NEW TECHNOLOGIES: THE REVOLUTION IN SUBSTATION CONTROL AND PROTECTION

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INTRODUCTION

The utility industry is not exactly one of the most progressive parts of our modern industrial society. Change takes place-but only slowly. We all know of the profound reluctance to change anything that has been the same for 30-40 years. Especially, when that way has been successful and is something with which everyone is comfortable. But, radical changes are coming in the way in which substations are designed. Computers which now affect nearly all aspects of our lives will revolutionize the design of substations in the near future. Other technologies will also effect how substations are designed, optical sensors and fiberoptics for example. The technologies we are discussing are already being applied at BPA, but not widely. For example, you will find fiberoptics and digital communications in use at Celilo and on series capacitors.

SUBSTATION CONTROL AND PROTECTION

Since the beginning of time (about 1937) we here at BPA have designed substations with lots and lots of individual components. We don't use sheets of marble for mounting relays and meters anymore. But, much of our technology hasn't progressed very far since the time when a stone mason was required to change a relay or a meter. Substation control rooms are full of the familiar black projection mount cases containing electromechanical relays. When electronic relays are used, they still are things unto themselves. We still use discrete systems for practically each function that needs to be performed. Often, especially in the case of protective relays, the components are duplicated or triplicated in order to meet the needs of reliability and availablilty.

OUTDOOR EQUIPMENT

All of the redundant protections and controls connect to the single circuit breaker. Circuit breakers have been very complex mechanical devices, especially at EHV levels. Recent technical advances have greatly reduced the mechanical complexity and improved the reliability of circuit breakers. But, the breaker's control circuitry has not changed significantly in 40 years. The controls still depend on electomechanical relays to perform elementary control and logic functions. The relays are available from fewer sources as demand for these old technologies decreases. This makes them expensive and difficult to find with proper performance characteristics.

International reliability surveys have shown that 20% of all major and 13% of all minor circuit breaker failures are caused by failures in the breaker's control system. This number has remained unchanged in the newest generation of circuit breakers as the breaker control technology has also remained unchanged.

Current transformers (CT's) involve a complex insulation structure, either oil-paper or SF6 gas. The technology employed in oil current transformers has been proven by time, but factors of design and quality control become critical at EHV levels. Gas CT technology is now available, but gas CT's must be built in clean room conditions because of particle or moisture contamination.

INDOOR EQUIPMENT

If we look at the discrete systems found in most substations:

- Protective relaying and transfer trip
- Alarming and overload monitoring
- Sequence of events and data logging
- Fault location
- Fault recording
- SCADA
- Operator control and status display
- Revenue metering

We find that most of these systems use the same inputs. PT and CT signals and circuit breaker status are routed from box to box at great expense. Lots of discrete devices depend on data that could be collected once and then shared over a data bus. Current signals are probably the biggest problem since they present a considerable personnel hazard. Heavy cables, needed to handle the high level PT and CT signals are not only expensive, difficult to install, and modify but are also susceptable to interference.

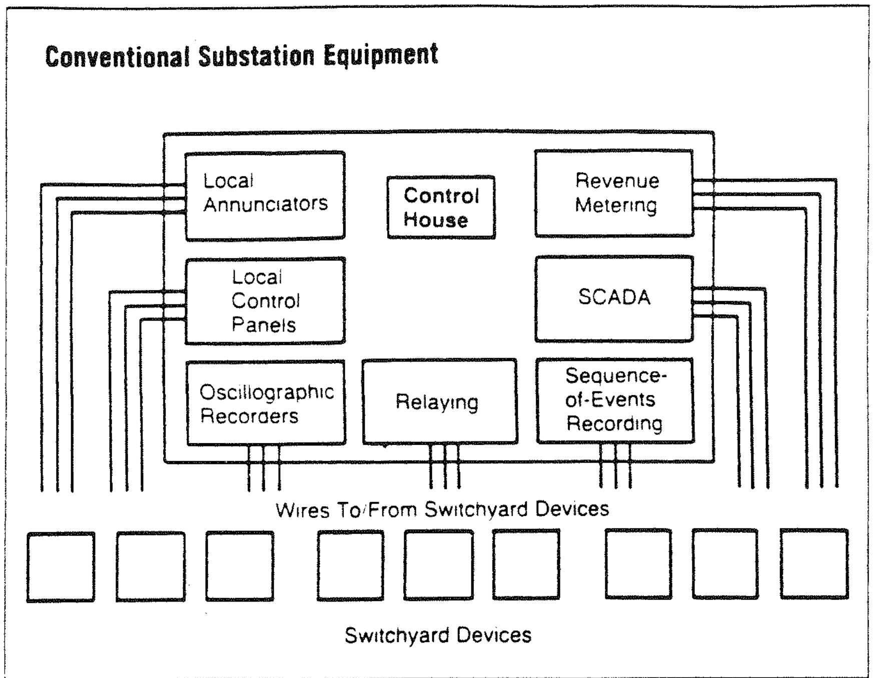

Fig. 1. Conventional substation design.

All of these systems often take a lot of maintenance. For example, relays need to have their calibration verified, usually on a 2 to 3 year cycle. Even then, there is no way of knowing if the relay has failed until it misoperates or fails to operate.

NEW TECHNOLOGIES FOR SUBSTATIONS

Most of BPA's engineers are familiar with the new technologies that will affect the future of substation controls and protection. Optical fibers, computers, and digital communications are not exactly new items. The big changes lie in how these technologies are being applied, specifically how they will be integrated into one system. Systems that have been designed using relay logic will be replaced with electronics. Discrete functions will be merged into a single integrated control and protection system based on optical data transmission. The trays full of heavy cables will be replaced by a few optical fibers and a few power cables. See Figure 2.

A number of options in high voltage current measurement exist. There are presently a number of devices under test on power systems around the world. These include devices which employ shunts and digital electronics and devices which employ the Faraday Effect sensing current by the varying polarization which light passing through glass ring experiences due to a magnetic field. All these systems use fiberoptics to transmit the signals to ground potential and provide low level signals. BPA has experience in fiberoptic systems. They are used for field testing, on series capacitors, and at Celilo. They have proven rugged and reliable after the normal growing pains.

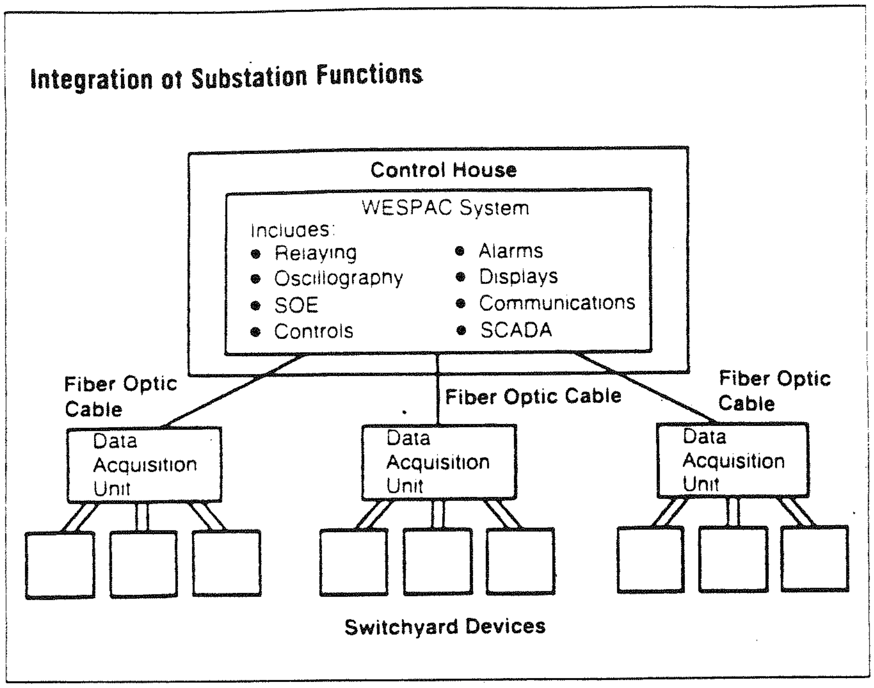

Fig. 2. Integrated substation design.

Developments that are now becoming realities really started in the early 1970's when BPA started working on multiplexing signals in a substation switchyard. Multiplexed data communications has been used extensively by ASEA Brown Boveri in the HVDC Expansion Project. ABB has a system they refer to as P13 that communicates within the Celilo station by way of coaxial cable. When an operator at Celilo orders the closing of a disconnect switch, what he in reality is doing is sending a digital message over the interplant bus to a building out in the switchyard where the message causes a relay to close and operate the disconnect.

Digital relays have been around for some years. The relays that are being developed now do lots more than trip for faults. The relay being tested by GE (developed under EPRI sponsorship) includes fault location, sequence of events, fault recording, remote setting, and makes toast. Well not quite.

EPRI has had a ten year program to develop integrated substation control and protection. Both Westinghouse and GE have participated in the design and development of integrated systems that provide a wide range of functions. Both have been installed at various locations throughout the country for evaluation. Deans substation at Public Service Electric and Gas in New Jersey has both the GE and Westinghouse equipment installed on a common communication bus.

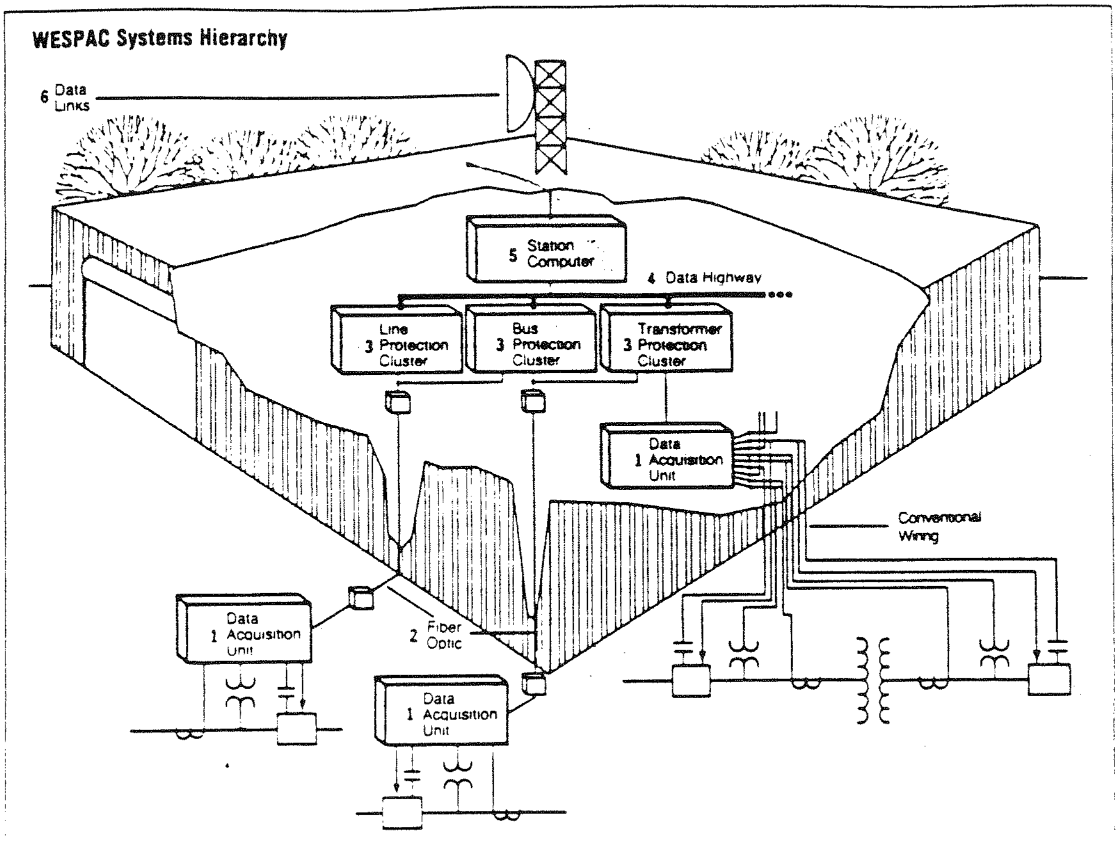

Figure 3. Westinghouse integrated protection and control system.

One of the important accomplishments of the EPRI development is the specification for interplant communications. Equipment based on the EPRI specification can be expected to work together independent of the manufacturer. The data highway concept is simply a local area network for a substation that permits sharing of data throughout the station to serve a variety of functions. Extensive use of optical fiber digital communications makes it unnecessary to run PT and CT circuits throughout the switchyard and control house.

A number of projects are underway in the industry to employ microcomputers to monitor the condition of outdoor substation equipment. The status of the circuit breaker is critical as all the redundancy in the protection circuitry is lost at the circuit breaker. Also, circuit breakers are manufactured indoors in clean room conditions. Industry data has demonstrated a higher failure rate after maintenance. Reducing unnecessary maintenance will go a long way in improving circuit breaker reliability.

TABLE 1. FEATURES OF THE HIGH TECHNOLOGY SUBSTATION

Optical current measurement	The simple insulation structure will make the high voltage portion of the CT very reliable. Saturation problems are avoided. Low level signals, potentially low cost.
Fiberoptics	EMI resistant. Free from cable damage due to high magnitude fault currents. Signal multiplexing possible. Reduction in wiring and cabling costs.
Solid state breaker controls	High reliability and low maintenance.
Self diagnostic systems	Prediction of failures in many cases, reduced maintenance, increased reliability.
Digital communications	Elimination of wiring, cost reduction, reliability improvement.
Self diagnostic systems	Improved reliability, reduced maintenance.
Adaptive relays and controls	Automatic resetting of relays for changes in system conditions, preprogrammed operation for certain failures or conditions.
Enhanced SCADA control	Increased information available to SCADA operators, increased control capability. Diagnostics for outdoor and indoor equipment possible from remote locations.
Enhanced data logging and analysis	System and equipment performance can be logged and analyzed.

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THE BPA ADVANCED BREAKER CONTROL PROJECT

Optical current measurement, digital relaying, fiberoptic communications, and integrated control and protection are realities. These technologies are ready now. Several manufacturers have commercially available products that BPA needs to evaluate. In order to gain some experience with these products, we are in the early stages of a demonstration project. Initially, this project will consist of a single circuit breaker position with associated controls and protections. Keeler, Pearl and Allston are the sites presently being considered.

A project steering committee has been formed and tasked to develop specific plans for the demonstration project.. The committee has representatives from System Planning, Electrical and Electronic Engineering, Maintenance, Operations, and the Lower Columbia Area. The project will include the following features:

- Optical current measurement
- Use of low level signals for measurement and control
- Electronic breaker controls
- Optical fiber data communication
- Integration of all "standard" protection and control functions into one system
- Interconnection with existing protection equipment requiring high level signals
- Expert systems to monitor high voltage equipment performance

It should be stressed that these technologies are not "new". Our world is run by them. The Advanced Breaker Control project is not research, but design development. Look at the equipment:

<u>Optical CT's</u>

Considered a commercial option by TVA after 5 years of testing the Westinghouse device.

ABB is offering solid state CT's for series capacitors.

Square D is offering an optical CT

<u>Solid State Breaker Controls</u>

Not yet developed, by a simple application for an industrial controller

Fiberoptics

Applications at Celilo, Ross and Big Eddy, series capacitors, testing, commercial telephones

Digital and solid state relays

Wide spread application, but will have to be modified to accept low level signals.

Control interface by digital bus

Celilo controls, system testing equipment, EPRI project

AREAS FOR DEVELOPMENT

Although all the technology is available, some specific areas need additional development. These include:

- Presently no digital relays are available for series-compensated lines
- Redundancy concepts for integrated control and protection systems are not well developed
- Integration with existing equipment is a problem because of the mixing high and low level signals.
- Solid state circuit breaker controls are not commercially available

ISSUES

The BPA advanced breaker control project will need to address some important issues. We see the following areas as being of particular importance to the success of advanced control and protection:

INTEGRATION	How will the intelligence be distributed? Relays could be part of the circuit breaker, standalone, or part of master computer.
REMOTE DATA	What level of information is required remotely?
REDUNDANCY	Any and all systems fail. In order to improve reliability redundancy is usually employed. Utility engineers have established practises of installing redundancy in power system protection and design. Excessive redundancy adversely effects reliability.

OBSOLESCENCE	Computers are a fast paced technology. Ten year old state of the art equipment is not even maintainable today. This issue will have to be planned for in the design of a state of the art system. It cannot be hardware dependent.
STANDARDS	Integration of many functions into a single control system cannot be used to hold utilities captive to a single manufacturer. Standards for interconnection of different manufacturer's products will be very important. Utilities needs to guide the standards not the manufacturers.

CONCLUSIONS

The utility industry has not taken advantage of the new technologies developed in the past decade. BPA has applied these technologies for applications where integration was not a strong issue, and where the technology was required or was the lowest cost. These technologies are not easily incorporated with existing substation technology in a piecemeal fashion. To take full advantage the substation must be designed with this technology from the ground up. There can be no doubt that these technologies will be applied in substations.

Changes are coming. We can lead or we can follow, but we cannot deny the inevitability of technological progress.