SMART HMI TOOLS FOR NUMERICAL RELAYS-
MORE THAN JUST A SETTING ASSISTANT

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INTRODUCTION

The liberalization of the electricity market has clearly brought about an increased pressure on the power system management to reduce costs. The pursuit of potential savings through maintenance is of special importance. Standardised concepts are increasingly used as well as multicultural products that cover the complete functional requirements of a feeder circuit. Interdisciplinary beginnings are occurring in the power system management and the asset management areas.

A medium sized Distribution System Operator (DSO) maintains an asset population of some 1000 relays. The age of the individual relays in the asset population may vary between 1 and 20 years consisting of numerous models and some makes. Their associated protective schemes have to be engineered, commissioned, routine-tested, administered and their performance analysed after power system fault clearance. The budget for such expenses may amount to some 30% of the total operating costs.

For economic and operator reliability reasons, the DSO therefore has a strong interest in smart human-machine interfaces HMI's supporting the vast majority of the relays in the system.

Beyond the traditional use as HMI tool, facilities for system fault analysis and quick power system restoration after an outage become vital for efficient system operation management.

THE CONTEXT

Today’s numerical relays and associated HMI tools cover a much wider application range as their analogue counterparts. Most numerical relays provide ‘scheme’ functionality, with no or few external devices to complete the scheme. All the external complexity i.e. function-dedicated relays and wiring is transferred into the relay. Thus traditional engineering has become obsolete, respectively is arranged for by built-in programmable logic controllers and I/O allocation matrices.

The comprehensive list above shows that modern HMI's must provide functions that were previously handled by different parties and tools.

Ongoing developments in numerical relaying involve both enhancements in performance and even more functional integration.

New relay settings have to be brought in, in particular for the "glue logic" of multifunctional devices. This results in more complex devices. It becomes apparent at all relay management steps; setting, commissioning, testing and fault analysis.

Out of the total scope of relay functions only some 60% is used in a specific application. Smart relays and HMIs therefore hide all the unused functions and their associated set points. Thus reducing the complexity to the needs of the actual application. The relay setting procedure is restricted to essential parameters, preparing good default parameter sets, standard configurations, etc.

The challenge is to achieve a scalable and profiled human-machine interface where only the relevant parameter and data appear in a given context and in an intuitive and visual way.

SCOPE OF HMI TOOL BOX

Smart HMIs provide for an excellent data management and consistency. They comprise of tools for parameterisation, fault reporting, fault recording, fault analysis, filing and retrieval, data publishing and well structured system-wide relay data bases. Operating under MS window, they have become an indispensable tool for the engineer in the dialogue with the relay and the associated management tasks.

It is essential that the dialogue, particularly with combined protection and control intelligent electronic devices IEDs, remain transparent. Each application domain must be autonomous and must not interfere into other program parts (Fig.1). Both, HMIs and IEDs must operate without repercussions to other pass-word protected domains. The user can only dialogue with one of the segregated and password-protected functions at the time. Entrance to any of the other implemented functions of an IED can only take place via inputs and outputs.

The semantic network of the File Manager (Fig. 2) structures projects systematically in a system-substation-bay-relay order. Particular IEDs are simply chosen from a library and dragged into the project. By double-clicking a particular IED, all domains and sub-domains, such as set points, input/output allocation, configuration matrix, commissioning tools and line load data may be accessed.

The HMI’s menu tree is a true replica of the associated IED data organisation; this consistency facilitates identical off-line and on-line dialogues.

All built-in functions are sorted in one window and can be easily allocated to the engineered I/Os, LEDs, buffers and communication ports without intermediate steps.

Configuration and parameterisation is limited to the released relay functions. Filters suppress unused functions and their associated set points. All settings and modifications may be verified graphically in the associated R/X diagram.

The fault report is an unquestionable record of all relay
operations along with real time tags. Testing and diagnostic tools measure load data online. External meters and manual wiring checks become widely obsolete.

POWER SYSTEM-WIDE FAULT ANALYSIS

After a power system fault has occurred, the primary concern is to analyze the fault quickly and comprehensively to draw the right conclusions and initiate corresponding measures. The associated graphic tool supports the in-depth analysis of fault records generated by digital protection relays or digital fault recorders DFR.

The Comtrade1 Viewer visualises the fault current and fault voltage traces. The graphically displayed fault quantities at the cursor positions and their differences are also available in figures and listed in tables. The point on wave of the cursor refers time-related to the vector diagram. A zoom ensures appropriate resolution of interesting areas in tiny detail. Users can visualize fault records in different views depending on the task and take any measurements they require. For a comprehensive fault analysis R/X diagrams, vector diagrams and bar charts derived from actual fault currents and voltages may be displayed. It also calculates sequence impedances, r.m.s. values, vectors, and harmonics.

Fault clearance of power system faults involves a number of relays at distant locations in the system. However, relays and DFRs deliver the associated fault record and fault report for post fault analysis only at their own local time base. This particularly complicates the fault analysis of tele-protection schemes, where the protection scheme consists of two or more distributed relays. A joint time base to capture the complete scheme performance at a reference time is missing. The real-time repercussion of remote events within the fault clearance process on the local relays, e.g. sequential opening of breakers on parallel lines, current reversals etc. cannot precisely be reconstructed.

A new feature allows placing several records downloaded from distant IEDs or DFRs on top of each other, synchronizing them on a common time basis. This unique feature opens up a new quality in the analysis of faults.

The new tool can retrieve fault records from distributed databases, and reconstruct them in a new record on a joint time base. This allows ‘real time’ analysis at each location particularly beneficial for fault investigation on complex system configurations.

After the files have been loaded, the part of the fault record to be replayed is selected. Markers can be set in order to synchronize the records into a joint time base. Fault records may be downloaded from individual numerical relays and DFRs in the distribution system via the telemetry system, dial-up modem or, if there is no communication link available, manually transferred to the relay management terminal into the engineer’s office.

The tool also accepts records from other relay or DFR makes. It supports the COMTRADE (C37.111-1991 and P37.111/D11) file format. Thus, the tool is particularly advantageous in distribution systems, where the relay population consists of various relay generations and relays or DFRs of different make.

OFF-LINE DISTANCE-TO-FAULT LOCATION

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1 standard enabling the use of data captured by digital fault recorders DFR
Quick Power System Restoration is an essential subject for system planners and operating engineers. At a time where bulk power systems operate close to their design limits, the restructuring of the electric utilities has created more vulnerability to potential blackouts. Prompt power system restoration is essential for the minimization of downtime and costs to the utility and its customers, which mount rapidly after a system blackout.

Essential for quick power system restoration is the fast location of the fault. Distance-to-fault calculation techniques based on fault impedances evaluate fault loci on all connected lines from only one substation. Extensive communication networks are not required. The system operator can quickly arrange for a reconfiguration of the distribution system and the maintenance personnel may begin their repairs instantly. However, separate distance-to-fault locators or numerical distance relays with implemented fault locators is not necessarily standard in distribution systems.

The HMI tool offers now an economic option, if off-line fault location suffices. The tool retrieves off-line for each event the current wave forms from the substations’ overcurrent relays (50/51) and the voltage traces from one single voltage relay (27) and reconstruct them in a new record on a joint time base Fig.4.

With the fault associated current and voltage traces, it calculates off-line the distance-to-fault. Extra hardware is not required.

The algorithm is derived from state-of-the line protection relays. It applies positive and negative sequence quantities. Thus, the readings are not influenced by imprecise zero sequence settings and parallel line zero sequence coupling [2].

ENGINEERING OF SUBSTATION LANS TO IEC 61850

Engineering of substation communication networks using non-interoperable IEDs of different make used to be difficult. The recently introduced communication standard IEC 61850 now paves the way for interoperability between products of different make. The key to exchanging configuration data between IEDs of different vendors in the substation is the Substation Automation Configuration Description Language (SCL) standardized within IEC61850. All relevant IED information is available as text in a standardized file, based on XML.

Any IED conforming to IEC 61850 must now provide such a device description, which defines the configuration of the device, its functional scope and communication features.

This allows IEC61850-compliant devices featuring functionality from different vendors to be more easily integrated into the substations’ LAN.

A system configurator available with modern HMI tools assists the user in designing the substations’ communication network. The user does not need to acquire XML or SCL know-how. This results in considerable design cost savings.

Figure 5, Network subscribers (left), their properties and IP addresses (right)

Figure 6, Marshalling list (top) and source/destination items

The “network” area all basic information on the network structure at a glance, such as subnet ...user ...IP address Fig. 5. In the ‘configuration’ area one defines the information to be exchanged between the individual nodes. The source and destination objects are clearly arranged in separate windows and in a hierarchical tree structure. Data objects are copied into the interconnections table with a mouse click or by means of drag & drop.

THE USE OF INTERNET TECHNOLOGY
Proprietary HMIs cover all tools for the comprehensive management of vendors’ products or product ranges. For the total relay management this comprehensive functionality remains essential. However, for particular tasks, e.g. remote interrogation or commissioning, a simpler and non-proprietary tool that also serves for other makes would suffice.

Browser-based access to numerical relays represents a new platform for man-machine interfaces. Since standard protocols and software from the Internet world are used, no special programs are required on the user’s side. The communication runs via TCP/IP based protocols. While this may simplify the communication architecture, security aspects must be examined in detail. A high security level and solid standards are necessary for widespread IP-based communication with relays within the enterprise. Newly designed IEDs now provide, besides their traditional applications, embedded server for use in the Intra/Internet. Enhanced capability of web browser technology, e.g. better interactive and animated full graphic features of static or dynamic real-time data, make today’s web browser technology an attractive companion to proprietary human machine interfaces. These features, together with robust security provide the utility with the possibility to use standard Internet browsers not only to monitor substations, but also to control them. TCP/IP networking and Internet technology facilitates communication with the protection relay with a standard PC. This tool also features a graphical representation of the most important operational data: Voltage and current phasors. Tripping characteristic with the actual operating point, status of the data communication links and messages. The available "views" reflect all relevant information which has to be considered when commissioning the relay.

The power system becomes transparent. All authorised persons will have access to relevant data from anywhere at any time. This is of special interest to the nomadic working style of the maintenance personnel. Particularly system restoration and commissioning of tele-protection schemes where data from booth line ends is required benefit from this approach. The commissioning engineer may reconfigure remotely located relays from the local line end.

Furthermore, search engines and heuristic methods may pave the way from data management and Management Information Systems MIS towards modern knowledge management. Ethernet is today deterministic and fast enough for modern architectures. The substation net may be even divided into sub-networks. Intelligent bridges and routers control the data. The IED-embedded servers possess their own IP address in the intra/internet, i.e. they can be interrogated from the net, or even initiate own inquiries.

OLE process control (OPC) server channel and TCP/IP protocols are used to transfer the data from the IED to the utility’s Intranet/Internet web server. The OPC channel allows vendor-independent access to communication networks, which are based on object linking and embedding (OLE). The IED-embedded server uses standard Internet technologies including HTML and Java, to ensure that a common web browser can be used to open the HTML pages. The IEDs’ tag processing on the HTML page is based on the JAVA applet technology. When the user opens a page, a JAVA applet is automatically started to retrieve the real-time data.

CONCLUSION

HMIs have become indispensable tools for the engineer in the dialogue with the relay and for total relay management. They reduce the complexity of the relay to an adequate working level. Recent developments also extend their functionality beyond their initial tasks. Fault analysis and tools for distribution system restoration complement the tool box. Browser-based access to numerical relays for specific tasks accompanies HMI applications. Standard protocols and software from the Internet world require no special programs on the users’ side. Thus this tool is non-proprietary and suitable for any make proving this technology. While this may simplify the communication architecture, security aspects must be examined in detail. A high security level and solid standards are necessary for widespread IP-based communication with relays in its sensitive security environment.

REFERENCES

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