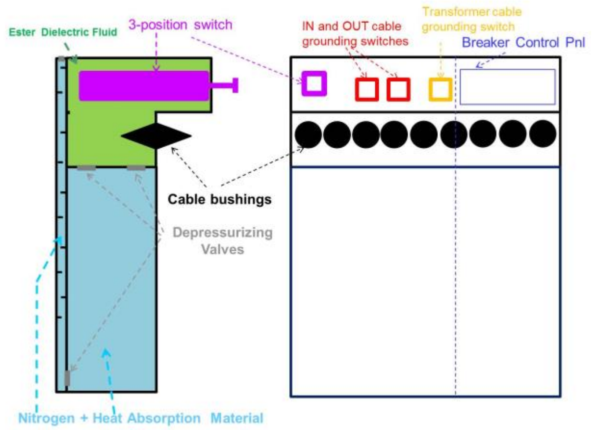

Figure 6. Smarter RMU with Ester Dielectic

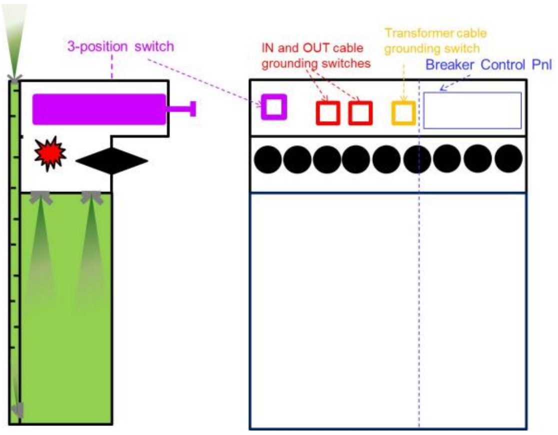

Figure 7. Pressure relief scheme during internal Arc-Fault.

CONCLUSION

As RMUs are expected to have a life-span of more than 50 years, so it is apparent that any new purchases and RMU new installations must be compatible with current and to a greater extend with the future Smart Grid requirements as per the applicable DNO's "Asset Management"/"Life-cycle Cost" policies.
This also applies to the refurbishment of old RMUs. The conventional motorized LBFM-RMU is clearly outdated as it lacks the ability for **instant and automatic loop sectionalisation** without causing serious operational and maintenance problems in the Smart Grid context.

The local intelligence embedded in the "Smarter RMU" provides additional practical application possibilities, such as back-up protection in case of telecom break-down or DMS/ SCADA malfunction and for distribution networks which do not yet have a DMS/SCADA managed system *i.e.* a "self-healing" protection system.
Self-healing protection in an existing network can be implemented through the integration of a few "Smarter RMUs" delivering protection performance equivalent to a SCADA system at a fraction of the cost.
This feature makes the "Smarter RMU" the perfect unit for Micro-Grids or for any user who is delaying the application of a major DMS/SCADA installation and needs a temporary cost effective protection scheme which will also be compatible with any future DMS/SCADA installation.
The use of breakers for transformer protection or loop sectionalisation or both has produced so far very positive results. The three-breaker RMU meets all future "Smart Grid" requirements using breakers for transformer protection and loop sectionalisation. The main disadvantages are high cost and bulky design.
The "Smarter RMU" concept provides the same performance as the three-breaker RMU at a fraction of the cost. It allows for a more compact design and it makes it possible for existing conventional RMUs to be upgraded with ease, further reducing costs. It can be easily integrated in any network with or without SCADA providing in both cases a "self-healing" protection performance.

REFERENCES

[1] J.M Biase, Y.Chollot, J.Tobias, "Circuit –Breaker RMU improves MV/LV Transformer Protection", CIRED 2009
[2] P.Deschamps, P.Alibert, J.M.Biase, "Reduce the number of outage by introducing circuit breaker in the distribution network, dream or reality?", CIRED 2011
[3] B.Opitch, M.Haslinger, M.Spangler, "Intelligence for smart grid last mile", CIRED 2011
[4] F.Giammanco, L. Giansante, "A low cost high performance MV RMU with circuit breakers for use in remote controlled MV-LV substations" CIRED 2011
[5] F.Gaillard, P.Lauzevis, A.Hettich, F.Farago, T.Malikova, P.Michalovic, P.Dyer, C.Guillaume, "OUTCOME OF SMARTLIFE: A EUROPEAN COORDINATION ACTION IN ASSET MANAGEMENT OF T&D NETWORKS." CIRED 2011