TITLE: APPLICATION OF ADVANCES IN MAGNETIC ACTUATOR, VACUUM INTERRUPTER AND MICROPROCESSOR TECHNOLOGY TO IMPROVE NETWORK PERFORMANCE THROUGH AUTOMATION AND BETTER PROTECTION GRADING OF AUTO RECLOSERS

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Summary:

Today's electricity utilities are challenged with achieving greater performance and reliability levels than ever before, generally with fewer resources available to them. Use of modern auto reclosers with Intelligent Electronic Device (IED) controllers is one of the most effective tools available to today's utility engineer to increase overhead network performance.

The challenge for auto recloser manufacturers is to produce equipment that is faster, more accurate, offers better reliability and is easier to adapt into existing systems than previous generations of equipment. Application of the latest in single coil magnetic actuator and vacuum interrupter technology allows simplification of mechanism design to provide greater lifetime and reliability while increasing speed of operation. Simpler mechanisms combined with use of appropriate current and voltage sensing technologies, such as Rogowski sensors and capacitively coupled voltage measurement techniques, permit today's recloser manufacturers to reduce size and weight while increasing the effectiveness of reclosers in overhead network automation and protection schemes.

Application of advances in microprocessor technology offer energy efficient, fast and accurate sampling of analogue values, flexible protection features and remote terminal unit (RTU) functionality to meet the increasing requirements placed on today's IED's.

This paper looks at the latest technologies that have been developed and the application of these technologies to increase network performance, facilitate network automation and reduce minutes of supply lost.

Introduction:

Auto reclosers have been used in overhead distribution networks since the early 1940's with the advent of the first hydraulic/oil devices. These early pioneers developed products that utilized oil as the interruption medium and oil as the insulation medium. This type of product requires regular maintenance and generally would not be considered as a viable option today.

The evolution of the recloser product then saw vacuum interrupters inside steel and aluminium tanks with oil as an insulation medium and porcelain bushings. This type of product is available from some manufacturers today but the demand for these types of products is being phased out due to the environmental risks and concerns associated with oil insulation in a pole mounted environment as well as ongoing maintenance costs.

The next generation of products that was introduced onto the market utilized SF6 as the interruption and insulation medium and further evolvement saw the use of vacuum interrupt inside an SF6 insulated tank using either porcelain or polymeric bushings. These products are also still available on the market but must be considered to be approaching the end of their product life cycle due to the environmental and health risks associated with the use of SF6.

The challenge for pole mounted switchgear manufacturers was to find safe viable long life alternatives to using oil and SF6 gas in their products.

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 of product is available from several manufacturers and whilst it has achieved the goal of eliminating the use of harmful insulants such as SF6 and oil, is this type of product really a safer longer life product? It is these Authors' opinion that it is not because whilst addressing the environmental issues it does not address the safety issues and the long life issues in an acceptable manner.

These types of products will not provide arc fault containment. Whilst it can be said that with three separate poles that it is not possible to achieve a phase to phase arc fault and therefore arc fault containment is not required, it is certainly possible to achieve a phase to ground fault that could propagate and in these types of faults arc fault containment is essential and lacking in these common designs.

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.

The ability to measure voltage on all six bushings and current on all three phases is another essential requirement to provide the functionality required by today's customers. Without the ability to measure voltage on all six bushings it is basically impossible to provide full distribution automation functionality. A limitation in utilizing cyclo aliphatic epoxy resin to provide both mechanical support structure and insulation is that it becomes simply impossible to provide voltage measurement on all six bushings.

Considering the above limitations that have been identified it is clear that vacuum interrupt solid dielectric insulation offers all the required environmental benefits of today's product specification demands, therefore this combined with a insulation system that allows for the solid dielectric components to be encased in an arc fault contained and vented metal tank clearly provides the solution not only from an environmental prospective but also from a safety and long life requirement.

<u>Combined Insulation System:</u>

Electrical break down in air occurs when the electrical field exceeds 2.4kV per mm. In practical applications in order to achieve a minimum 125kV BIL (requirement for 27kV switchgear) a 200-300mm clearance is required due to the non-even distribution of electrical fields.

However if this air gap has a barrier placed between the two electrodes this greatly reduces clearances required.

Dielectric strength of the combined insulation system is higher than that of the insulating material. This effect is generated by the barrier hindering the chain reaction of molecule ionisation required for electrical breakdown across air.

The combined insulation system must also provide the mechanical strength to withstand the forces associated with arc fault containment and fault level interruption. The insulation system must also be IP66 water proof and shaped to ensure electrical fields are minimised to withstand the required BIL/flashover levels.

Different insulation materials are used for different properties. Silicon for joins and flexible areas, polymers for rigid structures that provide strength. High pressure processes are used for each material to eliminate voids that can lead to partial discharge problems.

Combined insulation systems allow for current and voltage measurement to be incorporated into each bushing which is an essential requirement for today's distribution automation requirements.

Current and 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.

Rogowski current sensors have significant benefit over traditional current transformers.

They are as follows:

• Do not saturate at high current levels

• Not influenced by hysteresis

• Not influenced by DC component

• Do not generate dangerous voltages when open circuited

• Light weight

Voltage measurement is generally achieved today by capacitively coupled voltage measurement techniques in products that offer this functionality. The limitations of this method of measurement are associated with the levels of accuracy that an be achieved. Typically in cyclo aliphatic electric products this is a screen that is moulded into the epoxy mould and measurement accuracy is normally highly affected by temperature variation. By utilising a combined insulation system and conductive rubber screens, this significant variation in accuracy with temperature fluctuation is eliminated. Whilst the levels of accuracy remain elusive for metering purposes and will surely be demanded by future requirements, the levels of accuracy are the best available in products on the market today utilising this measurement technique.

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. In the event the HV line is de-energised the switchgear will continue to operate normally and be able to communicate remotely to send the required alarms. In distribution automation applications it may be necessary to operate the switchgear on a de-energised line. Taking these requirements into consideration the energy required to trip and close the device is critical to the hold up time of the batteries that provide the UPS system.

Magnetic actuator technology was first developed more than a decade ago and generally relied on rare earth permanent magnet latching. By eliminating the requirement for rare earth permanent magnets a simplified, longer life and more energy efficient actuator can be provided.

An intermit design ensuring that the vacuum interrupter and magnetic actuator are matched to provide the maximum in required forces and the minimum in required operating energy 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.

By utilising magnetic actuators a stored energy charged capacitor system can be used to provide the energy to trip and close the device. This system normally forms part of the control cubicle where the micro electronics and UPS system are located.

<u>Micro Electronics & UPS System:</u>

With the ever increasing capability of today's integrated electronics the ability to provide higher accuracy and faster system protection capability in pole mounted reclosers becomes possible. Using integrated circuits to provide DSP (digital signal processing) capability offers low cost high speed sampling capability that then allows for extended protection functionality.

Today's generation of products offer power quality monitoring capability, harmonic analysis, sag and surge monitoring capability which are all only possible due to the availability of micro electronic technology and the ever important ability to measure voltage and current on six bushings of the MV recloser.

Protection grading between devices can be significantly reduced again due to the measurement accuracy and faster sampling rates possible. Typically in the past protection grading between two reclosers in series would require a minimum of 200ms + of grading time. Products designed using Rogowski sensors and fast micro electronics sampling can be reliably graded to within 100ms operating time. This allows for up to eight devices to be graded in series on a single feeder and still allow the substation circuit breaker to operate at prospective fault levels in one second. Put simply, this allows more devices to be used on a feeder to offer more points or fault isolation and increase feeder reliability.

Real time calculation of symmetrical components and their utilisation in protection algorithms allows better discrimination for a more diverse range of fault types. This is only possible if current and voltage measurement together with symmetrical component calculation is utilised to provide more intelligent protection algorithms. An example of this is full directional protection for overcurrent earth fault and sensitive earth fault elements.

<u>Conclusion:</u>

Pole mounted medium voltage auto reclosers will continue to play a critical role in the future of electricity distribution overhead line protection. Pole mounted auto reclosers offering a longer life and solid dielectric insulation systems with arc fault containment and venting will evolve to dominate the market in the future. These products will be required to provide maintenance free long life and DSA functionality. This will require the measurement of voltage on all six bushings and the measurement of current to ever increasing accuracies.

Advancements in electronics will continue to drive increased functionality and interconnect ability utilizing ever increasing speeds available in communications infrastructure. Open architecture communications systems will allow multiple manufacturers devices to be utilized on common networks.

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.

References:

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