IEC61850 application to Low Voltage and Medium Voltage installations: Emax 2 changes the game

1. IEC61850

IEC61850 is the protocol of choice for smart electrical installations. As electrical installations become more and more complex, with the addition of new features and functions, communication systems play a key role to simplify the whole architecture.

IEC61850 for:

- Standardization & Interoperability
- Horizontal & Vertical communication
- Flexibility

Some of the most important advantages of IEC61850 are:

- Reduced wiring: each electronic device is connected via an Ethernet port, and such connection is used to transfer all data, as opposite to laborious hard wiring of relay outputs and logic signals
- Easy reconfiguration: systems can be re-engineered without the need for rewiring, devices just need to be reconfigured
- No need for dedicated wiring accessories: standard Ethernet cables and connectors are used
- Electronic descriptors of devices: no more manual configurations possible errors

Architecture of IEC61850 is extremely flexible, yet it can be described very simply: Intelligent Electronic Devices, such as relays, implement functions required for protection and control in the form of logical objects (called Logical Nodes: each logical node is described by an acronym):

Example of Logical Nodes Overcurrent protection

Undervoltage protection Current measurement



One key feature of IEC61850 is horizontal communication, i.e. IEDs can send information to each other when the need arises, without involving a communication "master" such as the supervision system.

Such communication can take place in the form of extremely fast, dedicated data frames called **GOOSE** messages, which can be sent at any moment from one device to any number of other devices, which can then take specific actions (see examples below).

This eliminates communication delays and bottlenecks caused by centralized control systems.





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2. IEC61850 devices by ABB: Emax 2 under the spotlight

ABB Medium voltage protection relays have been mapped within IEC61850 communication since several years. The current product family is called **Relion**.

Low voltage installations have traditionally been protected by simpler devices, with no connectivity. When supervision was needed, it was often implemented by spare devices such as gateways or generic I/O modules. These solutions, often complex and expensive, lacked the flexibility and efficiency of full IEC61850 systems, preventing smooth integration of LV and MV installations.

Since 2014, ABB Low Voltage Circuit Breakers **Emax 2** have a **native IEC61850 interface**, which can be used for interconnection with Medium voltage protection devices and their supervision systems. Seamless integration can thus be achieved, with significant advantages in terms of protection effectiveness and system reliability.

3. A typical example: the MV / LV transformer station

Figure 1 shows a typical diagram of a portion of an electrical substation, where MV to LV transformation is performed. The most critical component, the transformer, is protected by automatic circuit-breakers both on MV and LV sides.

In our example, thanks to the innovative Emax 2 Ekip trip units equipped with IEC61850 communication modules, LV and MV are both interconnected via Ethernet. This allows seamless integration, and several advantages.



Fig 1: A standard MV/LV substation

Hereunder, some of the most interesting features:

a. Overcurrent selectivity

When a fault occurs at A, LV breaker should open as fast as possible, while the MV breaker ought to wait. When the fault location is B, however, the medium voltage protection is expected to operate. LV and MV protections thus have to be coordinated for selectivity (discrimination). The traditional technology to achieve such coordination is based on correct setting of the time-current curves (with suitable delays). IEC61850 achieves better results by means of horizontal (device to device) communication. If a fault occurs at A, it is possible to realize a communication architecture such that:

- LV CB detects fault and starts timing to trip
- MV protection relay does the same
- At the same time, LV CB sends a GOOSE message
- MV relay receives the message and delays opening
- LV CB opens: after few milliseconds the fault is clearedMV stays closed

This process requires devices to be configured in advance in order to know which signals they have to receive and which ones they should discard: configurations far more complex than the one shown can be managed.

b. Self diagnostics

Application described in a. is very similar to Logic Selectivity (Zone Selectivity) as implemented by hard-wired signals. There is, however, a fundamental difference: the same communication bus used for the exchange of selectivity signals is also used to transmit "heartbeat" signals, so that devices check that their communication partners are in good conditions and operating properly. For example, the Emax 2 may send a GOOSE once every 500ms: if the REF fails to receive it, this means that either Emax 2 has been put out of service, or the connection has been broken: the REF 615 can be configured to change its behavior in both cases, e.g. switching to instantaneous (or close to instantaneous) tripping time.

c. Supervision and remote control

Both **a**. and **b**. cases present horizontal communication. This doesn't mean that vertical communication isn't present: the IEC61850 system can include a supervision system that collects data, creates trend analyses, provides suitable automation logic...

Of course the supervision system can use data from breaker / protection as from a sensor, or it can act on IEDs, e.g. sending remote commands to circuit breakers that can act as actuators.

Even data transfer can be made more efficient with respect to traditional protocols: each electrical measurement can be associated with a deadband, so that variations of the value larger than a specified limit cause transmission of a message: smaller variations can be disregarded.

d. Interlocking

Closing the MV breaker can be a critical operation. You may want the MV CB to close only when the LV breaker is in closed status. This is implemented in IEC61850 by a combination of horizontal communication and logic: LV breaker periodically sends its status (including of course open/ closed). When the LV breaker status allows, the MV CB will enable closing commands to be received from supervision system.

Event sequence can be the following:

- LV CB is closed: a status message is sent regularly to the network by means of a GOOSE message. All other IEDs are then aware that the breaker is closed
- In particular, MV relay is in an interlock state: commands to close the MV CB are rejected
- When LV CB opens, a GOOSE message is sent, reporting the change of state
- MV relay detects the change and enables breaker commands
- MV breaker can now accept a close command and energize the transformer.

e. Event logging

Because each device has a clock, it is possible to assign an accurate time stamp, based on a system clock, to each event. IEDs keep logs of events, which can be accessed after a trip or fault. After protection trips, such logs can be retrieved, so that service technicians can reconstruct the sequence of events, sorting them according to time of occurrence.

f. Breaker Failure detection

If breaker fails to open, a specific alarm is generated (Breaker Failure). The Breaker Failure alarm flag can be sent as a GOOSE. This allows an emergency sequence of actions to be implemented, such as:

- LV breaker detects faults and triggers a trip
- Trip fails, so an alarm is generated and sent over the network in the form of a GOOSE
- MV relay receives the GOOSE and commands opening the MV breaker. Fault is thus cleared; in addition the failure of LV breaker has been reported and logged by the supervision system, so that required maintenance can be scheduled. The above application works even for faults that only involve the LV side of transformer, and are not detected by the medium voltage protection, for example a ground fault on the LV busbar. An effective backup protection is thus obtained.

g. Easy scaling

Finally, all the above features apply equally well to more complicated stations, making it possible to scale up the benefits of IEC61850 as you move towards larger and more sophisticated applications. Just imaging a traditional solution with hard-wired interlocks, it's easy to see how the number of connections to be deployed and tested is significantly lower.

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