

Digital Switchgear: Switchgear Moves Into The Digital World



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Introduction

Some things evolve more slowly than others in this fast paced modern world in which we live. Switchgear has historically been built in much the same way that it has been for many decades. The time has come for a new era of switchgear construction; due to advances in technology we can build switchgear to be smaller, lighter and more reliable than ever before. This is the era of Digital Switchgear.

The Digitalization of Analog Signals

Protection and measurement systems in switchgear have always relied on analog current and voltage signals from traditional instrument transformers (current transformers and potential transformers).

Traditional instrument transformers use a ferromagnetic circuit with secondary outputs that are proportional to the primary current and voltage being measured - 1 A or 5 A for current transformers and 120 VAC or 240 VAC for voltage transformers.

Digital switchgear, on the other hand, uses low power output signals from current and voltage sensors which are inherently safer for personnel.

These sensors are often referred to as non-conventional instrument transformers (NCITs) or low power passive current or voltage transformers as per IEC 61869.

These voltage and current sensors which use a different measuring approach can transmit signals greater distances without losing high accuracy levels.

These signals can be generated and transmitted without the high heating losses of traditional measurement devices. The secondary outputs for these type of sensors are in the millivolt (mV) range.

With the availability of these new current and voltage sensors, it is possible to build switchgear in a better way: using fewer materials, while being more reliable, more energy efficient and safer for operators than ever before. The time for change is now.

Control Systems

The control systems in switchgear have traditionally been based on using electromechanical devices, these electromechanical protective relays many times had high power requirements (burdens) that needed very large high accuracy current transformers in order to function properly. Today's modern microprocessor based relays have multifunction, communication, and data logging capabilities (to name a few) all with very low energy burdens requiring only a small amount of energy. This opens up brand new possibilities with respect to the current and voltage measurement devices that can be used. Microprocessor based relays that are compatible with sensors have Low Energy Analog (LEA) inputs. Most sensors can meet these new requirements in a

much smaller and less costly footprint. The main criticism of the low power sensors is that they are unable to drive multiple devices. This disadvantage can be eliminated by using Sampled Values data sharing following the IEC 61850-9-2 standard [4].

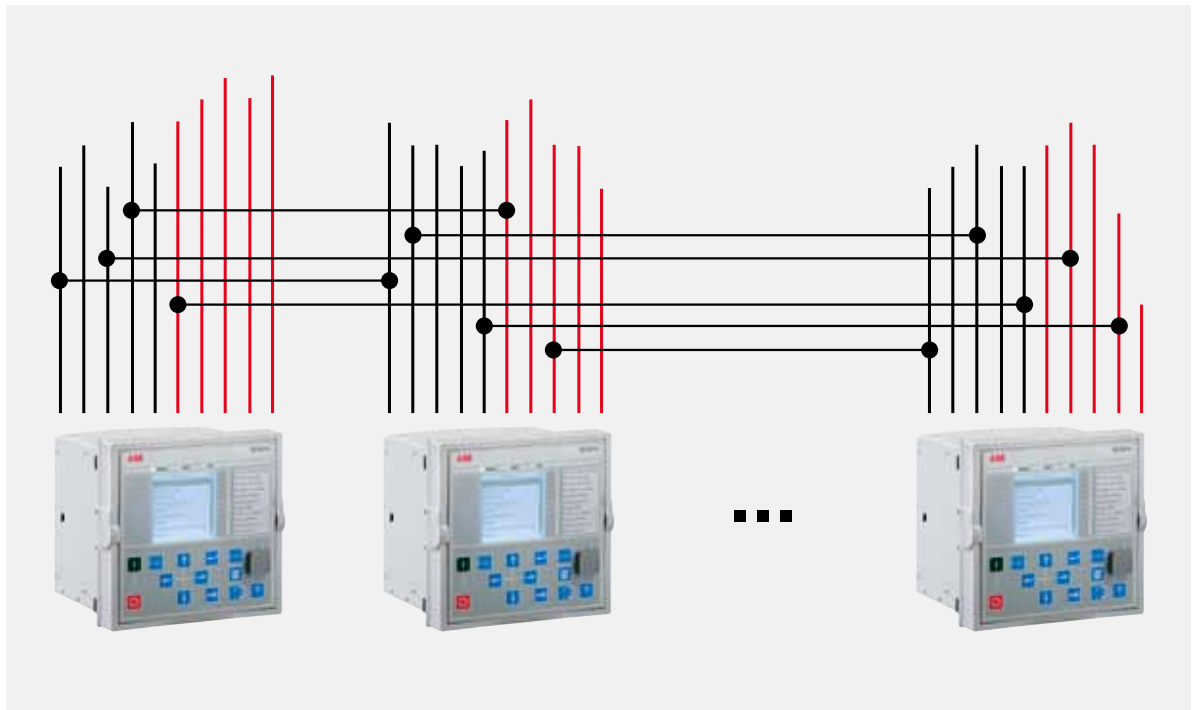
IEC 61850 Communications

Digital substations have become accepted among utilities with many installations worldwide. A natural extension of this proven technology is digital switchgear.

A main enabler for this technology is IEC 61850 process bus communications which can improve the overall system reliability. Voltage measurement has

01 Conventional
Control System
Approach

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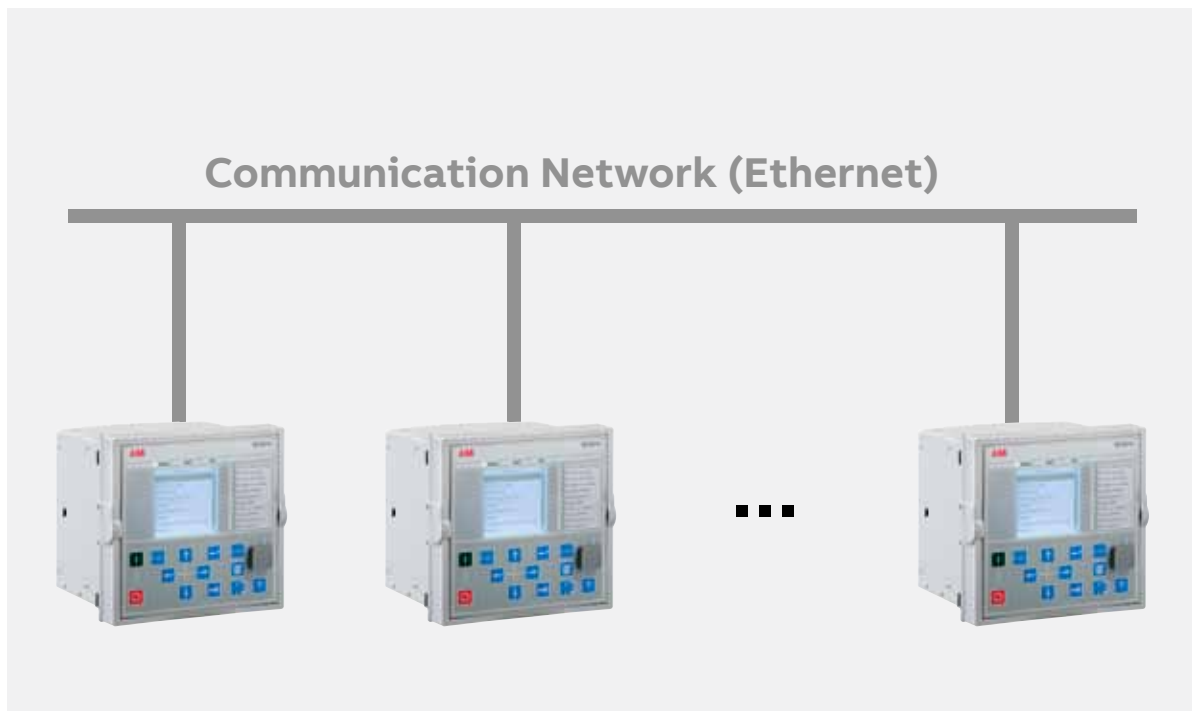


improved to the point that switchgear manufacturers can offer easily installed voltage sensors with digital outputs providing excellent accuracy, stability, and fast frequency response. By going digital, these sensors preserve signal integrity and ease of connections by using standard communications cables. This can simplify system architecture and deliver the key benefits of IEC 61850 to end users.

Customers are facing an increasing demand for equipment data and the digital switchgear architecture opens the door for this data exchange. The digital switchgear solution's key technologies: digital protective relays and digital measuring devices position IEC 61850 as a communication protocol of

great importance in the future. Wide-scale adoption of digital messaging for switchgear communication is only possible if it is based on a common standard. IEC 61850 is not just a protocol, but rather a comprehensive standard defining a communication architecture and philosophies that specify how the functionality of switchgear devices should be described, how they should communicate with each other, what they should communicate, and how fast that communication should be.

All of this is essential in achieving multi-vendor interoperability and realizing the benefits of digital switchgear [1].



Non-Conventional Instrument Transformers (NCITs)

The current sensors are based on Rogowski coils for current measurement and voltage sensors on resistive or capacitive voltage dividers for voltage measurement.

A Rogowski coil is a device used to measure alternating current. It comprises a toroidal winding where the current carrying conductor passes through the center of the toroid.

The core, therefore, is pure air versus the ferromagnetic core used in traditional current transformers.

The current measured by the sensor is output as a low level voltage signal which is proportional to the derivative of the current. The Rogowski coil has superb performance and operates linearly over a wide dynamic range, from metering to protection, and completely eliminates the main issues of traditional current transformers from the inductive open circuit as well as saturation performance during fault conditions.

Designing with redundant sensors allows two completely independent protection systems, boosting the availability of the secondary protection system. The use of communication cables not only eliminates vast amounts of copper wiring, it also increases operational safety by eliminating high power secondary signals.

Since the first non-conventional instrument transformers have been installed, their reliability track record is impressive, [2]. This demonstrates the extreme reliability of the sensors.

Every copper wire in switchgear is a potential risk, whether it is from a CT or PT circuit or a 125Vdc control circuit wire. The highly inductive current transformer secondary circuit poses the greatest safety concern.

The hazard results when an energized current transformer wire is unknowingly disconnected creating an open CT secondary, causing dangerously high voltages to build.

This is likely to cause arcing, putting field personnel at serious risk of injury or fatality and equipment is

at risk from electrical fire.

Minimizing the copper wiring and replacing it with a single RJ45 output signaling cable, with output voltages measured in mV levels, greatly improves safety.

Going digital can cut the quantity of copper wires in a switchgear by more than 80 percent, which is a substantial cost savings and, more importantly, a significant safety and reliability enhancement.

Benefits of Digital Switchgear

Digital switchgear can be made smaller and more reliable than traditional switchgear.

It has a lower life-cycle cost and is easier to maintain than traditional switchgear. It offers increased safety and is more energy efficient than its analog equivalent.

Reduced footprint, and smaller physical size for voltage sensors equates into switchgear space savings in the form of floor space.

In many cases, you can completely eliminate PT compartments, which opens up a space that can be used by a circuit breaker often resulting in reducing the overall number of switchgear frames needed for the project.

Digital current and voltage sensors can be made much smaller and lighter than conventional sensors using far less materials such as copper and steel. This smaller size can also translate into less restrictive component mounting.

As such, the elimination of dedicated PT compartments and flexibility in mounting the voltage dividers can translate into a reduction from three to two frames for Main-Tie-Main arrangements.

Reduced floor space requirements result in lower total costs for switchgear housing in PDCs, or electrical houses (E-houses), and in data centers. In existing buildings, a reduced switchgear footprint will allow for increased clearance distances or the availability to house additional equipment.

Inventory Reduction and Component Standardization

The broad application range of the sensors means the same sensors can be used in more applications resulting in an inventory reduction. The broad application range of digital sensors reduces the inventory stocking requirements and standardizes the components used. In a typical switchgear lineup rated 3000 amps, 50 kA, 15 kV, there can be as many as ten variations of voltage transformers used and hundreds of different current transformers. By using digital sensors, all of these can be replaced with only two components. Using these same few part numbers will reduce lead times and eliminate costs for expediting special components. This allows manufacturers and users to more easily accommodate changing loads.

Safety for the operator is greatly increased by not exposing maintenance personnel to dangerously high voltage levels, Rogowski coil current sensors eliminate the possibility of ever having an open current transformer secondary circuit thus eliminating a potential hazard for personnel and equipment. Using remote control and remote testing allows for increased system safety and security. Personnel safety is increased since more tests can be done without putting test personnel close to primary voltage levels. Having fewer wires to install makes switchgear easier to maintain.

Energy savings during operation of the equipment are significant because there are no core losses, which gives the user a reduction on the total cost of ownership over the lifetime of the equipment.

This translates into a huge energy savings over the full term of equipment utilization for the end user. An example of the energy savings possible in a single switchgear lineup (sample switchgear with 14 frames and 42 CTs or Sensors) can be in excess of 250,000 kWh over a 30 year period [3]. At a nominal cost of \$0.06 per kWh that is \$15,000 in energy savings and an equally large reduction in greenhouse gas emissions while also reducing power losses, lowering environmental impact, and decreasing the chance of failure due to age related stresses.

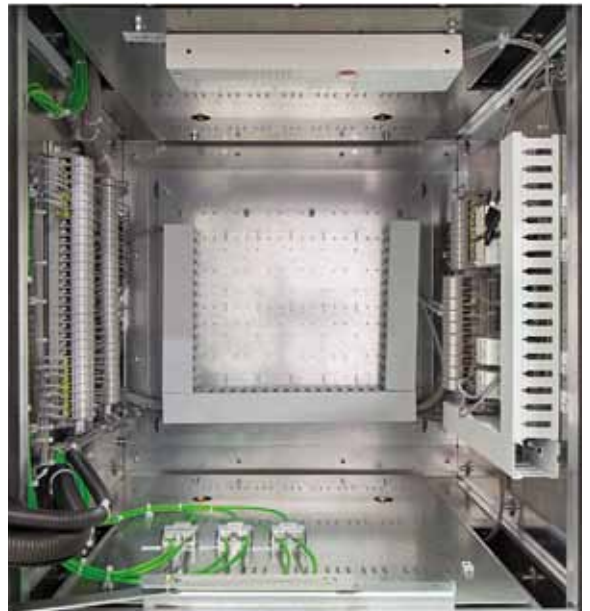
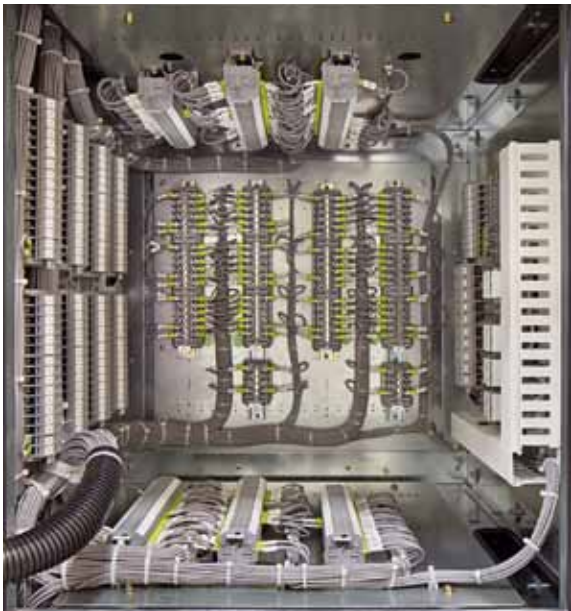
Speed, the digital switchgear concept, allows for a compression of the lead time from order to delivery and customization late in the delivery cycle is possible. Switchgear can be built earlier in the Engineering phase of the project since there is much less dependency on knowing the full details of circuit loads. CT and PT ratios do not have to be determined early in the manufacturing process. Changing loads, or changing PT configuration (i.e. Wye-Wye or Open Delta) does not mean a change in hardware. Most all changes are realized in the relay's logic.

Simplicity means there are fewer wires to install, commission and maintain. Fewer wires means there's a reduced chance for wiring errors which can use up a lot of valuable testing and commissioning time. Reducing the amount of wiring and the complexity of wiring means the overall system becomes more reliable and trouble free.

Fewer potential points of failure leads to increased reliability of the switchgear reducing outage potential and troubleshooting costs.

03 Typical wiring connections in conventional switchgear

04 Typical wiring connections in digital switchgear



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In addition to space savings from a reduction from three to two frames for Main-Tie-Main arrangements, the use of sensors makes the two frames more flexible since current and voltage sensors are not dependent on ratios/ratings.

Therefore, regardless of load variances, the same lineup can now be used for the following schemes:

- Open Transition
- Closed Transition
- Fast Transfer
- Zone Selective Interlocking

The range of measurements is improved by using the Rogowski coil current sensors, which by having no iron core, will never saturate.

The current reading maintains a linear output throughout a wider current range. Changes to load currents do not require any changes to the current sensors used as would be the case using conventional current transformers. Sustainability, universal standards such as IEC

61850, promotes trouble free future system expansions and can handle future load changes without mechanical reconfiguration of the system.

A Rogowski coil has advantages over other types of current transformers, due to its low inductance, and can respond to fast-changing currents, down to several nanoseconds.

Digital Switchgear comes to LV Equipment

With the introduction of the ABB Emax 2™ low voltage power circuit breaker with the ability to utilize the IEC 61850 communication protocol through an optional integrated communication module, the digital switchgear movement continues to make advances to include low voltage power distribution equipment.



Conclusion

The introduction of IEC 61850 in switchgear has provided a way for manufacturers to achieve the goal of interoperability. In addition to interoperability benefits, the footprint of switchgear going using NCIT sensors instead of conventional measurement transformers allows for a lower equipment cost. A massive reduction of cabling by going from many individual copper wires to a few Cat 5E type communication cables will mean reduced labor and installation costs for cables and associated equipment such as cable trenches and installation materials.

Also, accuracy and reliability improvements in low energy voltage and current sensors, and associated low energy analog (LEA) relays, provides utilities and engineering firms with a great incentive for future implementation of this technology.

Because the Rogowski coil has no iron core to saturate, it is very linear even when subjected to large currents, such as those used in electric power transmission, welding, or pulsed power applications. This linearity also enables a high current Rogowski coil to be calibrated using much smaller reference currents.

For larger currents, conventional current transformers require an increase of the number of secondary turns, in order to keep the output current constant. Therefore, a Rogowski coil for high current is significantly smaller than a conventional current transformer of an equivalent rating. Rogowski coils, open the secondary winding, increasing personnel safety.

Continuously self-supervising, through the use of digital signals and the state of the art IEC 61850 communication network provides great benefits by having a continuously self-supervising system with maximized error detection. By monitoring all component connections and detecting open circuits the system becomes intelligent, flexible and also allows for future expansions to be accomplished easily.

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