TITLE: ONLY SMART RECLOSERS BUILD SMART GRIDS

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Summary:

Smart Grid is on the agenda of almost every utility in the world today. A true Smart Grid starts with the automation of utilities distribution networks and a key building block for the automation of distribution networks is reclosers. What do reclosers need to provide this building block? This paper attempts to summarise the solution.

Introduction:

Power utilities worldwide face similar challenges every day to overcome generation, transmission and distribution issues which range from quality and uninterruptible supply to investment and commercial matters aiming at increasing turnover, avoiding penalties from the regulator bodies (in some countries) and ultimately increasing the financial return for investors.

Whilst there is not an unique universal accepted definition for Smart Grid, its concept certainly relates to the approach of deploying leading edge technology based products to optimize the power system operation, improve power quality, enhance equipment utilisation, reduce equipment maintenance and related repair costs, create or support new revenue-bearing services, decrease electrical losses on the distribution systems, reduce overall electrical demand, sell more kilowatt-hours of electricity, achieve labour-related savings, reach environmental goals (green mandates) and others.

Considering the business drivers above, current market opportunities in distribution automation involve Volt/VAR optimisation, fault detection, isolation & restoration, digital protection & control automation, general monitoring / diagnostic applications, leverage SCADA, DMS, OMS and GIS systems and others.

Specifically for the distribution sector which is arguably the most problematic and therefore least reliable part of the power system, fault detection, isolation and restoration enables electricity distribution utilities to reconfigure the electric grid remotely or automatically in response to unplanned and planned outages. Today's intelligent digital protection systems allow these processes to be automated. The primary benefit of fault detection, isolation and restoration is improved reliability often measured using the system average interruption duration index (SAIDI).

Reclosers are seen as the key Smart Grid building blocks available for fault detection, isolation and restoration programs in the distribution systems and the result of this fact has been an unprecedented increase of global demand for this product.

Many utilities are challenged with purchasing the cheapest solution. A complete solution in a recloser product considers a long life environment friendly tank that is arc fault contained and vented for safety, voltage and current measurement on both sides of the device and a powerful micro processor based control that can provide the complete Smart Grid solution.

A smart recloser offers a complete design solution with integrated smart grid capabilities offering not only remote control but automation and the analogue data measurement and logging capabilities to achieve the utilities business drivers. Smart reclosers provide automation for distribution automation, instantaneous analogue measurement for VOLT VAR optimisation, automatic fault detection including full directional capability for automated isolation and restoration, multiple communications protocols for Scada integration together with GPS mapping capability to be integrated into the latest DNS systems.

It is the view of the authors that only smart reclosers, hardware and software wise, build

smart grids and some important features of these computers on poles are briefly discussed in the following paragraphs.

Smart Hardware

Whilst a great deal of what a smart recloser is capable of doing is intimately related to the code its firmware and software enclose, the correct hardware is the ground floor not only to support this advanced software, but also ensure a long field proven maintenance free lifetime.

✓ *Magnetic Actuators*

For pole mounted switchgear one of the critical considerations must always be associated with energy required to operate the device. Because of the pole mount environment, a UPS power supply system is required to operate the controller and remote communications equipment. It is also important that the switchgear has the ability to be operated independent of HV supply presence to ensure the switchgear can be opened and closed on a de-energised line.

Magnetic actuators combined with vacuum interrupters allow for the maximum in required forces and the minimum in required operating energy which provides the best solution. Magnetic actuators also allow for high speed auto reclosing with duty cycles as fast as CO-0.1s-CO-1s-CO-1s-CO, utilising a stored energy charged capacitor system used to provide the energy to trip and close the device.

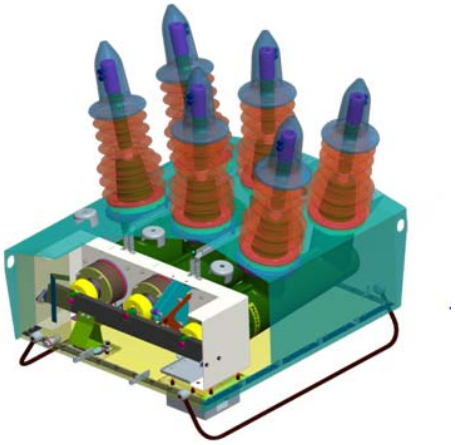

Figure 1 3D Modelling in Smart Recloser Design

✓ *Solid Dielectric Insulation: No Oil / No Gas*

Auto reclosers have been used in overhead distribution networks since the early 1940's with the advent of the first hydraulic/oil devices which utilized oil as the interruption medium and oil as the insulation medium. The evolution then saw vacuum interrupters inside steel and aluminium tanks with oil as insulation medium and porcelain bushings. The next generation of products utilized SF_6 as the interruption and insulation medium and further evolvement saw the use of vacuum interrupt inside an SF_6 insulated tank using either porcelain or polymeric bushings. Some of these products variants are still available on the market but must be considered to be phased out due to the environmental and health risks associated with the use of SF_6, regular maintenance and are not considered as a viable option today.

This has seen the introduction of a range of vacuum interrupt solid dielectric products into the market. The majority of these products utilize cyclo aliphatic epoxy resin and embed the vacuum interrupter into the cyclo aliphatic epoxy resin poles which are exposed to the environment. Magnetic actuator type mechanisms are then used on each pole to actuate the device. These magnetic actuators are normally encased in a mild steel or stainless steel housing which also provides the base plate for mounting the cyclo aliphatic resin pole. This configuration has achieved the goal of eliminating the use of harmful insulants such as SF6 and oil and should be the safe and environment friendly choice today.

✓ *Arc Fault Containment & Venting*

Whilst the solid dielectric has achieved the goal of eliminating the use of harmful insulants such as SF_6 and oil and addressed the environmental issues it does not address the safety issues and the long life issues in an acceptable manner.

In addition, reclosers must provide arc fault containment and venting in accordance with the requirements of IEC62271-200:2003. This important safety feature operates to ensure that the recloser will fail in a controlled manner in case a fault develops inside the tank and the arc cannot be extinguished resulting in internal pressure build up. This is a particular concern that

must be taken into consideration with the ever increasing live line installation practices used by electricity utilities around the world when installing new medium voltage plant and equipment not only in rural but also high populated urban area as part of their smart grid projects.

The patented arc fault containment and venting is achieved by manufacturing the tank from 304 grade stainless steel and providing an arc vent in pole side of the tank.

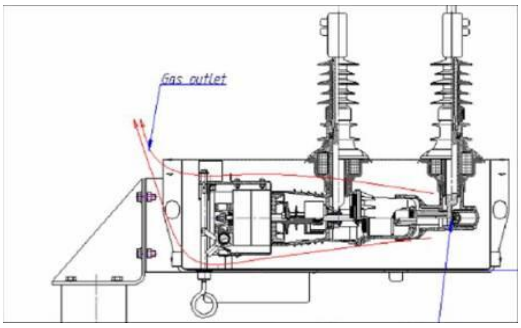

Figure 2 Arc Fault Containment & Venting Operation

✓ *Source & Load Voltage Measurement*

In order to provide the maximum in increased system performance utilising full DSA functionality as well as the required protection settings demanded by today's utilities the ability to measure current and voltage on all six bushings is required.

Whilst the majority of reclosers can be upgraded to allow for this complete measurement arrangement, it is often achieved by means of after sales accessories fitting.

Smart reclosers must be fitted with a complete set of measurement accessories which means voltage measurement on all six bushings and current measurement on all 3 phases and residual to allow for complete measurement, protection and automation functionalities to be implemented and this can be achieved by capacitively coupled voltage sensors and current transformers fitted as standard.

✓ *Reliable Electronics Design*

Smart reclosers are literally advanced computer on the poles. Poles on the other hand are harsh environment for computers to be in, with high level of vibration and electrical disturbance and nuisance. For this reason, when aiming at long life reliable products every aspect of the electronics design matter and must be considered.

Since the recloser tank is positioned closer to the MV lines where the electrical fields are stronger and also due to the tank vibration during the duty cycle operation, it is an intelligent approach to remove all active electronics from the tank and place them in the control cubicle where the above mentioned issues are minimized. PCB´s placed in the tank have proven to be a weak point in switchgear design in that not only the failure rate increases significantly but the maintenance always requires more work, which ultimately means higher costs.

Smart reclosers must have modular design which makes the production, testing, troubleshooting and eventual replacements considerably easier and quicker. The modules themselves enclose the military graded PCB´s and therefore should be built of mild steel constituting a Faraday´s cage for the electronics it houses while providing the good mechanical strength as well.

The communication between the different modules must be made via short and well screened cables to reduce interference and nuisance in the mV signals while eliminating poor electrical contact by robust and proper connections, making the inside of the controller cleaner and better. Such communication should also be ruled by a reliable protocol such as CAN, widely used in industries where errors can be fatal, such as automotive and aircrafts'.

The combination of the above incremental design enhancements contributes for an outstanding field performance that can only be perceived once the equipment is in service.

✓ *FPGA based controller*

Smart recloser controls require sophisticated signal processing to offer advanced protection, measurement and automation functionality.

A field programmable gate array (FPGA) provides the capacity to perform parallel

processing allowing complex algorithms to be processed simultaneously.

An FPGA can calculate all of the fundamental protection and measurement components including sequence components and data. By utilising an FPGA and the synthesis tools you can optimise the analogue system and allow the controller main processor direct access to the analogue signal database of the FPGA.

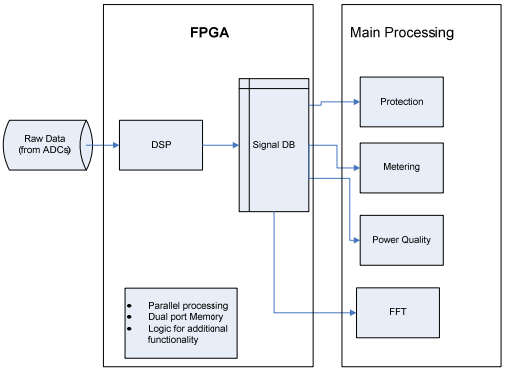

Figure 3 FPGA Based Controller Diagram

✓ *Simple & Powerful Field Support*

A strong side of Smart Grids is remote communication which allows operators to monitor and control recloser from great distances and therefore save the costs of having operators sent to the field. However, whilst communication media exist and evolve every day, they also experience outages and are not always available. In addition to these, some level of operational maintenance will always be required when replacing a battery, a module or doing some cleaning perhaps.

When these situations occur the recloser must feature a complete yet simple operator interface that allows for full local monitoring and configuration of protection and communication settings by means of intelligent navigation. Items such as large LCD able to display all required information at once eliminating excessive scrolling, combined with useful fast keys and signalling LED´s make the field experience simple.

The operator interface must also provide full language support allowing users in different countries to take the very same advantages of powerful equipment like smart reclosers.

Smart Software

Combined with powerful hardware availability, smart software development opens the way for a virtually unlimited range of possibilities regarding protection, automation, communication and data logging. This is important to highlight because Smart Grid trends and needs are dynamic and well engineering softwares (embedded firmware or PC based application software) must be ready for an ongoing and fast development.

Nevertheless, current fundamental and basic functionalities for smart reclosers include:

✓ Full Directional Protection

Today´s power system is formed by different circuits which are being interconnected to one another due to load sharing, load transfer, backup requirements, etc, forming a larger multi source grid where source and load sides cannot always be determined. From the recloser standpoint the impedance and therefore short circuit levels, as well as number of other different protection devices installed, differ from the upstream to the downstream circuits.

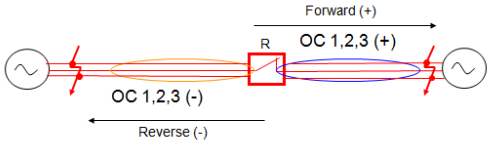

Figure 4 Full Directional Protection on Multi Source Grids

The full directional protection capability allows the recloser to be programmed with completely different and independent protection settings (including AR map, curves and times) depending on which is the fault direction: forward or reverse. The controller programmed with the correct torque angle is able to determine such direction and apply the correct protection settings aiming at proper fault isolation.

Such functionality relies on complete voltage and current measurement and is a must for smart reclosers.

✓ Built-In DSA Algorithms

Live load isolation and self healing are other two concepts that are becoming more and more important as the grid gets diversified and the requirement for an uninterruptible supply is demanded by not only regulatory bodies but by customer as well.

On situations where the main source is out it may be required to prevent live load to back feed it by means of Voltage Recloser Control (VRC) which monitors the voltage presence on both sides of the recloser and inhibits a close operation in case voltage is sensed on load side but not on source´s. Smart implementations further allow for source and load sides to be configured and also have a ring mode.

VRC is also input to self healing algorithms such Automatic Backfeed Restoration (ABR) which allows normally open points to function as smart backup switches that restore supply to a lost primary feeder from a backup secondary feeder just by deciding alone that the situation required so. Proper previous study is required but once the equipment have been correctly programmed they will “think” and act to reduce outages and their affected areas as well as restore key load supply such as hospital or utilities head offices.

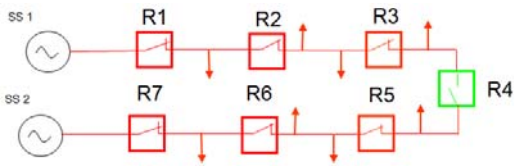

Figure 5 Self Healing Algorithm

As the number of reclosers deployed throughout the grid becomes greater, utilities are also faced with the challenge of achieving correct and feasible grading between protection devices in series.

Functionalities such as Zone Sequence Coordination (ZSC) and Temporary Time Addition (TTA) allows recloser in series to keep synchronized during a fault isolation process when they are configured with similar or identical protection curves, respectively. This last case may be required when the feeder is sectionalized by a large number of reclosers graded among one another and all of them must trip under 0.8s – 1.0s before the main SS circuit breaker.

✓ Powerful Software Package

Designed along with the switch and controller, powerful PC based application softwares must also be available from manufacturers to allow complete configuration, data monitoring and interrogation of the devices for protection and automation design, as well as power systems studies and even equipment troubleshooting.

This software must also allow the user to smart manage files related to different devices as well as allow for content sharing and transfer (copy) among them.

More advanced software also intakes the device´s latitude and longitude coordinates to track it down using Google Maps for instance, allowing the user to visualize the actual equipment on the pole and also its surrounding areas.

Graphic interface makes coordination and grading studies simple and easy by providing the user with a range of standard and non standard curves (including user defined curves) and modifier parameters for customizations. Such interface also displays the changes made to the curves as they take place.

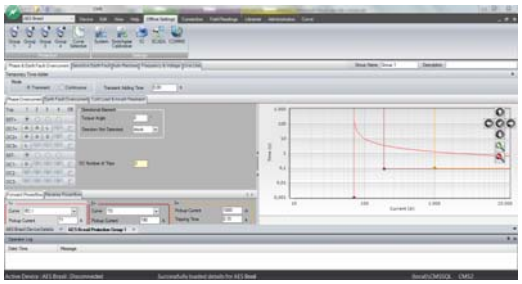

Figure 6 Full & Smart Software Package

Application softwares combined with smart controller firmware allow full configuration of protocol settings, including points ID´s, classes, deadband, etc, making the integration of the devices possible to any pre existing master station. After all, limitations are not smart.

✓ Data Logging

Smart Grid management is all about understanding the grid and managing interconnectivity to better distribute loads and reduce peaking where possible. The data available from smart reclosers can be

remotely accessed from Smart Grid Scada control to provide detailed and accurate information on each feeder which can then be used for load distribution and growth planning.

✓ Simulation

Simulator tools that allow network fault scenarios to be developed and tested is a critical part of developing and commissioning Smart Grid solutions. Complex power simulator sequences are not easily simulated however using primary and secondary current injection tools can be easily programmed and injected into devices using PC bases simulation tools.

✓ Full remote Engineering Access

With the availability of TCP/IP communications systems today access via a common communications channel to multiple remote devices is now common practice. With the IP stack provided in the intelligent controller Scada protocols can be routed, Scada master and proprietary protocols can be routed to vendors remote software packages to allow full engineering access to smart recloser controls. TCP/IP communication is the future of the distribution Smart Grid.

Conclusion:

Smart Grid is the future of the electrical distribution industry. Many utilities have large budgets and detailed Smart Grid plans in place to be implemented over the next decade and the careful choice of the recloser that the utility chooses to be the best building block for their Smart Grid program will be one of the key drivers in the utility Smart Grid success.

Biography:

Neil O'Sullivan is Managing Director of NOJA Power Switchgear Pty Ltd. He is a member of the IEEE and has over 20 years experience in the electricity industry. His industry experience involves design, manufacture, marketing, sales and service of medium voltage switchgear products. His work in the industry has seen him travel extensively throughout the world working with utilities on every continent. With this experience comes a reasonable understanding of current utility activities and practises in the applications of medium voltage switchgear on their networks.

Bruno Kimura is Operations Director of RMS Electric Ltda, NOJA Power´s exclusive distributor in Brazil. His experience include intensive training in switchgear at NOJA Power head office in Australia, provision of training and technical support to a great number of power utilities in Brazil as well as business development activities both in Brazil and overseas.