Visualization and HMI (Human-Machine-Interface) in Substations

Abstract

This paper reviews a modern computer-based design for visualization and manual control of substation and feeder apparatus. This visualization design – actually a "Human-Machine-Interface" or "HMI" - focuses primarily on application in medium voltage (12kV – 38kV) and high voltage (69/138kV and up) electric utility and plant substations. Included in this paper: brief history of substation visualization, page types and examples, animation techniques, redundancy, security and advantages.

History of Visualization in Substations

In order to better understand the architecture of modern substation visualization, it is helpful to review the progression of earlier designs, from hard-wired solutions, through early computerized visualization, to the computer-hosted HMI.

> ***Terms used in this section**:*
> *IED – A computerized "Intelligent Electronic Device" of any size or complexity, located in the substation or on the line/feeder and with some ability to communicate with other local and remote IEDs. Examples of IEDs: substation RTUs, protective relays, panel meters, voltage regulators, tap changer controllers, recloser controls, transformer monitors, recorders, etc.*

Hard-wired Solutions

Some form of visualization has always been required in electrical substation, historically in the form of electromechanical panel meters, alarm lights, physical "mimic bus" renditions, and control switches. The purpose of this visualization was to provide situational awareness and to enable local control by substation operators. Many substations continue to employ elements of these legacy designs in their visualization designs. Two legacy designs are shown in Figure 1 below:

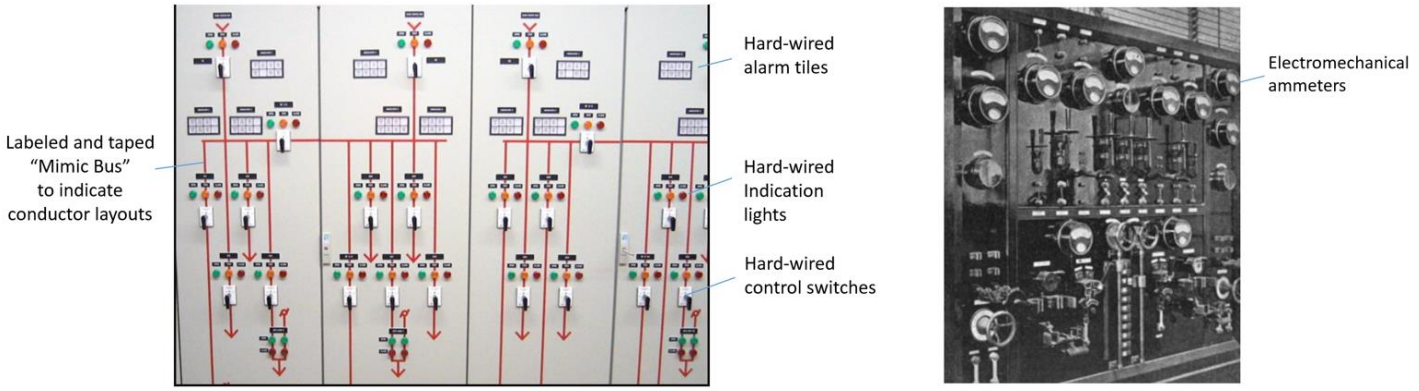


Figure 1: Two examples of legacy substation visualization

Computerized Solutions

The advent of the industrially-hardened computer chip brought intelligence, configurability and reduced wiring to substation visualization. Hard-wired alarm annunciators were replaced with software-driven designs where alarm conditions could be accessed through communication protocols from IEDs. Single-purpose panel meters were replaced with computerized multi-function versions, where one meter could measure and digitize three-phase currents and voltages and accurately calculate volts, amps, frequency, power factor, Watts, VARs, harmonics, energy and hundreds of other values.

Figure 2: Computer-based Tile Alarm Annunciator and early (1995) Bitronics Multifunction Panel Meters

First Generation HMIs: PC Hosting

In North America, the first generation of PC-hosted substation HMIs appeared in the 1980s and were an outgrowth of the industrial HMI and the industrial PC used in factories. While powerful, flexible and well-supported, the early hardware lacked the specific features required for substation applications, including 48-125V dc battery power, wide temperature range and electrical noise immunity. Most also used fans, filters, rotating media and inverter power which contributed to lower reliability and higher maintenance than desired in these unmanned, remote substation applications. Software challenges included separate HMI and RTU databases, long learning curve, and lack of support for utility protocols, utility applications and substation symbol graphics. During this time, a US engineering firm estimated that the cost of the substation HMI was as high as the other substation automation combined. As a result, only a small percentage of the largest substations used these early generation HMIs.

Second Generation: Much Better PCs

By the late 1990s, the PCs hosting the HMI application became ruggedized with the same power supply and environmental immunity as other IEDs in the substation, and new communication software added support for utility protocols such as DNP3, IEC 61870-5 and IEC 61850. New utility-specific HMI software reduced learning curve and implementation cost, and application expanded. Challenges of the HMI being a separate system with a separate HMI database remained.

Third Generation: Browser Technology

Browsers for the web made possible universal viewing of pages served from computers without any special software, and, by the mid-2000s, this architecture gradually started to replace PC hosting of the HMI application. The big advantage was that the HMI application became part of the RTU, using the same database. Pages served from the RTU could be browsed by simpler PCs or "thin clients", both cheaper and more rugged. The browsing PC could also be dedicated and local, or remote, or carried into the substation as a portable laptop.

New PC Challenges: Security Patching and NERC CIP Compliance

The ubiquity of PCs, combined with an architecture designed for easy addition of third-party software, makes them a target for hackers. In environments where the PC is in close proximity to maintenance personnel, frequent security patching is challenging, but manageable. Patching PCs in 100 unmanned and remote electrical substations is a much more consuming task. Furthermore, the HMI is often a broadband-accessed device, on the "security perimeter" of the substation, making it a critical cyber asset according to many national security agencies, including the US Department of Homeland Security. This mandates stringent and costly cyber security measures, including firmware and configuration tracking, access logging and password management.

Fourth Generation: Built-in "Direct Video"

In an effort to reduce cyber security compliance efforts and to reduce costs, suppliers of modern RTUs – now more often referred to as "Automation Platforms", "Automation Controllers" or Gateways" – are building the HMI into the RTU. In one common design, web pages are both served out and browsed by the same computer, necessitating only monitor, keyboard and mouse connections. This eliminates the browsing PC or the HMI hosting PC, reducing one expensive box from the automation architecture, and simplifying compliance efforts. See Figure 3 below.

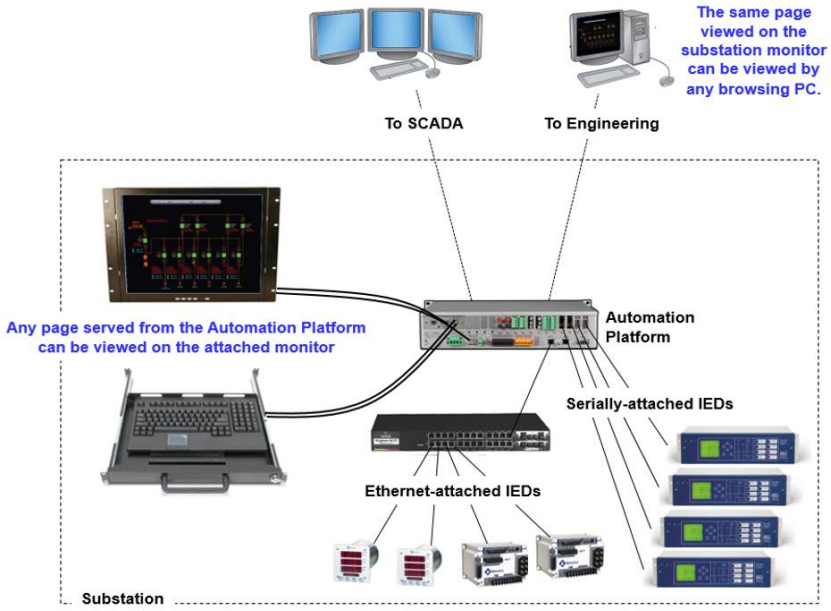


Figure 3: Substation automation system with the visualization HMI built into the Automation Platform

How "Direct Video" Visualization Works

The principles of the Direct Video HMI include both the hosting of the HMI application in the Automation Platform, and the direct attachment of the monitor and keyboard to the Automation Platform. Visualization is accomplished as follows:

1) The Automation Platform accesses real-time data from IEDs in the substation: I/O module IEDs, protective relays, panel meters, specialized controllers, etc. Typical components are shown in the substation rack pictured in Figure 4. These data are stored in a real-time database for access by the HMI application and other automation applications: Alarming, Sequence of Events Recording, SCADA, Email, Math and Logic, etc. A graphical representation of these "data sources and "data users" is depicted in Figure 5.

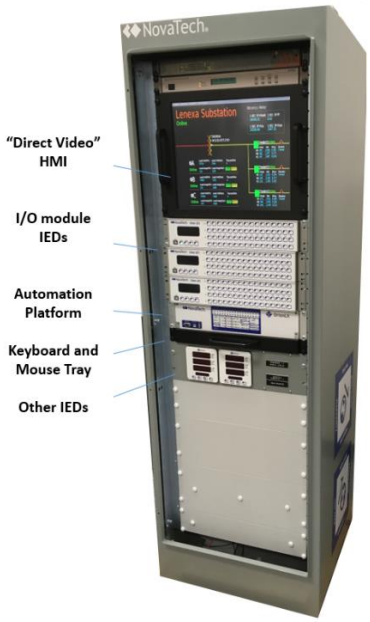


Figure 4: Components in a substation automation system including HMI, IEDs and Automation Platform

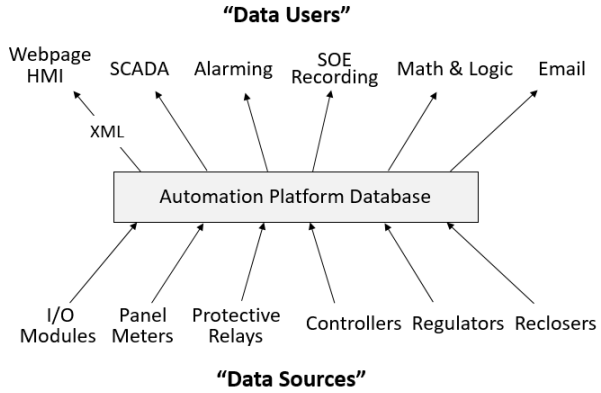


Figure 5: The data sources and data users in an Automation Platform

2) The automation platform exports real-time data to the web application using a mechanism such as XML file transfers. This real-time data animates the web page, enabling text and graphic elements to change as real substation events change. Animation techniques are described in a later section.

3) The custom webpage is developed using a graphics editor with tools to draw and import objects and link objects to the imported data. Tools and styles vary, but desired features here are open, non-proprietary products that create pages that are "scalable" for page viewing on monitors of different sizes and for viewing on cell phones.

4) The monitor itself may be conventional or touch screen, and may be connected to the Automation Platform with any of the standard commercial techniques such as VGA, HDMI, DVI or Display Port. Important features here include environmental ruggedness and ideally, a 48-125V dc power supply. Dual monitor support may be important in the larger, more critical substations.

Visualization Applications in the Electrical Substation

The versatile modern visualization system provides multiple pages for expanded situational awareness. Common types of pages are described below.

The **animated one-line (or single-line) diagram** is a graphical representation of the substation apparatus and conductors from an overhead view. A single conductor is shown instead of the actual three-phase conductors to simplify viewing and page construction. Animation typically includes real-time numerical display of power system measurements, breakers and switches shown in red or green to indicate opened and closed status, some form of higher-level alarm annunciation, and navigation to other pages. Control of breakers may be done from this page, but it usually performed from the animated IED "zoom screen" described in the next section. Figure 6 below is a one-line-diagram used for a central US distribution substation.

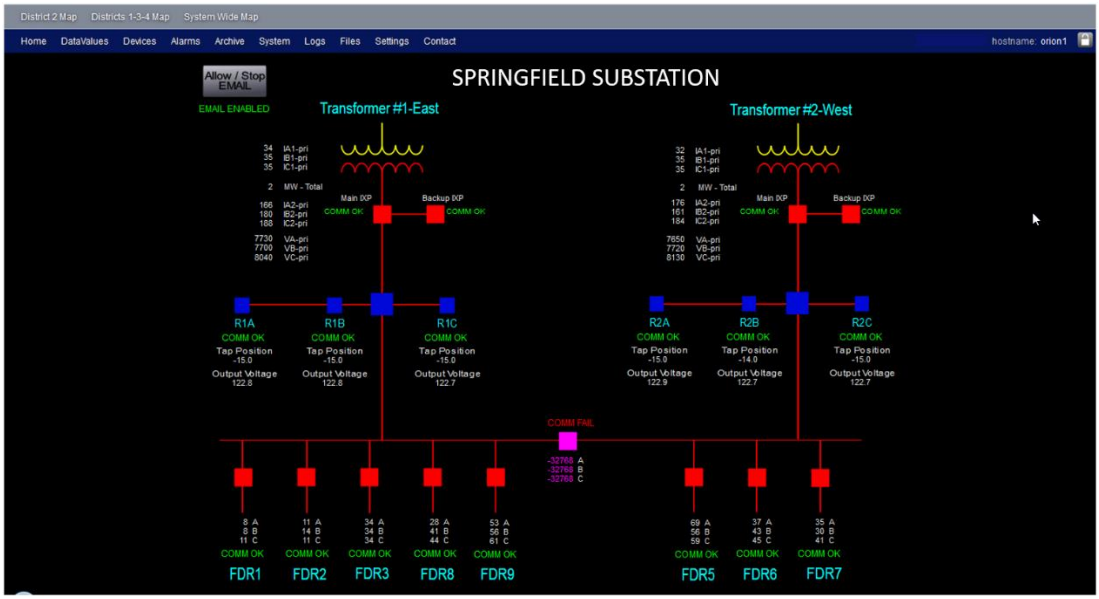


Figure 6: Typical substation one-line-diagram

The **animated zoom screen** is accessed from the one-line diagram page by clicking on a URL link graphic, usually a breaker or other apparatus. The zoom screen is designed to appear as the real IED appears in the substation and includes animated front panel LEDs and numerical data displays. If the IED being simulated is capable of tripping and closing breaker, the control buttons will usually appear on this screen.

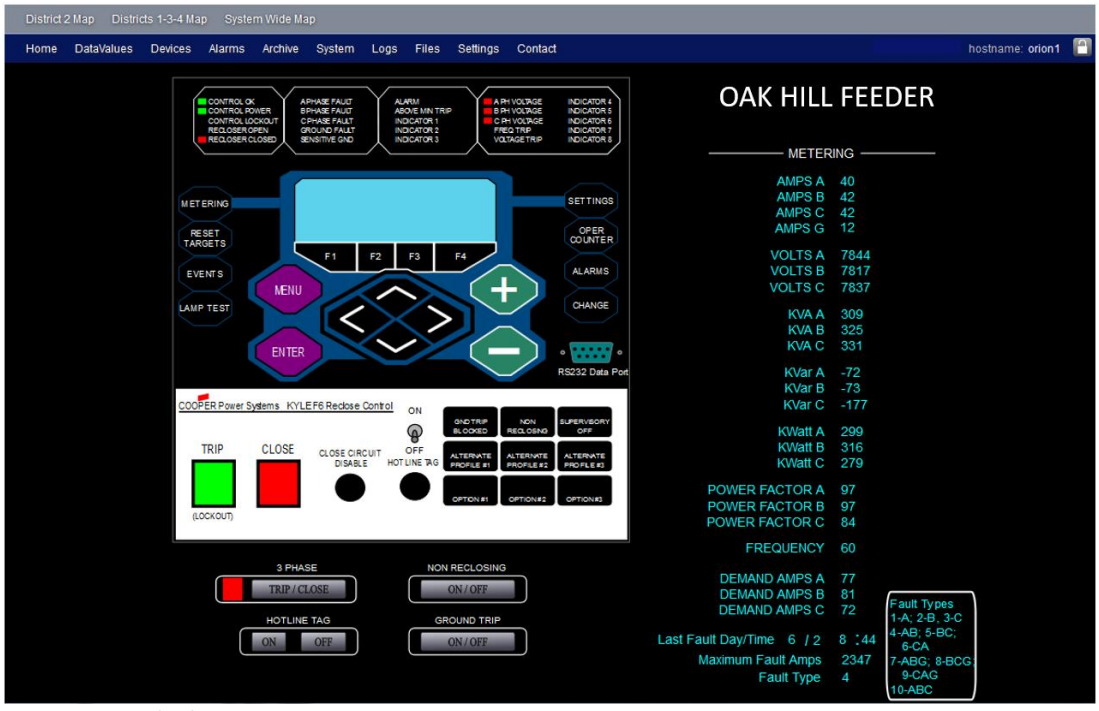
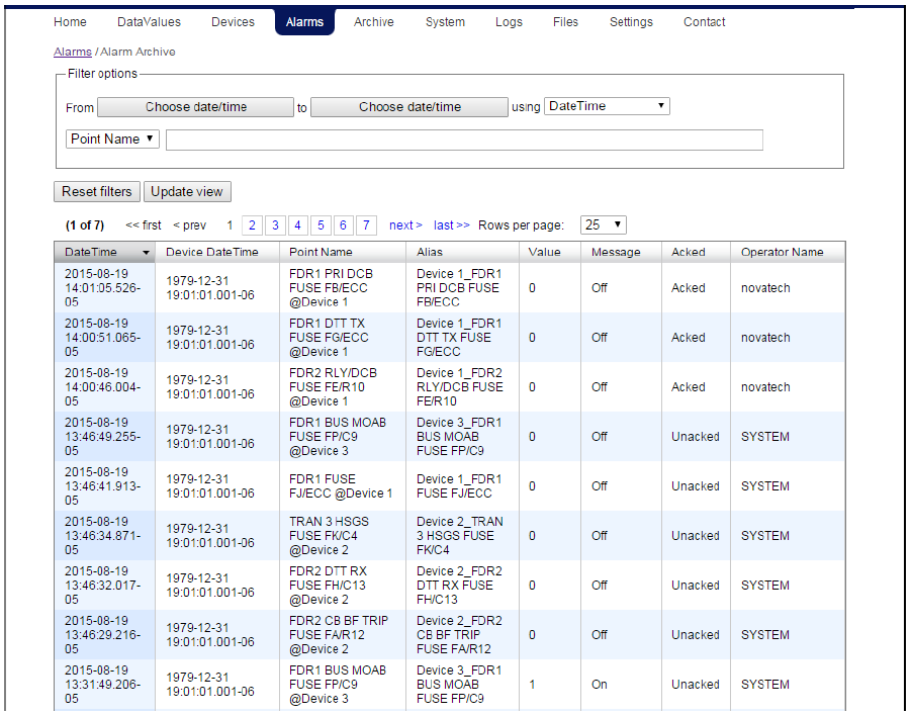


Figure 7: Typical substation zoom screen

The **Tile Alarm Annunciator** displays active alarms on one or more pages. Typical animation convention is for active alarms to blink red, acknowledged alarms to go solid red, and for inactive unacknowledged alarms to go dark green. Acknowledgement is done by clicking on the tiles or touching them. A typical annunciator is shown in Figure 8.

Figure 8: Software-based Alarm Tile Annunciator

The **alarm history**, shown in Figure 9, provides more alarm detail including time stamps and a history of all of the instances of a point going into and out of alarm, when acknowledged and by whom. Important features for the alarm history include a "windowing" feature where a beginning and end time window can be selected plus point filtering to simplify location of specific points and a column editor to simplify viewing.



DateTime	Device DateTime	Point Name	Alias	Value	Message	Acked	Operator Name
2015-08-19 14:01:05.526-05	1979-12-31 19:01:01.001-06	FDR1 PRI DCB FUSE FB/ECC @Device 1	Device 1_FDR1 PRI DCB FUSE FB/ECC	0	Off	Acked	novatech
2015-08-19 14:00:51.065-05	1979-12-31 19:01:01.001-06	FDR1 DTT TX FUSE FG/ECC @Device 1	Device 1_FDR1 DTT TX FUSE FG/ECC	0	Off	Acked	novatech
2015-08-19 14:00:46.004-05	1979-12-31 19:01:01.001-06	FDR2 RLY/DCB FUSE FE/R10 @Device 1	Device 1_FDR2 RLY/DCB FUSE FE/R10	0	Off	Acked	novatech
2015-08-19 13:46:49.255-05	1979-12-31 19:01:01.001-06	FDR1 BUS MOAB FUSE FP/C9 @Device 3	Device 3_FDR1 BUS MOAB FUSE FP/C9	0	Off	Unacked	SYSTEM
2015-08-19 13:46:41.913-05	1979-12-31 19:01:01.001-06	FDR1 FUSE FJ/ECC @Device 1	Device 1_FDR1 FUSE FJ/ECC	0	Off	Unacked	SYSTEM
2015-08-19 13:46:34.871-05	1979-12-31 19:01:01.001-06	TRAN 3 HSGS FUSE FK/C4 @Device 2	Device 2_TRAN 3 HSGS FUSE FK/C4	0	Off	Unacked	SYSTEM
2015-08-19 13:46:32.017-05	1979-12-31 19:01:01.001-06	FDR2 DTT RX FUSE FH/C13 @Device 2	Device 2_FDR2 DTT RX FUSE FH/C13	0	Off	Unacked	SYSTEM
2015-08-19 13:46:29.216-05	1979-12-31 19:01:01.001-06	FDR2 CB BF TRIP FUSE FA/R12 @Device 2	Device 2_FDR2 CB BF TRIP FUSE FA/R12	0	Off	Unacked	SYSTEM
2015-08-19 13:31:49.206-05	1979-12-31 19:01:01.001-06	FDR1 BUS MOAB FUSE FP/C9 @Device 3	Device 3_FDR1 BUS MOAB FUSE FP/C9	1	On	Unacked	SYSTEM

Figure 9: Alarm history page

The **Sequence of Events (SOE) and Archive Report** displays a time-stamped sequence of substation events and archived data. See Figure 10. As with the Alarm History, desirable features include time windowing, point filtering and column editing.

Reset filters | Update view

(25 of 40) << first < prev 20 21 22 23 24 25 26 27 28 29 next > last >> Rows per page: 25

ID	DateTime	Device DateTime	Point Name	Alias	Value	Online	DTime
51173194	2015-01-15 19:00:00.256-07	2015-01-15 19:00:00.127-07	SYSTEM PF TOTAL @Logic		0.962342	online	no
51173193	2015-01-15 19:00:00.256-07	2015-01-15 19:00:00.127-07	SYSTEM MW TOTAL @Logic		35.262976	online	no
51173192	2015-01-15 19:00:00.256-07	2015-01-15 19:00:00.126-07	SYSTEM MVAR TOTAL @Logic		9.96108	online	no
51173188	2015-01-15 19:00:00.256-07	2015-01-15 18:59:54.14-07	WEST PHASE C AMPS @West Slave		56.8	online	no
51173093	2015-01-15 19:00:00.256-07	2015-01-15 18:59:57.877-07	NORTH PHASE A AMPS @East Slave		72.5	online	no
51173189	2015-01-15 19:00:00.256-07	2015-01-15 18:59:58.296-07	SF PHASE A AMPS @West Slave		127.1	online	no
51173185	2015-01-15 19:00:00.256-07	2015-01-15 18:59:54.14-07	ALCO PHASE C AMPS @West Slave		71	online	no
51173186	2015-01-15 19:00:00.256-07	2015-01-15 18:59:54.14-07	WEST PHASE A AMPS @West Slave		55.3	online	no
51173094	2015-01-15 19:00:00.256-07	2015-01-15 18:59:57.877-07	NORTH PHASE B AMPS @East Slave		73.9	online	no
51173187	2015-01-15 19:00:00.256-07	2015-01-15 18:59:54.14-07	WEST PHASE B AMPS @West Slave		62.8	online	no
	2015-01-15	2015-01-15	SF PHASE B AMPS @West				

Figure 10: Archived data table

The **trending page** enables selected archived data to be graphically depicted over a selected period of time. See Figure 11.

Archive / Trending

Filter options

From 2015-1-14 00:00:00 to 2015-1-15 00:00:00 using DateTime

Point Name ALCO PHASE A AMPS @West Slave, ALCO PHASE B AMPS @West Slave, ALCO PHASE C AMPS @West Sl

Reset filters | Update view

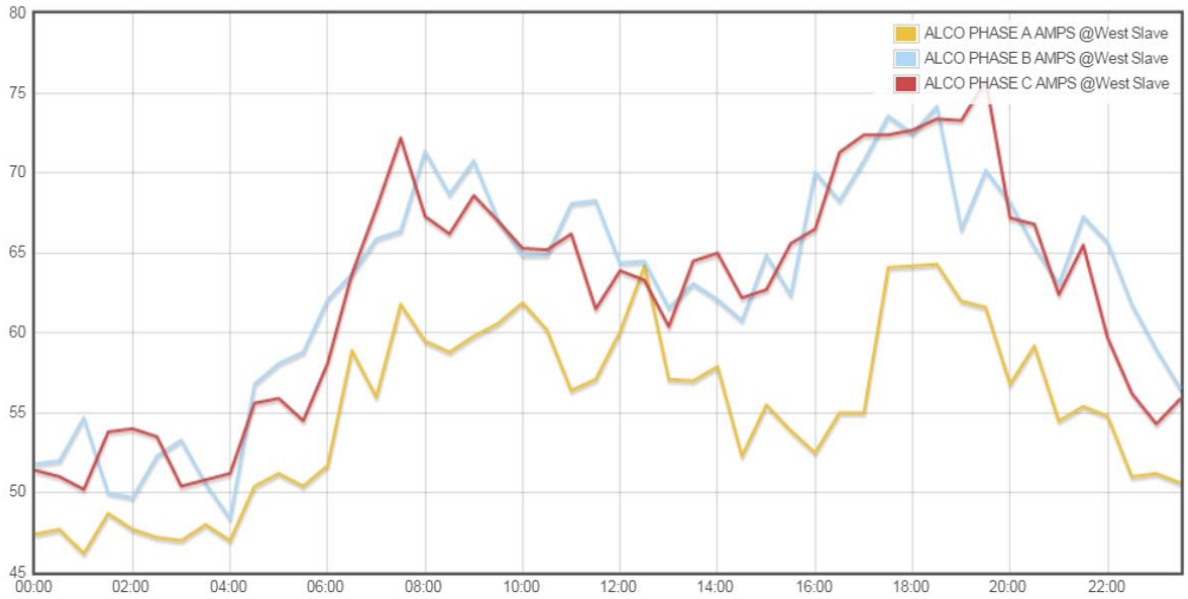


Figure 11: A one-day trend of three line currents, every 30 minutes

Animation Techniques
Animation enables the substation visualization system to reflect real-time operating conditions, to highlight abnormal conditions, and to simplify viewing.

Display Real Time Value
Analog values, such as Amps, Volts, Watts, VARs, etc can be displayed on the screen, changing in real time.

Display Text Strings
A text string may be the name of the user who is logged in, an Event Report from a Schweitzer protective relay, or a text message; these can be useful on a visualization screen.

Change Color
Color is effective for indication of machine state or urgency, notably if it is in contrast to screen items that are not colored. Typical application is for indicating the OPEN (Tripped) and CLOSE state of a circuit breaker on one-line-diagrams, in green or red respectively. Another application is to indicate the state of an alarm or front panel LEDs.

Appear and Disappear
This technique enables messages or graphic elements to appear or disappear as conditions change in real time. For example, the words “Comm Fail” and “Comm OK” could alternatively appear. Another example is depicting a control switch in two different locations.

Blink
Blinking adds more visual distinction, and can be combined with color on alarm annunciators to add more meaning; e.g. blinking red means an active alarm that is not unacknowledged, while red not blinking mean an active alarm that is acknowledged.

Navigation to other pages
Moving from page to page is a normal part of the substation visualization experience, and the same navigation techniques exist in substation visualization as in moving among pages when browsing the internet, including clicking on standard and custom page names, clicking on on-page symbols and clicking on text. A custom and standard navigation bar is shown in Figure 12.

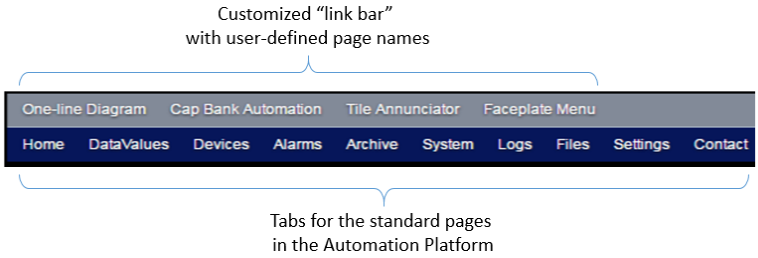


Figure 12: Customized link bar and standard link bar used to navigate between pages

Automatic Page Redirect
Techniques may be included in the HMI to automatically move to a designated “home” page after a period of inactivity, or move to a designated alarm page when certain alarms occur.

Color to Indicate Animation Failure
Because visualization screens are animated with real-time data, and because these data may not always be available (e.g. due to communication failure to the source IED), some means to determine if the animation is not being updated is important. One method is to highlight failed animation with a special color such as magenta.

Substation Visualization Examples

One-Line-Diagram and Zoom Screen

A typical one-line diagram and zoom screen are shown below in Figure 13. This page is served out from an Automation Platform that also serves as an RTU and Alarm Annunciator at a central US municipal utility. It is used primarily to monitor and control switched capacitor banks to maintain system power factor to desired levels.

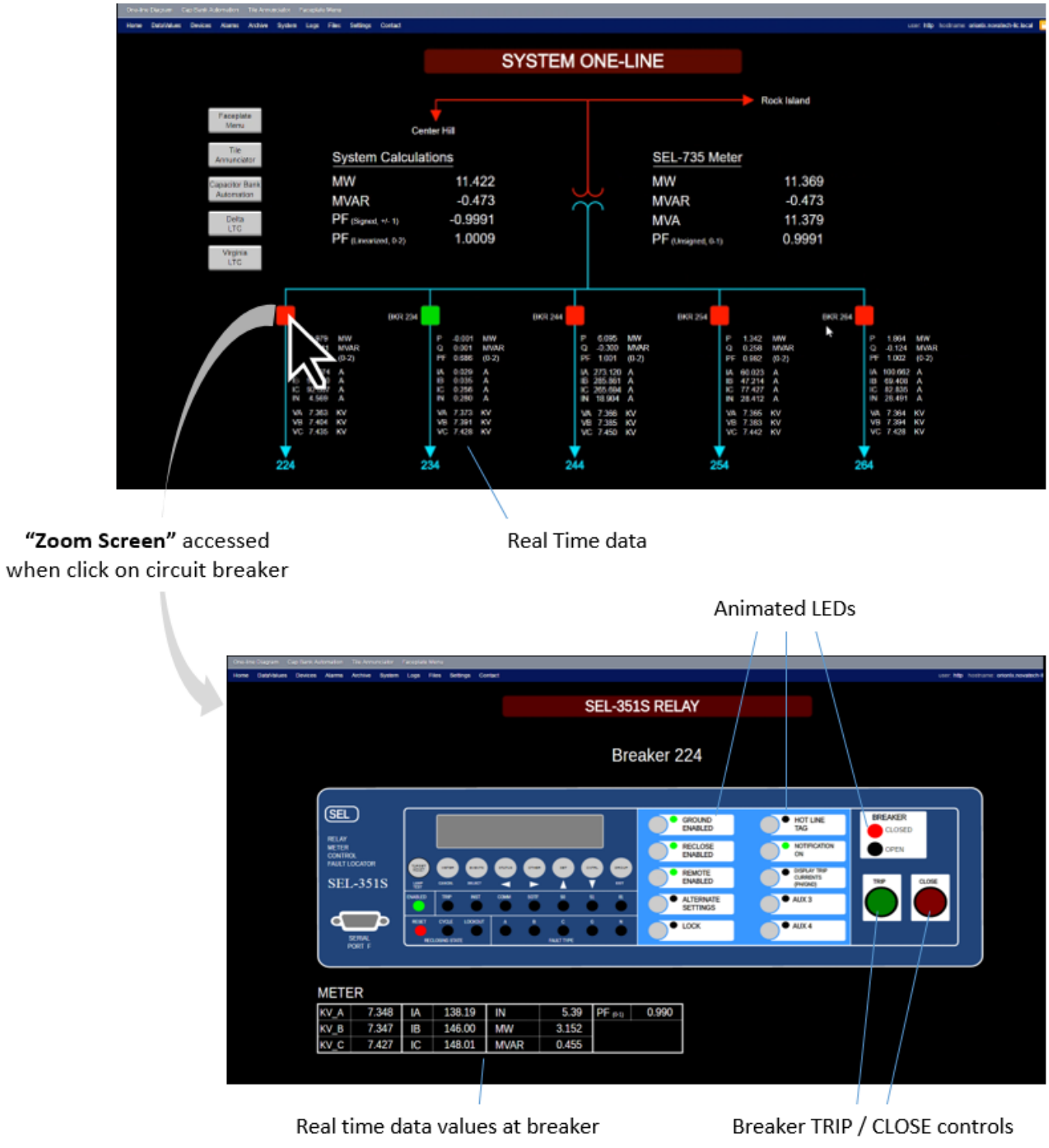


Figure 13: Substation HMI one-line diagram and IED zoom screen

Industrial One-Line Diagram

The page in Figure 14 is a one-line-diagram for a medium-voltage distribution system for a Midwest US corn processing plant. The design is purposefully simplified to minimize distraction and to focus attention only where important. It limits the use of color, in this case only to red or green indicating breaker OPEN or CLOSE status. Numerical displays are limited to transformer loading and feeder amps. Clicking on any breaker navigates the user to another more detailed page with breaker control and details on the protective relay protecting the circuit.

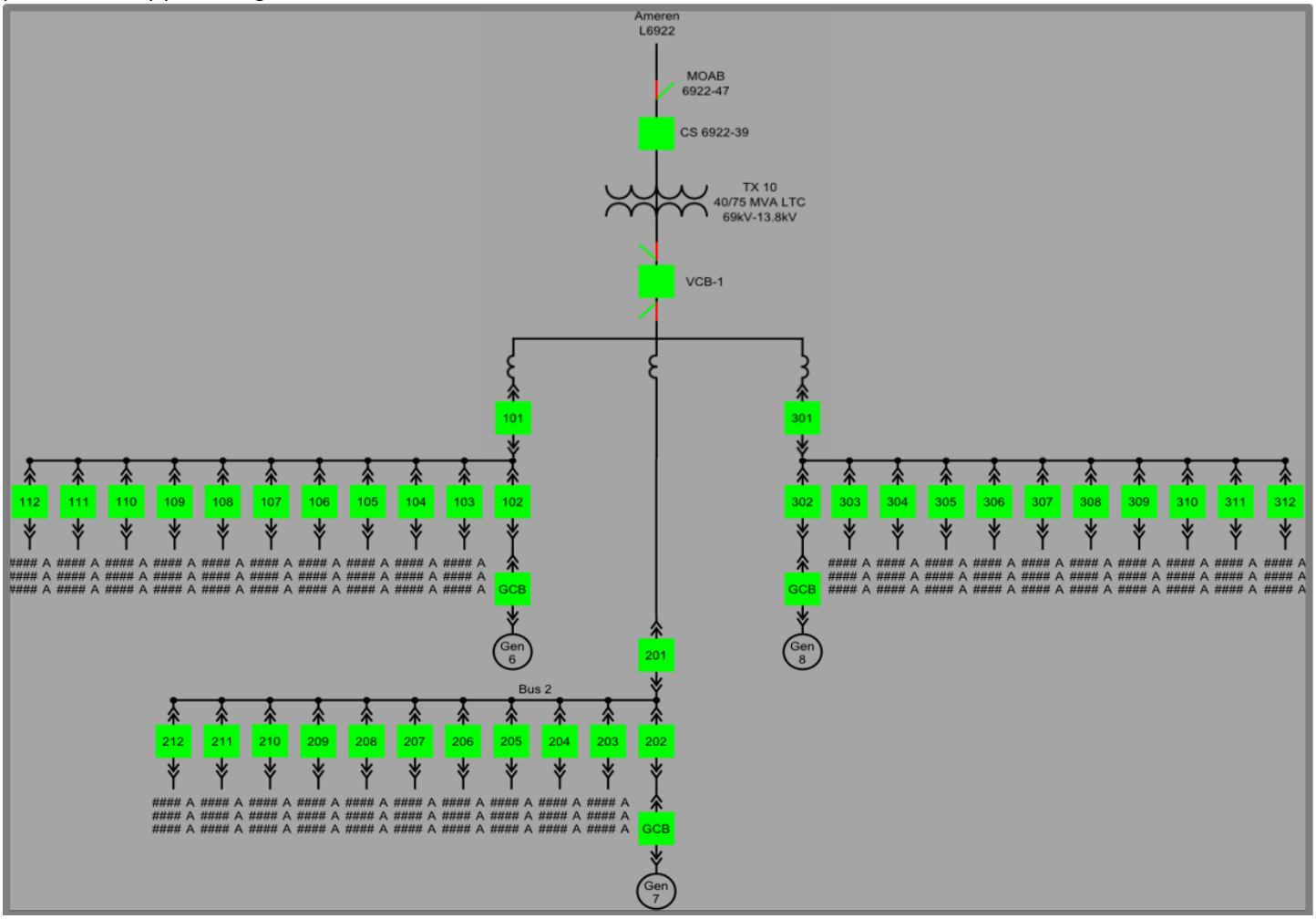


Figure 14: One-line-diagram of an industrial medium-voltage substation

Voltage Regulator Controls Screen

Controls for per-phase regulators on a distribution feeder are shown in Figure 15. Animation includes display of regulator position and voltage, amount of voltage reduction in effect, and alarm and mode messages. Controls include RAISE/LOWER, blocking and selection of control modes.

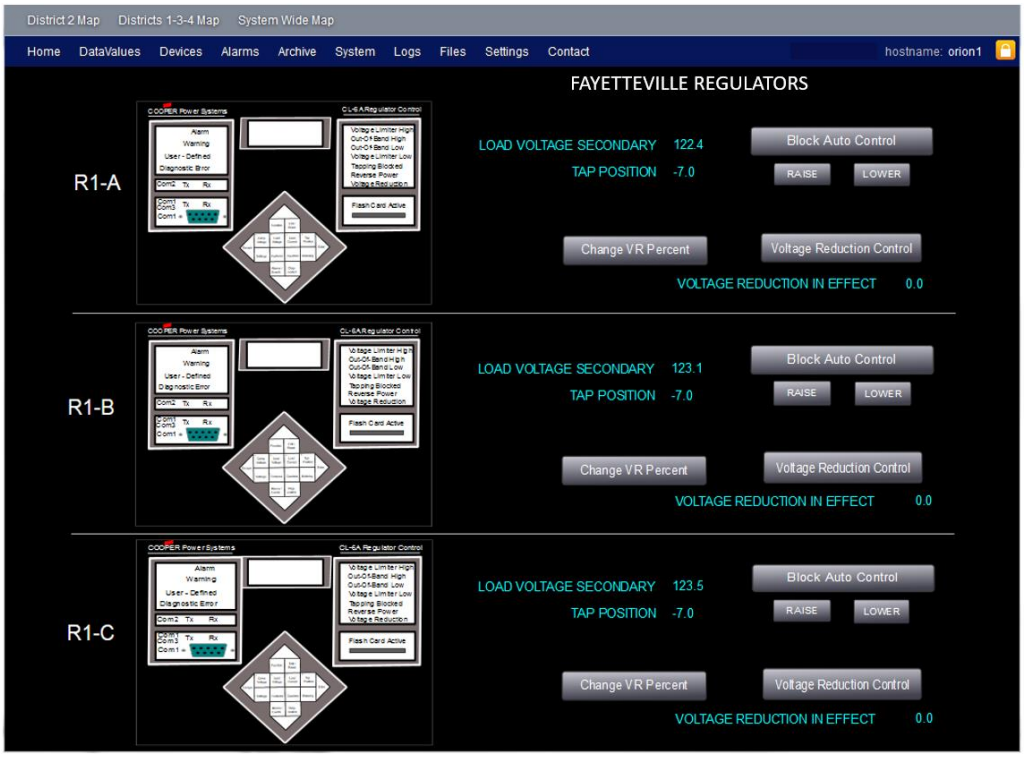


Figure 15: Voltage regulator controls

Transformer Monitoring and Control Screen

The page below in Figure 16 includes monitoring and controls for a HV transformer. LOCAL/REMOTE and AUTO/MANUAL controls are designed to appear the same as the physical control switches previously used for this application. This page is accessed by clicking on the transformer symbol on a one-line-diagram.

Figure 16: Transformer monitoring and controls screen

Techniques to Reduce Engineering Configuration and Commissioning Effort

The largest costs in implementing a complete substation HMI can be the configuration and commissioning efforts. The following tools can reduce this effort.

"Indirect Addressing"

In most applications, the same IED may be used in multiple locations in the substation, for example on each feeder. The animation of a modern multi-function IED, such as the SEL® relay shown in Figure 17, involves linking over 80 graphical elements with points in the RTU database. In a larger substation with 30 relays, this means over 2400 configuration steps, a huge effort. Indirect Addressing requires only one IED to be animated, and for the point names to contain a variable, or "indirect address". The variable is in the page URL, and is populated to the points when the page is loaded.

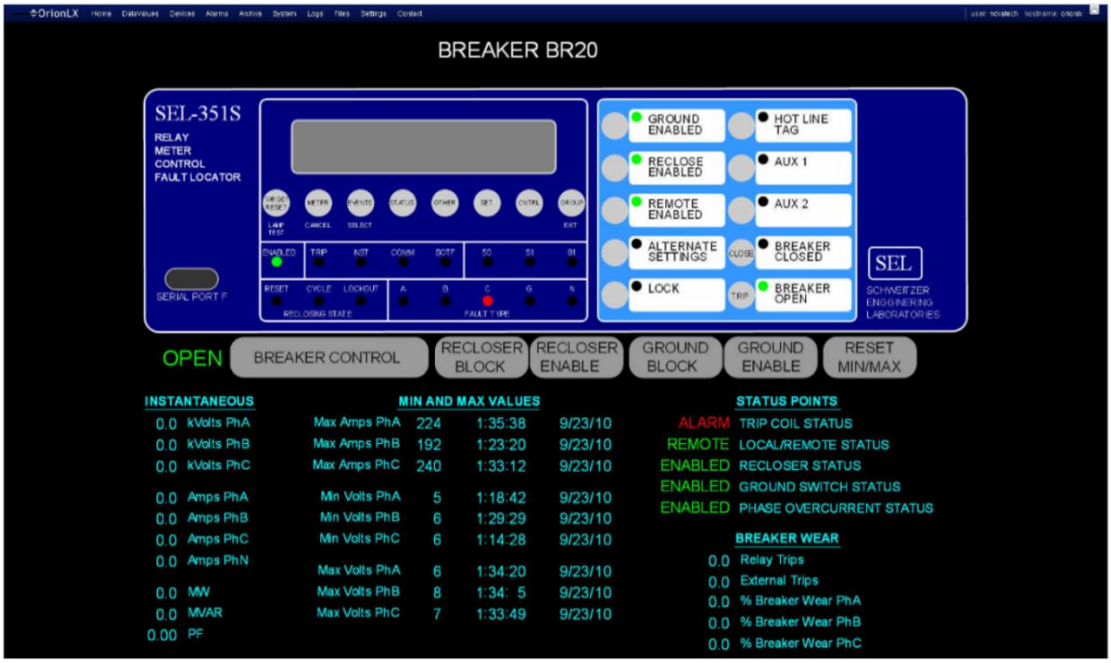


Figure 17: A zoom screen for a Schweitzer protective relay with over 80 animated graphic and text elements

Pre-Drawn Image Library

If the HMI supplier can provide a large library of pre-drawn images, such as the ones depicted in Figure 18, engineering effort can be reduced and image consistency better maintained.

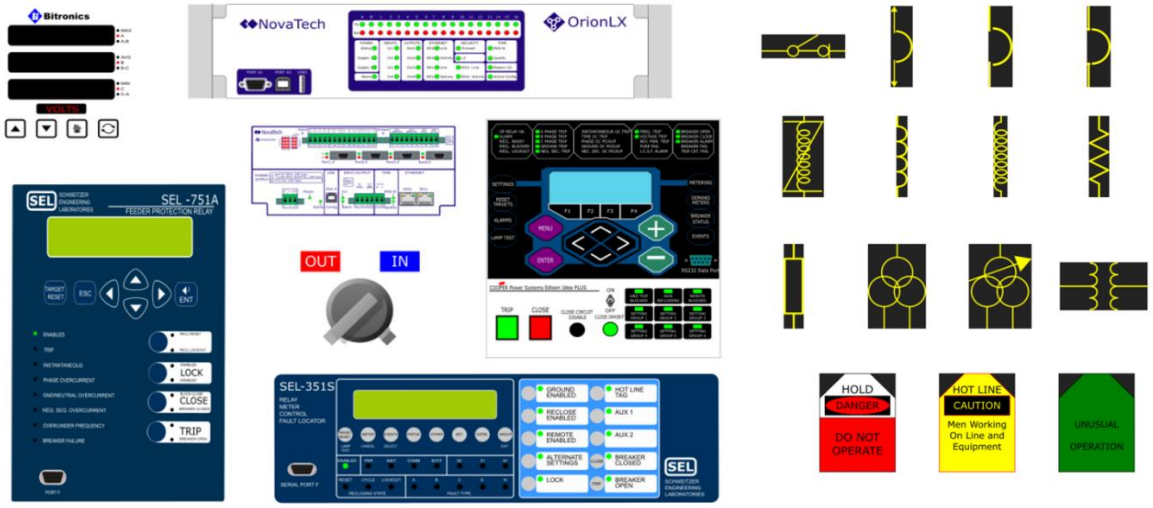


Figure 18: Typical pre-drawn library images including animated IED faceplates and symbols

Import Pictures and Screen Captures

Import of maps and other user-recognizable images reduces engineering drawing effort and improves HMI intuitiveness.

HMI Page Creation Guidelines

Unlike many aspects of substation automation design, the HMI must interact intimately with the user. This requires the design team to design the HMI for regular use by another group of people, and likely a group with lower technical skills; this increases the importance of graphical consistency and intuitiveness. A software engineer may be capable of making the HMI work, but users and people familiar with human factors need to make it usable. Design guidelines below.

Avoid overcrowding

Users should not have to search out what they need from a crowded page. Zoom screens should be used to drill down for more information. Messages and graphics may appear and disappear as conditions change, which simplifies page viewing.

Avoid Excessive "Eye-Candy"

Colors, blinking and other animation should be restricted to annunciation of conditions requiring operator attention, not for visualizing normal conditions. Fancy graphics may help sell the HMI to a decision-maker, but that is not what users want.

Create a "Flight Book"

In the military, visualization is crucial, and must be designed and documented to be understood by unskilled personnel. The substation HMI should be clearly described in a detailed document – a "flight book" – which will speed up the operator training and reduce operator errors.

Concerns About Computer/Software-based Visualization

As in any endeavor where new technology replaces old, new concerns crop up, a few of which are reviewed below.

Learning Curve

Learning the new symbols and navigation of a complicated HMI requires more time than learning the simpler legacy visualization. The visualization must be designed for the first responders – the troubleshooters – to get diagnostics fast without logging in or searching through pages; this reduces learning curve.

HMI Performance

Display of critical data and response to manual control actions are nearly instantaneous in legacy non-computerized systems. Computers and software add latency. In order for the substation HMI to serve as a real-time visualization tool, it, and the associated automation system, must reflect real changes in the power system within a short period of time, typically within one or two seconds. Latency longer than that may result in technicians making improper control actions. If breaker and switch control are included in the HMI, control actions must be acted upon quickly, again, within a second or two. Under circumstances where the hosting computer is periodically heavily loaded with other tasks, the performance of the HMI must not degrade to unacceptable levels.

New Failure Scenarios

A computer and software approach to visualization introduces new scenarios for loss of situational awareness and control. These include computer hardware failure, software malfunction, firmware upgrades, etc. As a result, critical HMI applications may require a backup system comprising of manual control switches and physical panel instrumentation, or redundancy, described in a following section.

Security

A powerful local substation computer with a broadband connection to the enterprise, connected to all substation IEDs, and capable of opening and closing HV breakers, is a real security concern, notably compared to a non-computerized legacy system. Unless the visualization system is isolated and performs no control, extensive security measures should be implemented. These are described in a following section.

HMI Redundancy

Comprehensive HMI redundancy can address concerns about loss of visibility and loss of control. For safety reasons, operator actions on one HMI should be replicated on the other HMI to ensure consistent awareness. When an alarm is acknowledged by an operator on the Active HMI, it should appear as acknowledged on the Standby HMI. Similarly, when a tag is placed or removed on a controllable element on the Active HMI, it should appear, or disappear from the standby HMI. These real-time operator actions must be retained through power cycles, and preferably, should be bi-directional; e.g. tags placed on the Standby HMI should appear on the Active HMI. Another key feature for HMI redundancy is the ability to test configurations prior to going live. One approach to accomplish this is to force one of the HMIs into a special "test mode".

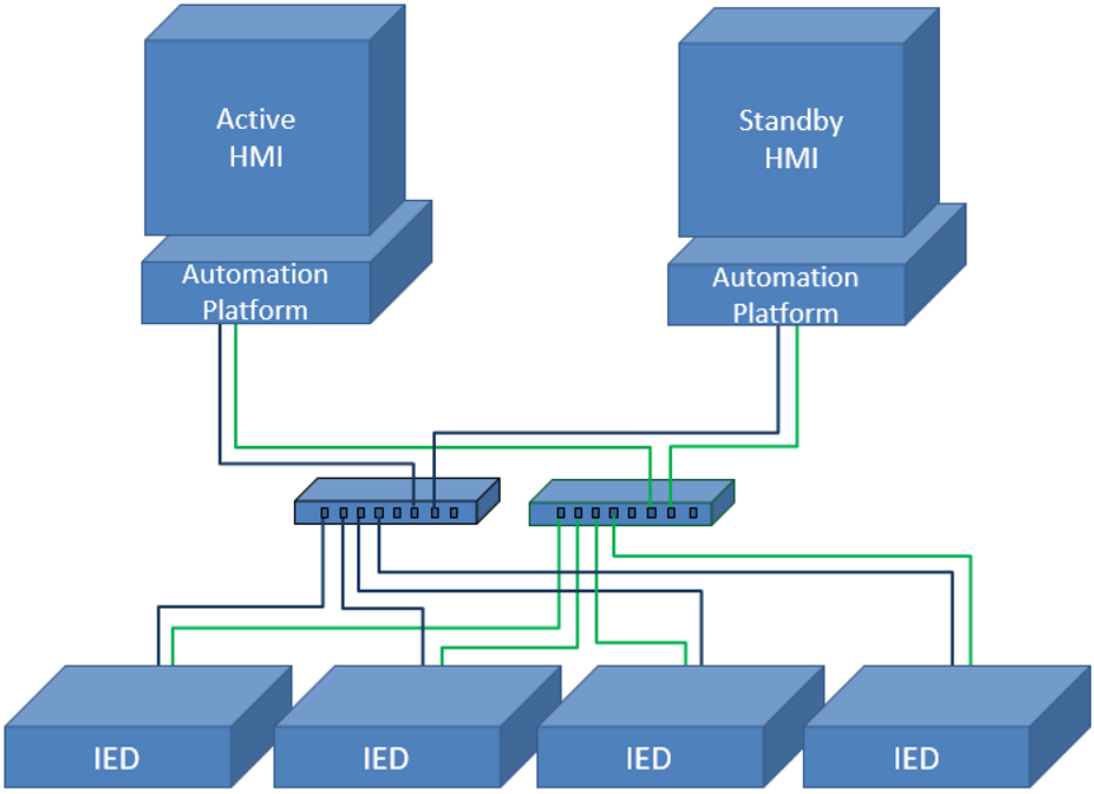


Figure 19: Substation automation application with redundant HMIs, Automation Platforms, and networking.

A redundant substation automation system with redundant HMI is shown in Figure 19 above. Any redundancy design for HMI, Automation Platform, network or IED should follow the design guidelines below as much as possible:

- The system should continue to meet performance requirements with the failure of any system component.
- A failure in the Active should not cause a failure in the Standby and vice versa
- Any failure should be automatically detected, identified, and annunciated.
- Any failure should be able to be fixed without rendering the system inoperable.
- A technician-level employee should be able to operate, maintain and repair the system
- Changes can be made to the system while continuing to meet user systems performance requirements

Visualization Security

Terms used in this section:
Malware - software that is intended to damage or disable computers and computer systems.
RSA SecurID - A two-factor authentication technology based on two factors — something you know (a password or PIN) and something you have (a cell phone app, USB stick or key card) that displays or provides a special alphanumerical code.
Phishing Scheme - Attempt by scammers to trick you into giving out personal information such as your bank account numbers, passwords and credit card numbers.

Local visualization with legacy alarm tiles, panel meters and indication lights requires only minimal security such as restriction of physical access to keep unauthorized personnel from viewing data, forcing authorized controls or vandalizing the visualization hardware. If settings are able to be made to the visualization devices, access should be restricted through at least strong passwords and other access restriction measures described below depending on substation criticality. These measures can reduce the introduction of malware or corruption of data by altering CT/PT ratios or scaling factors.

The computer-based HMI requires stringent security, notably in critical higher voltage transmission substations and where the HMI includes breaker control. This ensures that only authorized operators operate substation apparatus, acknowledge critical alarms and change settings, and that the HMI is not rendered inoperable through malicious attacks. The following is a partial list of security measures to be adopted.

- **Physical security** including locks, surveillance, intrusion sensors, etc.
- **Firewall**, the first line of defense to monitor incoming and outgoing network traffic and to allow or block specific traffic based on a defined set of security rules. In an HMI design, this would include which protocols are permitted on which physical and virtual ports, bi-directionally. Some newer firewall designs include filtering at the application level, and can block protocol commands that should not be used by the specific HMI applications.
- **IP Address Controls Lockout**, essentially a special firewall function, restricts control actions only to pre-selected IP addresses.
- **Passwords,** strong, including long length and using all keyboard characters, limited in duration, significantly different when changed, etc.
- **Multiple Factor Authentication** to ensure that local and remote HMI users need more than just a password as an access factor. Too many passwords have been compromised by bad actors using phishing schemes and other attacks. A second factor should be mandatory for access, such as something the user *possesses* (e.g. RSA SecurID, or key), or something the person *is* (fingerprint or other body signature).
- **Role-Based Access** so that HMI operators are only permitted to perform tasks consistent with their role and responsibilities. For example, a "Technician Role" may be able to view data, but not change settings; acknowledgement of a critical low gas pressure alarm may only be done by a "Manager Role"; only an "IT Admin Role" may change IP addresses or firewall settings, etc.
- **Remote Authentication,** such as LDAP or RADIUS, to enable passwords to be managed centrally, simplifying editing of roles or adding and removing of users from the system. This is important after discharging an employee for cause.
- **Second person authorization** can prevent attacks by lone actors. One technique requires a remote SCADA operator to grant HMI access to the operator, and only for a specified duration.
- **Malware prevention** using Trusted Platform Module, Secure Boot and other measures for Whitelisting
- **Open ports, when shipped, should be limited** to only those required for initial configuration access.
- **"Back Doors"** that bypass normal security measures (such as jumpers) should not be permitted.
- **Only secure protocols**, such as HTTPS, SSH, and SFTP should be permitted when accessing the HMI and viewing data.
- **Configuration Management** where a copy of the current HMI configuration may be automatically compared with the official configuration on file, and differences highlighted. Unauthorized changes can be pinpointed.
- **Syslog and access monitoring** logs all successful and unsuccessful login attempts, how the user attempted login (front port, HTTP, SSH, etc) and what the user did when attached.

Advantages and Economics

The modern software-based HMI reduces costs in the following areas of substation automation design.

Reduced Number of Boxes

A modern HMI replaces all of the following: Hosting PC or browsing PC, special computerized alarm panels, panel control switches and panel LEDs. A saving in engineering design, purchasing, wiring and panel space is associated with each replacement.

Improved Troubleshooting

Sending troubleshooters and engineers to the substation can be more efficient if they can remotely interrogate a powerful substation HMI in advance before leaving the service station.

Simplified Changes

Changes to alarm panels and mimic buses are inevitable over time, as IEDs and apparatus are added. These changes are more easily accommodated by a software-based HMI than with hard-wired systems.