# Advancements in technology and the challenges posed to electrical testing of Protective Relays and Controls

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***Abstract* -** As newer microprocessor based protective relays eliminate wiring controls and replace them with digital logic and test equipment automation is refined and becomes more user friendly the conclusion would be that it is becoming easier to electrically test and commission protective relays and controls. This is accurate if all of the following conditions are true; the relay settings and logic are flawless, the relay testing software is perfect, and everything works as expected. Of course if this was the case then we would not need to test protective relays or controls.

## I. Introduction

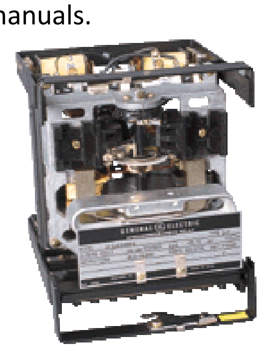
In the modern era of transmission protection relaying the power industry has made strides to automate the design, operation, and maintenance processes. The automation has been streamlined with smart devices, integrated analysis software, and remote terminals. Not so long ago the majority of the electrical systems still operated with electromagnetic devices and hard wired protection schemes. These advancements in technology demand a higher level of understanding from the engineers and engineering technicians that are tasked with the testing and commissioning of these systems.

## II. Electromagnetic Era

In the past all electrical protection, controls and associated test and commissioning equipment was based on the science of electromagnetics. This allowed for a narrow field of study to prepare an engineer and/or engineering technician for work in the field.

To understand electricity, one must have a fair knowledge of electromagnetic theory. This aspect of electricity is never going to change.

In the past, all electrical protection and control equipment were based on electromagnetic theory. Basic induction disc principle was a part of almost all relay functions in this era. Engineering technicians involved with testing of this equipment were required to know magnetic induction and electromagnetic principles. If an engineering technician understood a basic induction relay, he could fundamentally understand any of the various types of relays with a little research into the instruction manuals.



This basic principle meant that a manufacturer could only do so much to vary his designs to create an exclusive product. The result was lower competition and minute variances between relays from different manufacturers. Engineering technicians and engineers could learn one type of relay from manufacturer A and apply the concepts on a similar relay from manufacturer B with a few changes.

Most relays were single function devices. Control wiring and trip logic was depicted directly on all of the drawings to convey the entire functionality of the circuits. Engineering technicians could identify engineering mistakes made by design engineers and correct them in the field. Logic was executed using relays and control wiring in conjunction with the protective relays. For example, if the design requires a directional overcurrent unit, a directional unit contact could be connected in series with the overcurrent unit contact in the field.


Test equipment available for testing these products was again based on the electromagnetic principle with a limited number of manufacturers. This test equipment was comprised of transformers, variacs and basic circuits and was rugged and dependable.


With the advent of solid state and micro-processor technology, computer software and hardware started encroaching into the power industry. These advancements brought a tremendous number of advantages, however these advancements came with some unintended consequences.

## III. Modern Era

The evolution of technology in the last few decades has brought a significant change in electrical device protection, control, testing, and commissioning methods. The electromagnetic technology that had been a staple for over 50 years was replaced with solid state technology that briefly served as a bridge to the rapid developing microprocessor technology. These modern relays are based on digital logic and have multi-function capabilities compared to their ancestral counterparts. There are multiple manufacturers of relays with different firmware and software. It's a norm for a single relay to have all three phases in a single unit and perform multiple functions. With the advent of new technology, we can see a paradigm shift in relaying technology from electromagnetic/solid state relays to microprocessor relays.

The exponential growth in computer technology, digital processing and communication systems has its deep imprint on our power systems. This has led to a competition in virtually every sector of the power industry. We can see an increase in number of manufacturers of test equipment, protection equipment and third party testing companies. It's a common thing these days to have a particular manufacturer product being tested by a third party testing company, commissioned by a second company and maintained by a third company. There are different software and firmware versions for multiple types of test equipment. Most of this equipment is automated and has a capability of performing multiple tests. By simply pushing a button, the equipment performs a test, does all of the calculations and imports the data into a computer as a deliverable result. The advent of communication systems, such as remote terminal units (RTUs) and supervisory control and data acquisition (SCADA) has enabled the possibility of remote monitoring of equipment. Today, the entire electrical system can be remotely monitored and operated from a control room. This reduced the manpower required to monitor and operate the systems. The Human Machine Interface (HMI) has become the critical element to link the operator to the electrical system.

The modern era in power industry has brought significant increase in awareness in electrical safety, and the control and mitigation of electrical hazards. The development of technology has also increased the demand for skilled and educated professionals. A college degree and/or some elaborate vocational training in the power industry are essential to work in this field. The technological advances have changed the landscape of the educational sector. There are a lot of specialty areas in every engineering discipline. For instance, an electrical engineering degree could be obtained with specialty in communications, power, electronics etc. The rapid rise of aging workforce is starting to create a void in qualified labor [1]. The modern era is upon us with endless possibilities along with a lot of challenges to overcome.

## IV. Impact

The previous sections highlighted the challenges that technology and consumer demand has each contributed throughout the different eras. The idea of this section is to further support the cause that the engineers and engineering technicians must be more dynamic in their skills and knowledge in order to successfully and safely implement design into fully operational electrical systems.

The growth of technology has far surpassed the growth of education of the field personnel. The relay panels once used to be a wall of glass covers and an even more impressive nest of control wiring. The same relay panel today is a single black box with equally simplified control wiring. The once simple protective device designed to protect a single device must now be multi-functional and able to protect, compare, and communicate the fault with other systems. The industry has been a victim to loss of intellectual capital as the number of experienced personnel retiring and leaving the workforce has greatly increased in the past decade or two. This in return creates opportunities for newer generations that must be able to pick up the slack in knowledge of new and old technology. With each era of technology, a combination of free trade and the improvement of the semiconductor fabrication there is more competition in manufacturing of electrical power equipment.

The impact of technology outpacing qualified field personnel is none more evident in the commissioning realm. Here the engineers and engineering technicians must be able to conceptualize the designed protection, turn the design into practical installation through digital logic settings, and then functionally replicate fault scenarios to verify correct responses in the system. The reduction in control wiring as briefly mentioned before is a result of the new black box devices that internally are made of hundreds of digital logic control schemes; thus reducing the need for single function protective devices.

As personnel aim to replicate intended protection schemes in the field the digital logic inputs and outputs must be evaluated for desired operation. Each protective device manufacturer has a proprietary software that only communicates with their product so when the personnel is troubleshooting inputs, outputs, and trip logics they must be familiar with each manufacturer's code source, syntax, and HMI display in order to correctly demonstrate desired operation.

An additional impact to engineers and engineering technicians is the wide ranging test equipment. Just as protective devices have progressed with technology so have the test equipment that used to confirm the protective devices are properly working. To build on the idea that today's projects are more streamline and fast paced, software companies have built automated test routines for common protective devices. Now the field personnel must interface brand "A" personal computer to a high performance piece of brand "B" test equipment, then successfully communicate with brand "C" protective device in order to upload the setting program files generated by an engineer elsewhere so that brand "D" automated testing software can run the test routine in order to simulate the fault scenarios required to operate the protective device. If and when this sequence breaks down the field personnel must have the experience and knowledge to quickly identify the break down and remediate the error. This person must be able to repeat every step at the next jobsite with a completely different brand of protective devices.

In an effort to reduce the common failures in commissioning associated with protective and control devices, administrative controls are implemented such as method of procedures (MOP). MOP's are developed to document each inspection element of the commissioning process. The documentation is beneficial when the actions can be mass produced across identical systems and designs but when any of the characteristics of the design or system do not match, then education, knowledge, and experience must account for the errors and omissions.

The next section will bring the reader into the decision making process that is proposed to companies and individuals both to bridge the gap that the loss of intellectual capital and the rapid advancements of technology has left.

## V. Bridging the Gap

There seems to be a trend that we need less knowledge and education to perform this critical function since the automation does most of the process and analysis. There can be nothing further from the truth. We have moved away from the single component test. The engineer and engineering technician performing these critical function tests in today's era must be better educated and have a sound understanding of both power and computer science. The critical issue is where we are going to find these qualified people in the power industry.

We can focus at the higher education system. The colleges and universities that are Accreditation Board for Engineering and Technology (ABET) accredited who have taken the role of developing the engineers of the future are a key step but is just the first step. The higher education system is limited by the society idea of getting a degree within 4 years. The electrical power equipment that was available decades ago is still around today and still is in use today. These colleges and universities still have to teach the basic principles of how the power system and their components are designed and function. In addition to the basic power, the engineers of today most now know computer programming, communication systems, security protocols, logic, and much more. Due to the technological advancement, todays colleges are able to teach students quicker and provide more information, but are unable to keep up with the overall technology advancement within the power industry.

We can look at the design and testing companies. The people hired as engineers and engineering technician's right out of school might believe that they are ready to jump right into complex projects and make major contributions to projects, but companies know this is far from reality. Their journey is just beginning. No matter the education level, the bandwidth that these new employees have is quite narrow. Companies must invest in training their employees by both classroom and hands-on training. They must gain experience from working with more experienced seasoned engineers and engineering technicians. This training does come at a cost, both to the company and the company that use their services. Instead of having application engineers to ensure that their component is working properly, the demand for reliability requires us to ensure that the system works. Automated test plans and procedures are great as long as everything test satisfactorily. The testing engineers and engineering technicians must have the knowledge of how to fix the system when it fails. They must be able to retain this ability whether they have tested similar equipment last week, last month, or last year.

In addition the problem of educating our engineers and engineering technicians better, it is compounded by the issue of aging workforce and the inability to replace that knowledge and experience. In 2011 the average age of someone working in the power engineering field was 46.1 as compared to the average age of a U.S citizen of 37. [2]. It is estimated by 2020 that over 60% of this workforce will retire or leave on other grounds. [2] We have increased the amount of knowledge and education requirements to work on these systems, yet have lost ground on the ability to replace the experience and expertise. This continues to be a problem in our industry and is a constant area of concern for anyone involved in the field of power engineering.

There are some tools we can implement to help in bridging these gaps that have occurred. First, logic drawings which include detailed application specific logic integrated with the internal pre-developed logic from the manufacturers. We can place more detail in our coordination studies to include better explanations of protection philosophy, IEC 61850 details, and telemetry and communications details

Finally the most difficult aspect would be to standardize the use and management of firmware and software as well as minimal design and engineering deliverable requirements. These ideas are just those, ideas they may be adequate they may not be. What is true is that we need to recognize what is happening and start trying to come up with solutions.

## Conclusions

As engineers you can design complex equipment, complex systems, and complex processes. In the course of executing these designs we will by human nature make multiple mistakes and errors. We will turn these designs over to construction companies, who will in turn add to the engineering, mistakes of their own. We will purchase equipment produced by manufacturers with errors and mistakes and use test equipment manufactured with errors and mistakes but in the end someone has to make sure that when the switch is turned on there is zero mistakes. Who will that be?

**Citations:**

[1] Grice, Amy, Jackie M. Peer, and Greg T. Morris. "Today's Aging Workforce-Who Will Fill Their Shoes?" 1-9.Web

[2] Detwiler, Peter. "Want A Secure And High Paying Job? Get Into Power Engineering" Forbes / Energy. Web