APPLICATION OF RECLOSERS FOR RELIABLE SUPPLY IN RURAL OVERHEAD DISTRIBUTION NETWORKS

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ABSTRACT
Reclosers are self controlled devices, which are designed for switching load and fault current under remote operation. This makes reclosers a unique device with interesting functionality and special requirements for their design. The paper describes design and feature of modern reclosers. It covers the vacuum switching technology of the circuit breaker itself, the integrated sensors, the comprehensive protection and load flow functions, monitoring capability, the smart control logic and various communication features. The combination of these new technologies allows a very efficient operation of distribution networks. A consequent application of reclosers, distribution switches and control units leads to increased reliability of supply and reduced operation costs. Even though three phase applications are the most common ones, many countries still utilise single phase systems for very low loaded lines. Reclosers can be used for three and single phase lines.

INTRODUCTION
Overhead lines are utilised for efficient distribution of electrical energy throughout the world. They are, however, much more prone to network faults than underground cable systems, most of them being of temporary nature. For example lightning strikes, cable clashing, brush fires, animal interference etc.

Reclosers provide all the functions to isolate transient or permanent faults by a sequence of fast plus delayed protection trips within a reclose sequence. They are able to limit most faults to a very short duration, thereby keeping affected consumers’ disturbance to a minimum and a reduced number of consumers affected. This increases the availability of power for the benefit of consumers as well as utilities. Thorough network planning is required to determine the most appropriate locations for an economic and effective operation. Manifold protection functions, a control unit designed for stand alone operation and communication allows a highly automated network operation. Not only due to the shortened duration of the interruption due to the fault by the autoreclose sequence. Control functions also allow to pinpoint fault locations and to monitor the feeder status. There are certain control schemes available, which allow an automated changeover from one feeder section to another in case of network fault. This helps to keep the power supplied to as many consumers as possible. It will also help to manage the loading in the system and individual feeders.

This is a very important function to prevent system black outs.

APPLICATION OF RECLOSERS
Reclosers were developed in the 1940’s as an efficient alternative to fuses in distribution systems. Siemens Protection Devices Ltd has experience of autoreclose functionality since 1926 with the range of Reyrolle electro-mechanical protection relays.

While fuses are able to interrupt fault currents, they stay open and require purchase and manual replacement for power restoration. It could take a significant amount of time on long feeders to find the location of the fault or the blown fuse. This can lead to long restoration times especially in adverse weather conditions.

The recloser controller, either electro-mechanical or digital, provides an important tool for the utility to improve electrical service. This is especially important in rural systems allowing the utility company to meet the regulatory requirements for minimum outage times or improved power and service quality. Although not a power quality device, the Recloser-M Controller provides the utility company with sophisticated protection and control for efficient operation, together with a degree of power quality measurement options such as Sag & Swell and Demand logging.

These days, reclosers are mainly used directly on overhead lines or they may be installed in substations. Applications in industrial systems or wind farms are still rare, with their number increasing.

Application on feeders
For this historical typical application the recloser provides fault protection and ensures temporary interruption in as many occasions as possible, limiting outage times and containing the outage to a minimum area. Reclosers are designed to provide usually three; some times up to four reclose intervals with a variety of time-current curves to provide system coordination.

Commonly used on three phase systems, there are also reclosers available for single phase systems, where their functionality is very similar. Over the last few years utilities have been upgrading their systems by installing three separate single pole Reclosers plus a controller, that can selectively apply single or triple reclose sequences to each pole asynchronously. If three single phase reclosers are
operated by one single control it is referred to as a “Single-Triple Recloser”.

Most reclosers are operated by a rather sophisticated electronic control, providing a large number of protection and control functions plus various means of communication.

There are still a large number of more simple reclosers available. They offer self-controlled fault interruption with limited functionality and communication features.

**Application in substations**

This application is increasing in recent years and calls in fact for a circuit breaker. It is a very economic solution for rural feeders with low loading if the rated current does not exceed 800A and 12.5kA or 16kA for fault interrupting. Depending on the operator’s preference and the skill of the operating staff, the control can be kept as a substation relay but can also be adapted to recloser functionality.

Modern reclosers, based on vacuum switching technologies, can cope with these typical circuit breaker applications. Their advantage over a conventional circuit breaker is the integral testing of circuit breaker and control as per recloser standard [1]. This makes it very convenient for the user.

It is of further advantage if the control is part of a protection relay family. A number of reclosers provides this feature. It allows the operator to utilise the same relay software and makes it easy for the field staff that is used to the equipment.

**Network planning for optimal recloser application**

Reclosers are an effective solution for both existing and new installations. Their application is mainly focused on two areas:

- reduced power interruptions for a better network performance and
- automatisation of operation and maintenance for better cost efficiency.

Although many suitable locations for recloser installations appear obvious, a thorough network analysis enables an optimal network design in rural areas. It is especially important for coordination with other network equipment such as sectionalisers, fuses and load break switches.

**DESIGN AND TECHNOLOGY**

Modern reclosers utilise vacuum technology as the switching medium. It has been proven to be superior from the operating perspective as well as the environmental aspect. Equipment still exists which uses other interruption mediums such as oil or SF6 gas.

The high number of reclosing operations requires an actuator, which is capable of fast repeated operation. Magnetic actuators are used for most reclosers, while charged spring operators are still used for a variety of applications.

**Pole assembly**

For most reclosers a life tank or life pole design is used, where each vacuum interrupter is embedded in a weather-proof solid insulation. Epoxy resin is widely used, usually of cycloaliphatic type. Silicon, with its excellent hydrophobia, is rarely utilised because of the limited mechanical strength. The use of silicon bushings requires additional structural materials which lead to a larger design. There are some epoxy materials with hydrophobic properties; however, it is doubtful if this lasts for the lifetime of the recloser.

The vacuum interrupter is vertically mounted inside the pole insulation. Horizontal mounting of vacuum interrupter may have an impact on the switching behaviour and needs substantial mechanical support for a long service life.

**Voltage and current sensing**

Each recloser is equipped with integrated current sensing to enable the self-controlled functions. The current sensor is generally optimized for the respective control. A conventional type of current transformer combines high accuracy and allows the use of alternative relays.

Some reclosers are equipped with voltage sensors. While conventional voltage transformers are too large for integration within reclosers, so called low power or electronic voltage transformers are suitable. Resistive voltage transformers provide the highest accuracy. Capacitive dividers are an alternative for applications where accuracy is not so critical, as it depends on temperature and is prone to electromagnetic disturbances and needs calibration with the control.

**Operating mechanism**

Reclosers are usually operated by magnetic actuator enabling the recloser cycle, i.e. a high number of switching operations within a short period of time. The actuator is of a bi-stable type, locked in the end positions by permanent magnets to avoid any power consumption while in the idle state.

A mechanical pull-rod provides manual tripping and blocks any subsequent closing action, this is called lock-out. Good design prevents manual closing if there is no auxiliary power; only closing by the controller ensures that the protection is active.

**CONTROLLER**

The controller provides all the protection and control functions required to isolate transient or permanent faults. The controller provides essential local controls and indications together with event logs, waveform records and indication metering.

The following clauses describe important and innovative functions for reclosers, especially for application in rural networks.
Protection functions

Reclosers are used in almost all countries. Therefore, it must conform to a full range of ANSI and IEC protection and control functions. It became common practice to use ANSI numbering to abbreviate the protection functions. Fig. 1 shows an example.

Control functions

Large sweet-spot pushbuttons are necessary to make it easy for field staff to operate even while wearing protective gloves.

An ergonomic, intuitive interface menu structure is required for simple user access to all Controller settings, mapping of binary I/Os, function key configuration, indication LED’s and protection elements.

Each Controller uses software to communicate with the relay via a laptop. In addition to the transfer and alteration of settings, it allows downloading of waveform records, event records, fault data records, for analysis purposes.

Measuring functions

Recloser controllers are capable of measuring a large variety of system values. While current measurements can be taken by all reclosers, for voltage and power measurements the existence of voltage sensors is required. Accuracy depends on the type of voltage sensor; conventional and resistive sensors provide the highest accuracy.

Today reliability measurements become more and more important. IEEE 1159 describes the indices illustrating the power quality. Fig. 2 shows the calculation for the most important ones.

Multiple Communication Protocols

Various communication protocols are available to integrate reclosers into the SCADA system. Within the ANSI world DNP3.0 is the most common communications protocol. For IEC countries Modbus and the IEC 60870-5-101/103/104 protocols are widely used.

Reclosers in remote locations could be linked up via modems or RTU’s. Particularly for substation applications, IEC 61850 is expected to become common in the near future.

Flexible Physical Interfaces

The controller has a serial interface on the front fascia for connection to a laptop which facilitates settings changes and data retrieval. While RS232 ports are still common, most modern controllers provide access via USB port.

At the rear there are further interfaces for connection with SCADA or modems. General standard is RS232 interface or the adequate RS485 interface. The latter, being more suited for recloser applications, due to its lower susceptibility against electromagnetic disturbances.

Automation Function

Loop automation (Loss-of-Voltage Automatic restoration - LOV)

The LOV function is applied by Reclosers at the sectioning points along a feeder and by a Normally Open (Tie) Point at the junction of two feeders (see Fig 3). The purpose of this is to ensure automatic restoration of the system supply to as many consumers as possible.

Following a permanent-fault lockout of a source Recloser, power will be lost not only by the faulted section, but also by the downstream healthy sections of that part of the network. Automatic network reconfiguration improves system availability and reduces Customer Minutes Lost (CML) and SAIDI, by automatically isolating a faulted section and then restoring service to the unaffected healthy sections of the system in a reasonably fast time. This is achieved by sequential opening of a downstream recloser, which has not seen fault current, thus isolating the faulted section and then closing a Normally Open (Tie) Point to back feed the healthy sections. Automation is normally applied in areas where there are Normally Open (Tie) Points to other feeders which enable system restoration via back
feeds. Controller protection settings must, therefore, be bi-directional with forward and reverse settings to enable grading in either direction independent of system configuration.

LOV Automation should be considered as a one shot automated sequence after which, the normal NOP having been closed, manual operations should be taken to clear the fault and restore the system to its normal configuration.

Single-phase tripping/reclosing improves system reliability by keeping consumers in service, who are not on the faulted phase of a feeder. When a permanent fault occurs on one of the phases e.g. on the middle phase, only the middle pole recloser opens for the fault. If single-phase reclosing restoration of supply is unsuccessful because of a permanent fault, only the consumers on the middle phase are left without power, rather than all three-phases locking out. Single-phase operation will be applied especially in rural areas where many loads are single-phase and restoration can take longer because of travel distance.

Each pole has its own separate Fault detection/Trip and AutoReclose sequencing capability. Different modes of operation cater for the basic and or seasonal requirements of different types of load on the three phases.

CONCLUSIONS

Reclosers provide an efficient solution for both increased network reliability and automation, especially in rural networks. Modern reclosers can be used on feeders as well as in substations, since they combine self-controlled features of reclosers with the switching capability of circuit breakers using vacuum technologies.

In countries, where the distribution network is four wire i.e. three-phase plus neutral, this can be split into three single-phase plus neutral lines where, for example, each line can go up a separate valley and thus be subjected to single-phase faults (see Fig 4). There is an increasing demand for single/triple reclosers, which must be able to apply individual phase-by-phase AutoReclose asynchronously i.e. each pole has its own separate AutoReclose sequencing capability, with Lockout on either one or all three phases.

The Controller must provide settings to enable the user to choose the option of single/triple Trip/Close and single/triple Lockout combinations, including the option of what must happen under two-pole faults. The user must ensure that no equipment requiring a three phase supply e.g. Three Phase Motor, is connected, before setting this mode of operation.

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Single-Triple reclosing improves system reliability by maintaining supply to consumers who are not on the faulted phase of a feeder. When a permanent fault occurs on one of the phases e.g. on the B phase, only the B pole Recloser performs a Trip and Reclose sequence. The A and C phases, if unaffected, stay Closed maintaining supply to the consumers on poles A and C.

Fig. 3: System diagram showing normally open (TIE) point

**Single-Triple operation**

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State of the Art reclosers represent a very economic solution not only for new networks but also for systems which are grown over decades. In particular, aged distribution networks often need to be brought up to standard in order to cope with the greater demand nowadays for reliability and efficiency. That is what reclosers are designed for.

**REFERENCES**


Fig. 4: System diagram showing application of Single-Triple Recloser