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RESEARCH ARTICLE

ANALYSIS OF PROTECTIVE SYSTEM FOR HIGH VOLTAGE LINES USING PROTOCOL IEC 61850

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Abstract— The utility communication protocol IEC61850 standard provides methods of developing best engineering practices for protection, control, testing and monitoring. The intension is to indicate the significance and importance of using multivendor product to be used as a protection system for high voltage transmission lines. The purpose of using a multi-vendor products is to provide a comprehensive protective system which is immune to the failure of (a) similar hardware used in the multiple device employed for the same system.(b)to adapt varying algorithm for the detection of abnormality in the system. The philosophy discussed here will clearly bring out the advantages of using IEC61850 to achieve the protective system for EHV (extra high voltage) lines. EnerVista and MiCOM S1 AGILE are the software used to interface between the relay and PC.it is used to set the relays for communication through PC as well as analyse the data communication between the relays. The standard IEC61850 communication networks and systems will provide interoperability between the IEDs for protection, control, monitoring and automation in substation.IEC61850 is an international standard for electrical substation automation that will significantly improve the design and construction of electrical power systems in the future.

Keywords— IEC61850; Intelligent Electronic Devices (IEDs); EnerVista; MiCOM S1 AGILE

INTRODUCTION

Historically, substation protection, metering and control functions were performed with electromechanical equipment. This first generation of equipment was gradually replaced by analog electronic equipment, most of which emulated the single function approach of their electromechanical precursors. Both of these technologies required expensive cabling and auxiliary equipment to produce functioning systems. Recently, digital electronic equipment has begun to provide, metering and control functions. Initially, this equipment was either single function or had very limited multi-function capability and did not significantly reduce the cabling and auxiliary equipment required. However, recent digital relays have become quite multi-functional, reducing cabling and auxiliaries significantly.

Modern microprocessor relays are no longer merely protection devices for power apparatus but have evolved to perform many other functions that facilitate effective power system operation. Contemporary microprocessor relays routinely include metering, protection, automation, control, digital fault recording (DFR) and reporting. Because of this, it is now more accurate

to refer to these microprocessor devices as intelligent electronic devices (IEDs).As IEDs replace old electromechanical relays and prevail in today's power substations, the amount of data available from substations increases exponentially.

Cost reduction can be achieved in power equipment by improving power quality, personnel productivity, reliability and efficiency. These objectives are realized through software which is used to perform functions at both the station and supervisory levels. The use of these systems is growing rapidly.

IEDs with the capabilities outlined above will also provide significantly more power system data than it is presently available. It will enhance operations and maintenance, and permit the use of adaptive system configuration for protection and control systems.

Bay Protection Unit shall comprise two or more numerical relays to meet the protection requirements specified for each type of feeder. Bay Protection Units for all Switchyard Bays shall interact with relays over substation inter bay Network Bus to share information related to Bay Level Interlocking, fault data, alarms/ events etc.. However, the trip commands from Bay Protection Units shall be hard-wired directly to appropriate substation equipment. The critical interlocking data between Bay Protection Units and relays, including the substation level interlocks such as bus earth switch, bus bar protection trip etc., shall also be hard-wired to ensure complete bay level functionality even in case of failure of substation LAN. The interlocking information to be hard-wired between Bay Protection Units and Bay Control Units shall be decided by Employer during detailed engineering stage.

IEC61850 series is intended to provide interoperability between all devices in substations. Communication between these devices has to fulfill a lot of requirements imposed by all the functions to be performed in substations. Depending on the philosophy both the vendor - end user and on the state-of-art in technology, the allocation of functions to devices and control levels is not commonly fixed. This results in different requirements for the different communication interfaces within the substation. The IEC61850 series shall support any allocation of functions.[1]

UTILITY COMMUNICATION PROTOCOL 1EC61850

IEC 61850 is an international standard for electrical substation automation that will significantly improve the design and construction of electrical power systems in the future. IEC61850 industrial Ethernet networks are applied as the physical medium for power substation automation, which means that a host of legacy field buses must be connected to the Ethernet network. When used as a unified communication protocol in power automation, the IEC 61850 standard provides benefits that help power automation designers construct a complete, Ethernet-based communication system. [2].

A. IEC 61850 Substation Architecture

IEC61850-enabled IEDs get digitalized power grid condition data via process bus and merge units. IEDs communicate with each other using substation buses. IEC61850 is unique and is not a recast serial RTU protocol. It is designed specifically for Local Area Networks (LANs) to lower life cycle cost to use a device (cost to install, configure and maintain). IEC 61850 is a real object-oriented approach for substation automation. It supports standardized device models using names instead of object/register numbers and indexes. It is a standardized configuration language (SCL).Below fig1 shows the substation architecture of IEC 61850 where IED"s, meters and client computer are connected to the network through substation bus whereas merge unit are connected through process bus

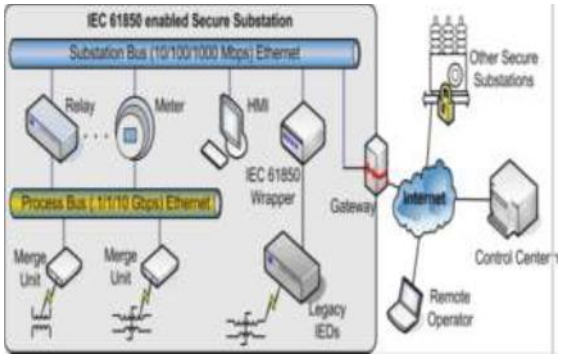


Fig1 substation architecture of IEC61850.[3]

B. Features of IEC61850

The key features that provide significant benefits to users are:

- Use of a Virtualized Model.
- Use of Names for All Data.
- All Object Names are Standardized and

- defined in a Power System Context.
- Devices are Self-Describing.
- High-Level Services.
- Standardized Configuration Language.

C. Benefits of IEC 61850

Benefits of IEC61850 standard are summarized as follows:-

- IEC61850 standard is unique in that it is not a recast serial RTU Protocol
- IEC61850 is specifically designed for local area networks to lower life cycle costs, cheaper to install, configure and maintain
- Real object orientated approach for Substation automation supporting
- It is a standardized device models using names instead of numbers and indexes
- It uses a standard configuration language, (SCL)
- It is feature rich with support for functions difficult to implement otherwise
- It supports a comprehensive set of substation functions
- Easy for configuration, design, specification, setup and maintenance.
    - High-level services enable self-describing devices & automatic object discovery.
    - Standardized naming conventions with power system context.
    - Configuration file formats eliminate device dependencies and tag mapping and enables exchange of device configuration.
    - It provides strong functional support for substation communication.
    - Higher performance multi-cast messaging for inter-relay communications.
- IEC61850 is extensible enough to support system evolution [3].

CONFIGURATION OF IEC 61850 PROTOCOL IN ENERVISTA

EnerVista UR Setup is a PC-based program for on demand monitoring and making configuration and setting changes to GE UR Relays. The EnerVista UR Setup software program provides a graphical user interface (GUI) that allows users to configure, monitor, maintain and troubleshoot the operation of UR relays connected locally to a PC or over local or wide area communications networks.

The EnerVista UR Setup software interface may be initiated in either off-line or on-line modes with a UR device. In order to downloading a file to a device in off-line mode, a device's settings file may be created or configured. When in on-line mode, the settings and actual values of a UR device can be configured or monitored utilizing real-time communications.

The GE universal relay D60 Line Distance Protection System is provided with optional IEC61850 communications capability. This feature is specified as a software option at the time of ordering.

The GSSE/GOOSE configuration main menu is divided into two areas: transmission and reception.

In transmission side there are four types:

- General
- GSSE
- Fixed GOOSE
- Configurable GOOSE

The configurable GOOSE settings allow the D60 to be configured to transmit a number of different data sets within IEC 61850 GOOSE messages. Up to eight different configurable datasets can be configured and transmitted. This is useful for inter-communication between D60 IEDs and devices from other manufacturers that support IEC 61850.

Fig 2 D60 Multilin Relay.[6]

The EnerVista UR Setup software main window supports the following primary display components:

- Title bar that shows the pathname of the active data view
- Main window menu bar
- Main window tool bar
- Site list control bar window
- Settings list control bar window
- Device data view windows, with common tool bar
- Settings file data view windows, with common tool bar
- Workspace area with data view tabs
- Status bar
- Quick action hot links

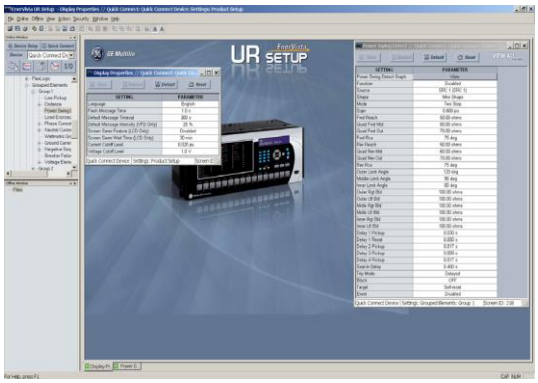


Fig3:EnerVista UR setup software main window.

Setting file templates simplify the configuration and commissioning of multiple relays that protect similar assets. An example of this is a substation that has ten similar feeders protected by ten UR-series F60 relays.

In these situations, typically 90% or greater of the settings are identical between all devices. The templates feature allows engineers to configure and test these common settings, then lock them so that they are not available to users. For example, these locked down settings can be hidden from view for field engineers, allowing them to quickly identify and concentrate on the specific settings.

The remaining settings (typically 10% or less) can be specified as editable and be made available to field engineers installing the devices. These are settings such as protection element pickup values and CT and VT ratios.

The settings template mode allows the user to define which settings are visible in EnerVista UR Setup. Settings templates can be applied to both settings files (settings file templates) and online devices (online settings templates). The functionality is identical for both purposes.

CONFIGURATION OF IEC61850 PROTOCOL IN MICOM S1 AGILE

MiCOM is a comprehensive solution capable of meeting all electricity supply requirements. It comprises a range of components, systems and services from Schneider Electric. Central to the MiCOM concept is flexibility. MiCOM provides the ability to define an application solution and, through extensive communication capabilities, to integrate it with your power supply control system. MiCOM products include extensive facilities for recording information on the state and behaviour of the power system using disturbance and fault records. They can also provide measurements of the system at regular intervals to a control centre enabling remote monitoring and control to take place.

The primary purpose of the IED Configurator tool is to manipulate configuration, based on the SCL (Substation Configuration Language) files produced within the system engineering process of an IEC61850-based system, and send it to a MiCOM IED. To satisfy the requirements of manual configuration at pre-commissioning stage, the possibility to create a blank configuration based on the MiCOM IED's capability (ICD) file is also available.

Other features of the IED Configurator allow for the extraction of configuration for viewing or modification and error checking of configuration data for pre-commissioning validation of the MiCOM relay configuration. It is important to note that the IED Configurator is used to configure only the IEC 61850 elements of the relay configuration.

Before the IED Configurator tool can manage an IEDs configuration, its communication parameters must be configured. In the MiCOM IED there are two configuration banks for IEC61850 configuration. The configuration bank concept is similar to that of setting groups for protection settings, promoting version management and helping to minimise IED down-time during system upgrades and maintenance. [4]

Fig 4 MiCOM P444 relay [7]

Fig 5 MiCOM S1 AGILE software main menu

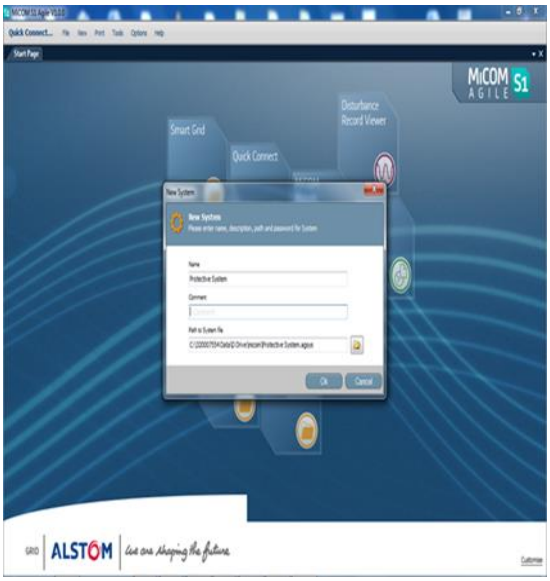


Fig 6 To create new system/project

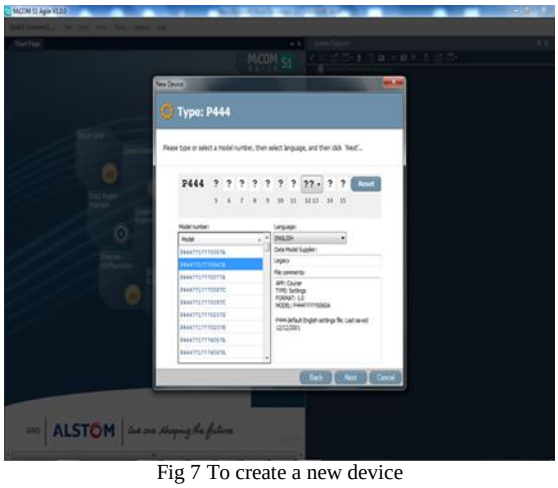


Fig 7 To create a new device

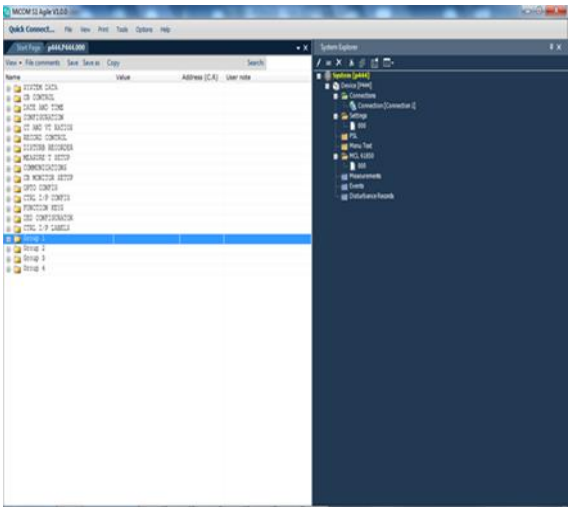


Fig 8 To do the settings

DUAL PROTECTIVE RELAYS

Different kinds of faults take place in different stations and substations. Overcurrent, undercurrent, earthing problems, high voltage, and low voltage many such faults could create problems which would lead to disaster and many other problems. So protection of these stations and substations is very much essential.

The relay provides five zones of distance protection. All zones are identical in terms of settings. However, zone 1 has extra adaptive mechanisms built-in to enhance the transient reach accuracy even when the voltage signals are supplied from poor quality voltage sources such as capacitive voltage transformers (CVTs). Ground zones 2 through 5, in turn, have an extra zero-sequence directional supervision implemented for their time-delayed operation after the memory expires. Consequently, zone 1 is recommended as an under reaching element, and zones 2 through 5 are recommended as overreaching elements and for time-delayed tripping. [1]

Short circuits and other abnormal power system conditions are rear, but may result in heavy losses if not detected and cleared as designed. Because of that power system protection systems are designed with primary backup relays, in most cases with different operating principles and different manufacturers. [5]

A. EHV (Extra High Voltage) Line Protection

220 KV line shall be provided with the following protection having 2 different uses and termed as Main-I and Main-II
Main-I: Numerical Distance protection scheme suitable for carrier aided protection

Main-II: Numerical Distance protection scheme suitable for carrier aided protection and with a hardware platform different from that of Main-I protection.

The Main-I and Main-II distance protection shall be of equal performance capability. The Main-I and Main-II distance protection relays shall be connected to two different protection groups.

- A backup definite time/directional earth fault protection unit with highest instantaneous function shall be provided in each Main protection system. The function shall measure zero sequence current and have suitable current/timer setting range.
- Open Jumper Protection: The open jumper protection function shall operate upon detecting negative sequence current and shall provide an alarm. The open jumper protection functions as a built-in feature of Main-I and Main-II protection.

B. Numerical Distance Protection Scheme

The numerical distance relays shall be the latest version meeting the in-service criteria specified elsewhere. The distance protection schemes shall be such as to facilitate compatibility with the protection at the remote ends of the 220 kV transmission lines. The reaches of relay for zones 1, 2 & 3 should be able to cover line lengths associated with this contract. The distance protection shall be of the non-switched type with separate measurements for all phase-to-phase and phase-to-ground fault types. The protection shall have two, independent, continuously variable, time settings each with a range of 0 to 5 s for zone-2 and zone-3. The type of tripping characteristics shall be user selectable.

The protection shall operate correctly for close-up three-phase faults and other adverse conditions. It shall operate instantaneously when the circuit-breaker is closed onto a zero-volt three-phase fault. The protection shall provide Phase segregated tripping i.e. single phase as well as three phase tripping. The protection shall have a maximum resetting time of 60 milliseconds.

The protection shall include Power Swing Blocking protection. The power swing blocking feature shall:

- be of three pole type.
- Block/unblock tripping during power swing conditions, separately for each zone.
- Have a continuously adjustable time delay on pick up of 0 to 5s.
- Have user configurable unblocking criteria in the case of fault detection during a power swing.

Shall include Fuse Failure Protection, which shall:

- Monitor all the three fuses of the CVT and associated cabling against open circuit.
- Inhibit trip circuits on operation and initiate annunciation.
- Have an operating time of less than 7.0 ms
- Remain inoperative for system earth faults

C. Digital Fault Recording

A Digital Fault Recorder shall be provided for each 220 KV line. The Digital Fault Recorder shall meet the following requirements:

- Shall be used to record the graphic form of the instantaneous values of analog inputs such as voltages and currents in all the three phases, open delta voltage and neutral current in the primary circuits in the case of a short circuit (fault) and a disturbance in the Power System, as per the required technical parameters.
- Shall be provided with a self-monitoring facility.
- Fault/disturbance logs shall be clearly identified by Fault ID, Fault date and time (hour, minutes, seconds and ms). Time stampings on fault records shall be synchronized with a GPS clock.
- The disturbance recorder shall comprise distributed individual acquisition units, one for each feeder and an evaluation unit which is common for the entire substation. The acquisition units shall acquire the disturbance data for the pre-fault, fault and post-fault periods and transfer them to the evaluation unit automatically for storage on a mass storage device.
- Shall be provided with sensors based on threshold values of voltage, current and frequency and rate of change of system frequency. External signals if required can also be used for triggering the DR. The starting sensors of the DFR, and pick-up, shall preserve the disturbance fault data on the non-volatile solid state memory of the acquisition unit. The setting of the starting sensors shall be flexible, and shall have reasonable range/steps. The settings of the starting sensors shall be field programmable

D. Sequence of Event Recording

Sequence of event functionality pertaining to the main protection applications shall be provided as a part of the individual protection devices.

The sequence of event recording shall:

- Have a time resolution of 1 millisecond or better.
- Be able to cope with up to 40 changes in any one 10 millisecond interval.
- The date and time should be printed to the nearest 1 millisecond followed by a tag describing the point which has operated.
- Events that occur while another event is in the process of being printed are to be stored for subsequent printing. Over 100 such events must be stored.

E. Auto-Reclose and Synchronizing check

Auto-reclose (AR) functionality including Synchronizing Check (SC) facility shall be provided in a separate device other than line distance relays. The interfacing between relays and Bay Protection Units for achieving the AR function logic shall be achieved at Bay Level using communication LAN as well as standby hard-wired logic between relay and Bay Protection Units. The intent of providing the hard-wired logic as a backup to the software logic is to ensure that in the event of failure of Substation LAN, the bay level functionality is not hampered. The AR function shall meet the following criteria:

- Be of single shot type
- Have single-phase and/or three phase reclosing facilities. It shall have a user-selectable option of single phase, three phase, single & three phase Reclosing or non-auto reclosure mode.
- Incorporate a normal/delayed auto reclosure option with a time range of 1 to 60s.
- Have a continuously variable three-phase and single-phase dead time of 0.1 to 5 s.
- Have a continuously variable reclaim time of 5 to 300 s.
- Be properly configured for the Double main and transfer arrangement, permitting sequential closing of breakers.
- Incorporate the necessary auxiliary relays and timers to provide a comprehensive reclosing and synchronizing scheme.
- Have facilities for selecting check synchronizing or dead line charging features. The user shall have an option to change the required feature.

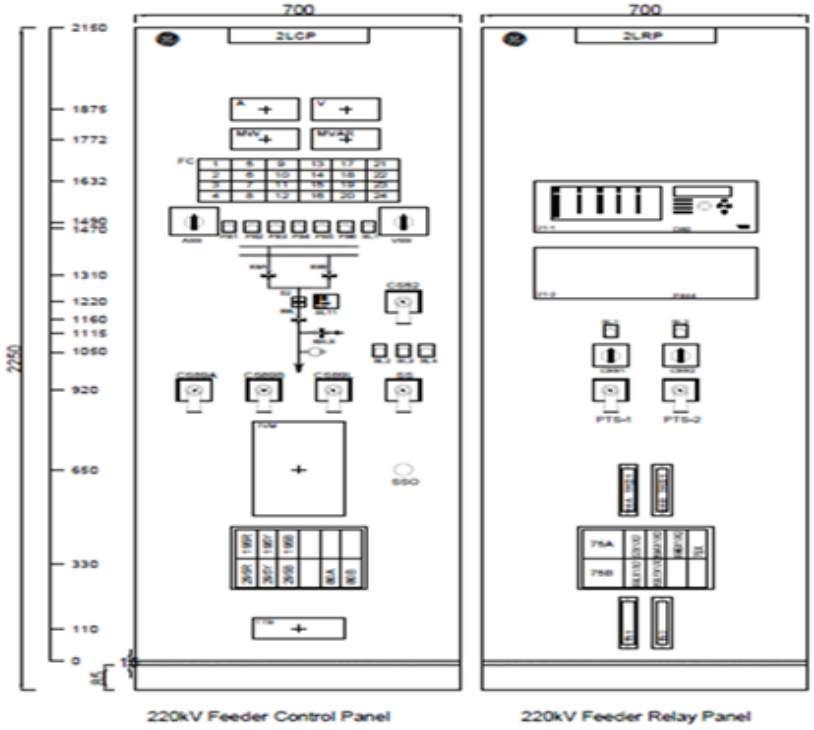
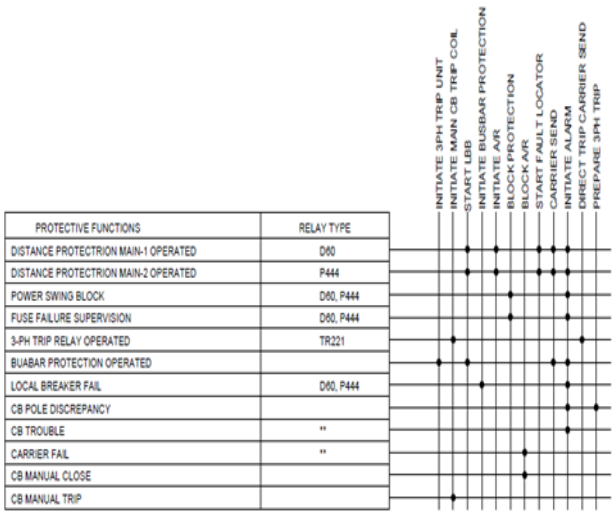


Fig 9 220KV Feeder control and Relay Panel.[6]



PROTECTIVE FUNCTIONS	RELAY TYPE
DISTANCE PROTECTRION MAIN-1 OPERATED	D60
DISTANCE PROTECTRION MAIN-2 OPERATED	P444
POWER SWING BLOCK	D60, P444
FUSE FAILURE SUPERVISION	D60, P444
3-PH TRIP RELAY OPERATED	TR221
BUABAR PROTECTION OPERATED	
LOCAL BREAKER FAIL	D60, P444
CB POLE DISCREPANCY	
CB TROUBLE	"
CARRIER FAIL	"
CB MANUAL CLOSE	
CB MANUAL TRIP	

Fig 10 220KV Feeder control and Relay Panel Trip Matrix. [6]

CONCLUSION

In this paper,IEC 61850 has Peer-Peer communication, which implies that the devices have the ability to read and write on the other device amongst them. This gives a greater advantage in terms of sharing a single output contact by both the devices. This single output contact shall either be a part of main devices or can be of separate device confirming to IEC61850 protocol. By adopting such method the main relays shall be made more compact and robust without any input/output contacts provided in them. The input/output contacts shall be made as a part of third device which will be activated corresponding to the commands coming from Main-I and Main-II relays.

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