The 2008 Revision of IEEE C37.2 Standard Electrical Power System Device Function Numbers, Acronyms and Contact Designations

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Introduction and History

IEEE C37.2 is probably the oldest IEEE standard still in regular use. It was first published in 1928 as AIEE No. 26, and provided a language to describe "automatic substations" as well as other applications. These "automatic substations" were self contained unattended rotary converter stations (ac to dc) to provide 600 volts dc for street cars, subways, and interurban rail transit. They had multiple (two, three, even four) rotary converters that would be brought on or off line as the load changed. This automatic sequencing included starting the rotary converters at partial voltage to reduce inrush, then changing to full voltage when the converter reached full running speed.

In order to describe these control systems on elementary diagrams, a set of device numbers and contact designations were standardized in AIEE No. 26. That original 1928 version had many device numbers that are still in use today:

- 27 – undervoltage relay,
- 40 – field relay,
- 49 – machine or transformer thermal relay,
- 50 – overcurrent relay,
- 51 – ac time overcurrent relay,
- 52 – circuit breaker,
- 72 – circuit breaker,
- 79 – ac reclosing relay.

There were others not so familiar to most of today's audiences:

- 1 – master element,
- 7 – rate of change relay,
- 10 – unit sequence switch,
- 19 – starting to running transition contactor,
- 22 – equalizing circuit breaker,

- 82 – dc load measuring reclosing relay (would not reclose on faults, but would on overloads!).

Not surprisingly, not all the numbers 1 through 99 were defined in the 1928 edition. For example, 16 was labeled “not used (reserved for future applications)” and 95-99 were labeled “used only in specific applications if none of the functions 1 through 95 are suitable”. Other device number definitions were added over time, as needs arose. For example, device 24 – volts per hertz relay was added in 1962 to cover this brand new function – a relay that was developed to provide protection against transformer overexcitation. Generator step up unit (GSU) transformers had failed on overexcitation heating (excessive volts per hertz) when utilities had started to apply field current to unit connected generator/transformers without taking the generator voltage regulator out of service at the very early stages of unit startup when the frequency was still a fraction of 60 Hz.

The standard has undergone numerous revisions -in 1937, 1945, 1956, 1962 and 1979 - but these have been relatively few considering the eighty year time span. In 1987, Device 11 – Multifunction device was added (three or more functions in one device). The handling of two functions had always been defined – as 50/51 for example – but not more than two.

There were major changes in 1996. Two methods were added for defining the contents of a multifunction 11 – the “empty box” and the “filled box” methods. Frankly, neither worked particularly well, as the empty box method conveyed hardly any information, while the filled box method was too cumbersome to use. That revision did add eight examples for the proper use of the suffixes “N” and “G” in ground detector relay applications. Then in 2001, IEEE C37.2 was reaffirmed with no changes.

Latest Revision

At an IEEE Power System Relaying Committee (PSRC) meeting in 2006, John Tengdin (the Substations Committee liaison to PSRC) made the infamous observation that “Nothing has changed, so we plan to reaffirm C37.2”. Fortunately, IEC 61850 expert Alex Apostolov spoke up and suggested that at least the WG should add a cross reference table between C37.2 device numbers and IEC 61850 Logical Nodes. IEC 61850 does show a cross reference table from Logical Nodes to C37.2 device numbers (Alex and John had seen to that during its early stages of IEC 61850 development) but the reverse did not exist. Then Eric Udren pointed out that there was no way in C37.2 to describe and document the communications network in a substation (whether Ethernet or serial RS-232/485). He proposed that Device 16 be used, as it was then labeled ”Reserved for future use” in the then-existing C37.2. So a Joint Working Group was formed – C5 in Substations Committee and I14 in PSRC plus corresponding members from the IEEE Industry Applications Society (IAS) and the IEEE Rail Transit Standards Subcommittee.

The proposal for Device 16 was to use it as a label for a Communication Networking Device with a unique set of suffixes - applicable only to Device 16. The first suffix letter is to be either S for serial devices or E for Ethernet devices. The subsequent suffix letters are used to more completely describe the device – with multiple suffix letters allowed:

- C – Security processing function (VPN, encryption, etc.)
- F – Firewall or message filter function
- M – Network managed function (e.g., configured via SNMP)
- R – Router
- S – Switch (Examples: port switch on a dial up connection is 16SS, an Ethernet switch is 16ES)
- T – Telephone component (Example: auto answer modem)

An example combination is 16ERFCM - an Ethernet router with firewall and VPN capability, which can be remotely managed via the connected network.

These example diagrams appear in IEEE C37.2-2008 and show the use of the suffix letters:

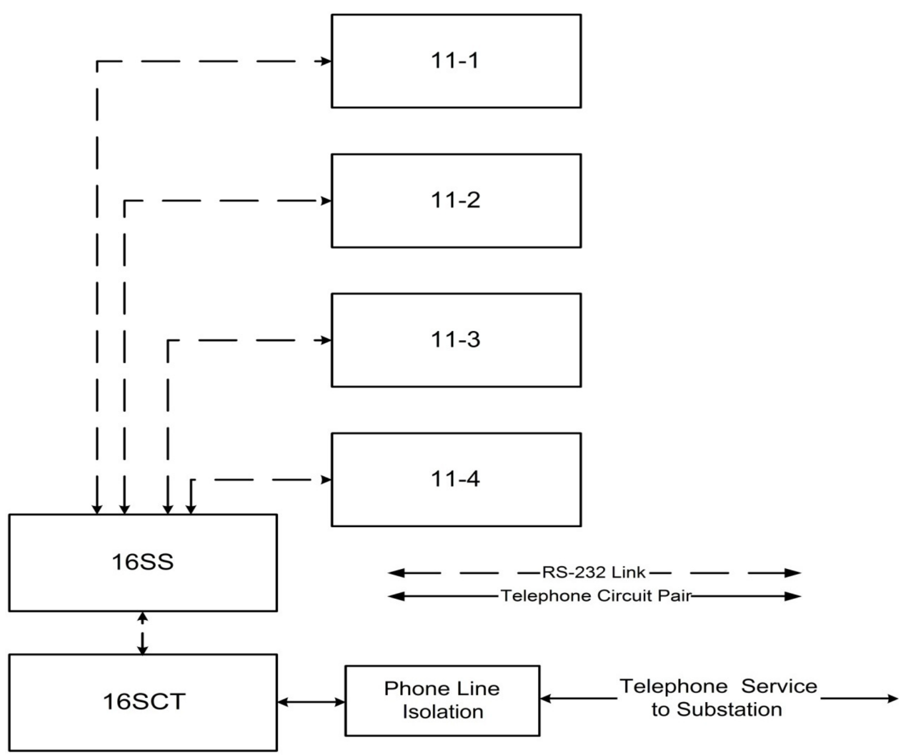


Figure 1 - Protective Relays with Serial Communications Devices 16

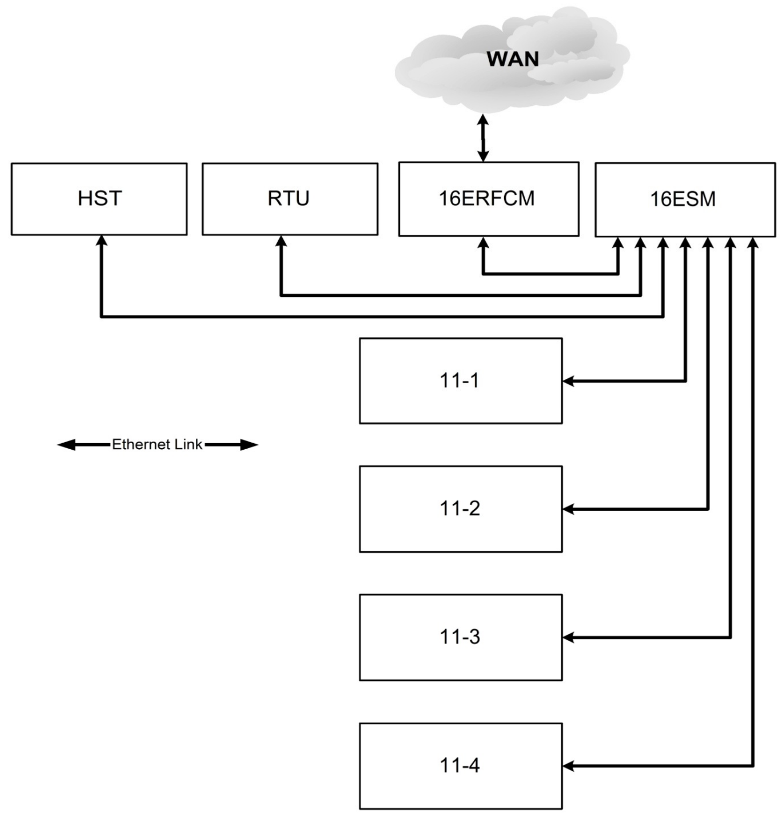


Figure 2 - Protective Relays with Ethernet Communications Devices 16

Some utilities are investigating or using IEC 61850 Part 6 - Substation Configuration Language applications. Typically, the engineer uses a configuration tool to describe the substation topology, the functions to be performed on the substation equipment, and to import device description data on individual relays and IEDs to be used. Relay and IED vendors supply descriptive data in the XML format described in 61850-6. The software tool, in turn, compiles the device and substation data to generate configuration files (SCD files) for transfer into the relays and IEDs via individual vendor software tools. This process is designed to save the engineer from the effort of mapping individual elements of information among the substation devices.

IEC 61850 object modeling focuses on the logical (not physical) devices and connections. The substation configuration language of Part 6 does not show switches, firewalls, or network management. Since redundant paths are identical from a logical node or client server object exchange standpoint, redundancy of communications is not part of the 61850-6 configured solution. But as Figure 3 shows, those networking devices can be separately described using C37.2 Device 16 with its suffixes. Meanwhile, the IEC TC 57 WG 10 that developed all of 61850 is working on Edition 2, which is now looking at requirements and strategies for redundancy to achieve reliability of the network-based protection and control system.

Figure 3 shows an example of C37.2 device number use in a dual redundant Ethernet relaying configuration, with no single point of failure from a protective relaying perspective. It shows all the physical connections and paths. A figure like this is required for design and installation of hardware, and may be required to document redundancy according to forthcoming NERC reliability standards if the network is used for protection-critical functions like IEC 61850 GOOSE messaging for fault tripping.

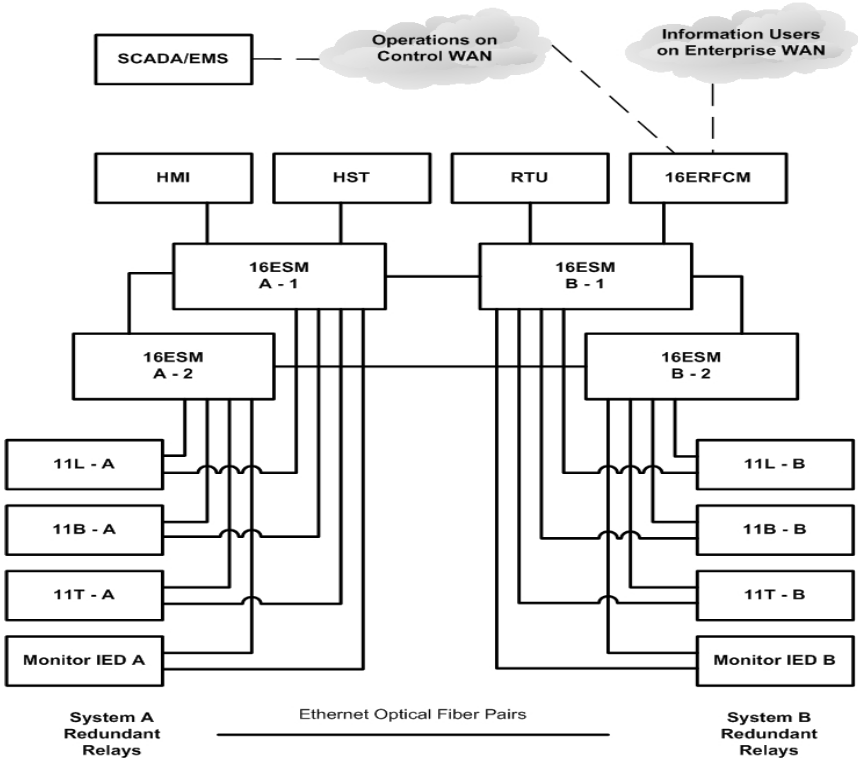


Figure 3 – Redundant Ethernet Communications Network for Substation Protection and Control

Acronyms

There are still more new functions in the new C37.2 Standard, defined not by function numbers but by acronyms. During the early stages of the revision effort, the PSRC - SC Joint Working Group explored the possibility of retiring and reusing some of the old, old function numbers. An e-mail survey, conducted for the working group by IEEE Strategic Planning Services, showed these old function numbers were still in use. So the WG decided to use acronyms for the additional functions. The first suggestion was to define within C37.2 a number of acronyms that were already in regular use. These were:

- DFR - Digital Fault Recorder
- HMI - Human Machine Interface
- PMU - Phasor Measurement Unit

- RTU - Remote Terminal Unit
- SER - Sequence of Events Recorder.

As the work continued, the WG ultimately added twelve more acronyms for new functions not previously defined in C37.2, for a total of seventeen. Note that these are functions that may reside in a single function device, or as one of several in a Device 11 multifunction device.

Here are all of the familiar and new acronyms with descriptions that appear in C37.2-2008. *Notes in italics give information not appearing in C37.2 itself*:

- AFD – arc flash detector - A device / function that detects an unintentional electrical arc in air. *(Arc flash detection in metal clad switchgear has been a frequently discussed topic at the present conference in recent years. AFD is the sensing function that may be a part of a Device 11 multifunction protective relay for a zone within the switchgear.)*
- CLK – clock or timing source - A device/function that receives an accurate timing signal input and distributes an accurate timing signal output to other devices. Note: An example of an accurate timing signal input is a signal received from a GPS (Global Positioning System) satellite clock. An example of an accurate timing output signal is IRIG-B (Inter-Range Instrumentation Group Type B).
- DDR – dynamic disturbance recorder - A device/function that records incidents that portray power system behavior during low frequency (0.1 to 3 Hz) oscillations, and abnormal frequency or voltage excursions. *(Definition from the Southeast Electric Reliability Council.)*
- DFR – digital fault recorder - A device/function that records, for analysis purposes, events on the power system. It records voltage and/or current waveforms replicating the primary power system voltages and currents when triggered by a sudden change in the waveforms or by an external event.
- ENV – environmental data - A device/function that measures and stores variables relating to the environment, such as weather data, ice buildup conditions, geomagnetic disturbances, earthquakes, and other similar phenomena.
- HIZ – high impedance fault detector - A device / function that detects high impedance faults on grounded or ungrounded systems.
- HMI –human machine interface - A device/function that displays data/information to and allows control of a system by an operator. A HMI may also be local to a specific device for operator interaction specific to that device.
- HST – historian - A device/function that continuously gathers states and values from a data concentrator or directly from protection and control IEDs (Intelligent Electronic Devices), and may also act as a recorder of data from which trends may be determined.
- LGC – scheme logic (*the function, as in a RAS– not a device like a PLC*) – A device/function that provides the programmed logic for a multi-device control/protective relay scheme, such as a Remedial Action Scheme (RAS) or an interlocking scheme.

- MET – substation metering - A device/function that is connected to CTs and VTs, and may calculate and store one or several of the following quantities - watts, VARs, amps, volts, power factor, demand, energy.
- PDC – phasor data concentrator - A device/function that collects phasor and discrete event data from PMUs (and from other PDCs) and transmits the data to other destinations. PDCs may buffer data for a short time period, but do not store the data.
- PMU – phasor measurement unit - A device/function that samples voltage and current with very accurate time stamps and calculates phase angles vs. a GPS time reference (synchrophasors).
- PQM – power quality monitor - A device/function that monitors electrical parameters used in power quality measurements. Parameters include (but are not limited to) RMS variations, frequency variations, unbalance, transients, harmonics, and inter-harmonics. The storage of historical values of these measurements may also be performed.
- RIO - remote input/output device - A device/function interfacing between the power system process (analog or digital) and the substation automation system that serves as a substation data repository of control and protection system information, but without connection to a SCADA master station.
- RTU – remote terminal unit / data concentrator - A device/function that serves as the primary interface (the data concentrator function) between a protection and control system and a SCADA system to provide operational data visibility to, and perform command operations from the SCADA control center.
- SER – sequence of events recorder - A device/function that records events (changes of state of equipment or functions) with a time reference (commonly from a GPS or IRIG-B receiver).
- TCM - trip circuit monitor - A device / function that monitors an associated circuit breaker's trip circuit for continuity and for the presence of tripping voltage, and sets an externally readable alarm when continuity or tripping voltage is lost (a surrogate for the traditional red light on relay and control panels).

The new acronym TCM deserves some special attention. For over 50 years, it has been a recommended wiring practice on circuit breaker trip circuits to connect the red panel indication light (illuminated when the breaker is closed) in series with the circuit breaker's trip coil. Thus the illuminated red light not only showed the breaker was closed, but it also showed that there was a tripping voltage source available and that there was continuity through the breaker trip coil and the 52a contacts (that interrupt the trip coil current after the breaker opens). This wiring practice started in the days of electromechanical relays whose tripping contacts were designed to <u>carry</u> (but not interrupt) trip coil current until the breaker opened. The breaker 52a contact would open at the end of the opening cycle and was designed to interrupt this highly inductive circuit. Note that 52 was defined in the original 1928 version – an auxiliary contact on an ac circuit breaker (Device 52) that is closed when the circuit breaker is in the closed position.

Some utilities connected a light to show the breaker closed position by the position of a separate

52a contact - generally not one in series with the trip coil. As substation automation came into use, utilities connected separate 52a and 52b contacts to the RTU to indicate breaker position remotely. In an unattended automated station, there is usually no one near the control panel to look the indicating lights. There was no remote indication of trip circuit continuity or the presence of tripping voltage on that trip circuit.

If the TCM function is installed, it provides an alarm contact connected to an RTU that indicates the trip circuit integrity of a closed breaker to a remote HMI, just as the traditional red light function indicates trip circuit condition at the substation. There are stand-alone TCM products available. Recent generations of microprocessor relays also include TCM, and can alarm for a trip circuit problem via an alarm contact or by a data communications message from the communications port or over an Ethernet network to substation concentrators and remote operations or maintenance centers. Condition monitoring of trip circuits via a TCM function will be an essential part of a condition based maintenance program that extends relay maintenance intervals while remaining compliant with new forthcoming NERC Protection System Maintenance standards

More Additions to the Standard

Breaker control circuit wiring - The 2008 update of C37.2 includes, as Figure 4 of the Standard, the same dc elementary diagram that was in the previous versions, and shows independent (separate) fusing for circuit breaker trip and close circuits. It does show the red light in series with the trip coil. One of the balloters of the 2008 update of C37.2 observed that the Power Systems Relaying Committee had published a working group report titled “Relay Trip Circuit Design”. That report included a diagram with this independent fusing, and also one with “coordinated trip and close fusing”. With coordinated fusing, the close circuit fuse is downstream of the trip fuse, so that a breaker cannot be closed if the trip fuses are not intact. That balloter suggested we add the coordinated fusing example to C37.2, and that has now been added as Figure 5 of the Standard, also shown as Figure 4 of this paper.

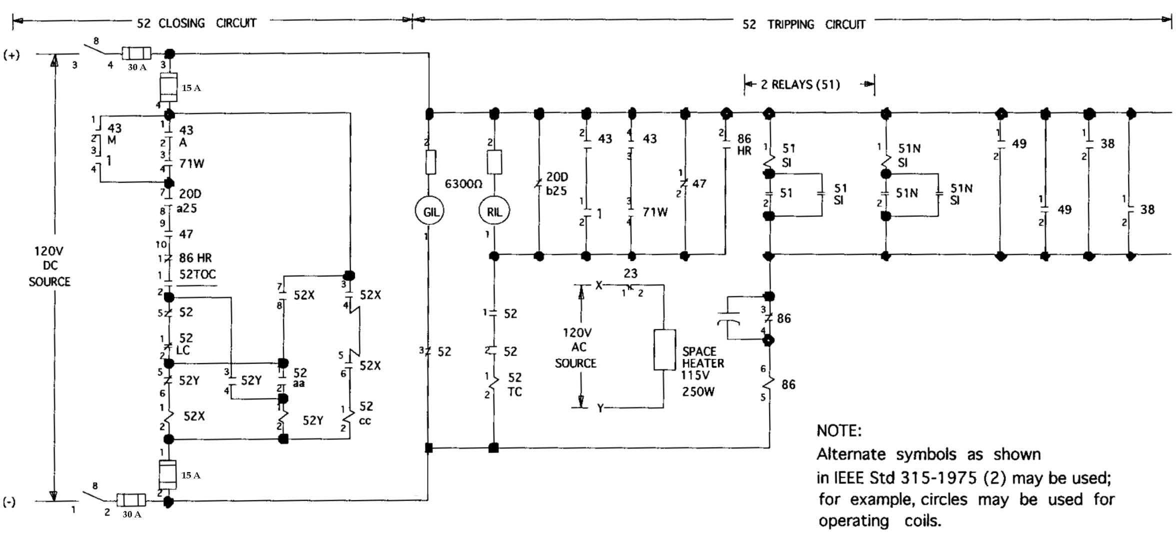


Figure 4 - Coordinated Trip and Close Circuit Fusing

Extensive IEC 61850 Cross Reference - The cross reference table to IEC 61850 Logical Nodes first supplied by Dr. Alex Apostolov has grown considerably. Since it now includes all the C37.2 function numbers and acronyms, it covers almost three pages in Annex D of the Standard. Here are a few examples from the table:

Portion of Multi-page Cross Reference Table in C37.2-2008 Annex D

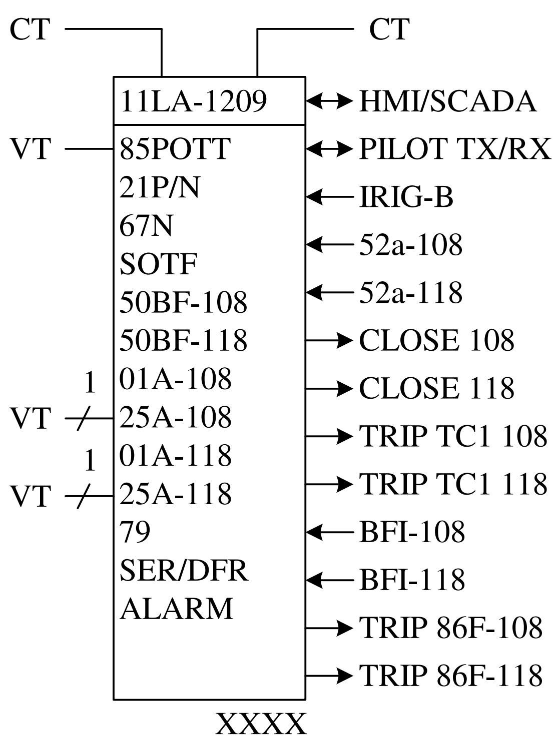
Functionality	IEEE C37.2 Reference	Modelled in IEC61850-7-4	Comments
Transient earth fault		PTEF	
Directional earth fault wattmetric protection		PSDE	Sensitive ground fault protection
Checking or interlocking relay	3	CILO	
Zero speed and under speed	14	PZSU	
Security Processing Function	16EC or 16SC		VPN, encryption module, etc.
Firewall	16EF		Or message filtering function
Network managed function	16EM		(e.g. configured via SNMP)
Router	16ER		
Switch	16ES or 16SS		Example: Ethernet switch is 16ES, Dial up port switch is 16SS
Ethernet Managed Switch	16ESM		
Ethernet Router with Firewall, VPN for secure communications	16ERFCM		See Annex A.2 Figure 2.2
Serial Encrypting Modem	16SCT		See Annex A.2 Figure 2.1
Other serial communications components	16ST		Example: 16ST = Auto-answer modem or telephone switch
Distance	21	PDIS PSCH	IEC Use one instance per zone. To build line protection schemes
Volts per Hz	24	PVPH	
Synchronism-check	25	RSYN	
(Time) Under voltage	27	PTUV	
Directional power /reverse power	32	PDOP or PDUP	Directional over power Directional under power Reverse power modelled by PDOP plus additional mode “reverse”

New Suffix Letters - Clause 3.4.5, *other suffix letters* in C37.2 has also been updated with the addition of ten suffixes not previously in C37.2:

- BU Back up
- DCB Directional comparison blocking
- DCUB Directional comparison unblocking
- DUTT Direct underreaching transfer trip

- GC	Ground check
- POTT	Permissive overreaching transfer trip
- PUTT	Permissive underreaching transfer trip
- SOTF	Switch on to fault
- TD	Time delay
- Z	Impedance

Device 11 List Box - During the balloting, one engineer voted Negative and attached a strongly worded statement of how ineffective the existing methods (empty box and filled box methods) were to represent the contents of a multifunction Device 11 on elementary diagrams. He also attached a copy of a method he had been using, which he called the "List Box" Method, as it provided a way to list all the functions in and connections to a multifunction device. The example he provided was for the center breaker in a breaker and half scheme with synch check reclosing from one source and breaker failure initiate to back up breakers. The example of Figure 5 is now in the standard. The XXXX at the bottom of the diagram is a place holder for the manufacturer's model number.



NOTES:
1. AC sensing connections are 3-Phase unless otherwise marked.
2. Functions apply to the multifunction device's designated zone of protection unless otherwise marked.
3. A/B designate System A and System B of the fully redundant system.
4. Device 01 is manual control of the designated power system element.
01A is local HMI and panel control.
01B is remote SCADA control.

Figure 5 - List Box Method for Device 11

Approval Process

The balloting invitation for PC37.2-2008 went to a wider range of IEEE groups than has been customary for Power Engineering Society (oops – our new title is "Power and Energy Society").

In addition to the usual Power Systems Relaying Committee, Power Systems Communications Committee and Substations Committee, the invitation was sent to the IEEE SA balloters list for the Industry Applications Society Standards Committee (responsible for the IAS "color" books), the IAS Rural Electric Power Committee and the IEEE Rail Traction Standards Subcommittee. There were 203 people in the balloting body. Balloting was completed in May 2008 and the document was approved by IEEE SA RevCom at its June 2008 meeting. It is now available from the IEEE web site standards store.

Conclusion - what does the new C37.2 mean to relay application engineers?

The 2008 version of IEEE C37.2 includes:

- A complete description of Device 16 and its suffixes – with example diagrams.
- The addition of seventeen acronyms.
- A complete cross reference table to IEC 61850 Logical Nodes
- The addition of a new "List Box" method to describe the contents of a Device 11 - Multifunctional Device.
- The addition of a Coordinated Trip Circuit Fusing diagram from a PSRC working group report.

Why should *you* care about these changes in IEEE C37.2?

To start, note that virtually every presentation at this relay conference will be describing or using a microprocessor based product. And essentially every one of those is a multifunction device (Device 11 in C37.2). In addition, many users are installing Ethernet networks and devices to link these new relays and need the new Device 16 to describe the substation network. The 2008 version of IEEE C37.2 – Standard Electrical Power Device Function Numbers, Acronyms and Contact Designations – saves these users from inventing new and varied schemes for representing the most critical and widely used components in new substation protection and control systems. It provides the documentation tools you will need for these new applications. If you use the Standard and discover gaps or have new ideas, share your observations with the PES Substations Working Group C5 – http://grouper.ieee.org/groups/sub/wgc5/index.htm

John T. Tengdin, P.E (IEEE LF' 2007) graduated from Purdue University, West Lafayette, Indiana in 1949 with a BSEE degree. His employment experience includes Dayton Power and Light Company, General Electric Company, Honeywell Information Systems, and the Tech Division of American Diversified Bank. He began work as an independent consultant in 1986, and formed OPUS Publishing as a two man partnership specializing in substation automation and cyber security in 1999, the predecessor to OPUS Consulting Group where he is a Senior Partner and Co-Founder. He has received numerous awards from the PES Substations Committee and the PES Power System Relaying Committee for his work on technical papers and standards, and from the IEEE SA for rapid standard

development. He chaired the joint C5 / I14 Working Groups that created this revision to IEEE C37.2. His 2007 Fellow citation was "for leadership in Ethernet local area network based protective relaying and control in electric power substations". He can be reached at j.t.tengdin@ieee.org.

Eric A. Udren has a 40 year distinguished career in design and application of protective relaying, utility substation control, and communications systems. He programmed the world's first computer based transmission line relay, led software development of the world's first LAN-based substation protection and control system, and managed development and application at Westinghouse, ABB, and Eaton Electrical. He has worked with utilities to develop new substation protection and control designs as a consultant since 2004. He is now Executive Advisor with Quanta Technology and is based in Pittsburgh.

Eric is IEEE Fellow, and chairs multiple standards working groups at IEEE Power System Relaying Committee. He is US Technical Advisor for IEC relay standards; and is member of the IEC 61850 substation communications protocol WG. Eric serves on the North American Electric Reliability Corporation (NERC) System Protection and Control Task Force, and Protection System Maintenance Standard Drafting Team. He has written and presented over 50 technical papers and book chapters. He can be reached at eudren@quanta-technology.com.