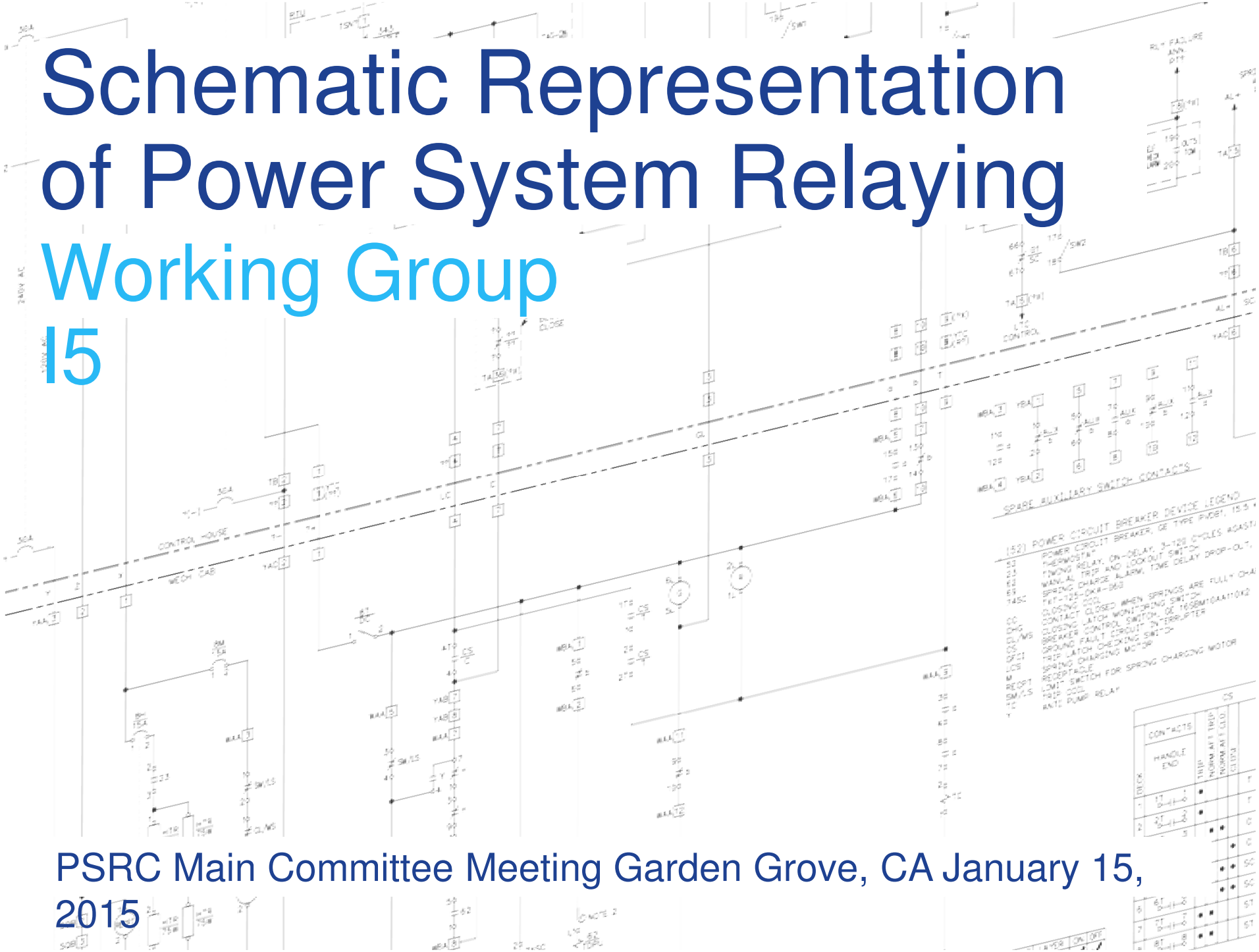
Schematic Representation of Power System Relaying

Working Group I5



PSRC Main Committee Meeting Garden Grove, CA January 15, 2015

PHILOSOPHY

Charles Sanders Peirce

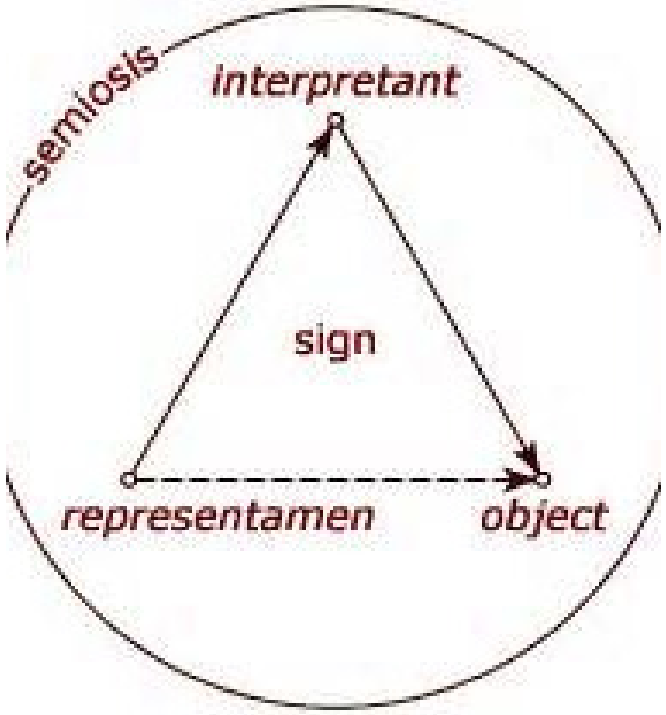
Triadic

Representamen-interpretant-object

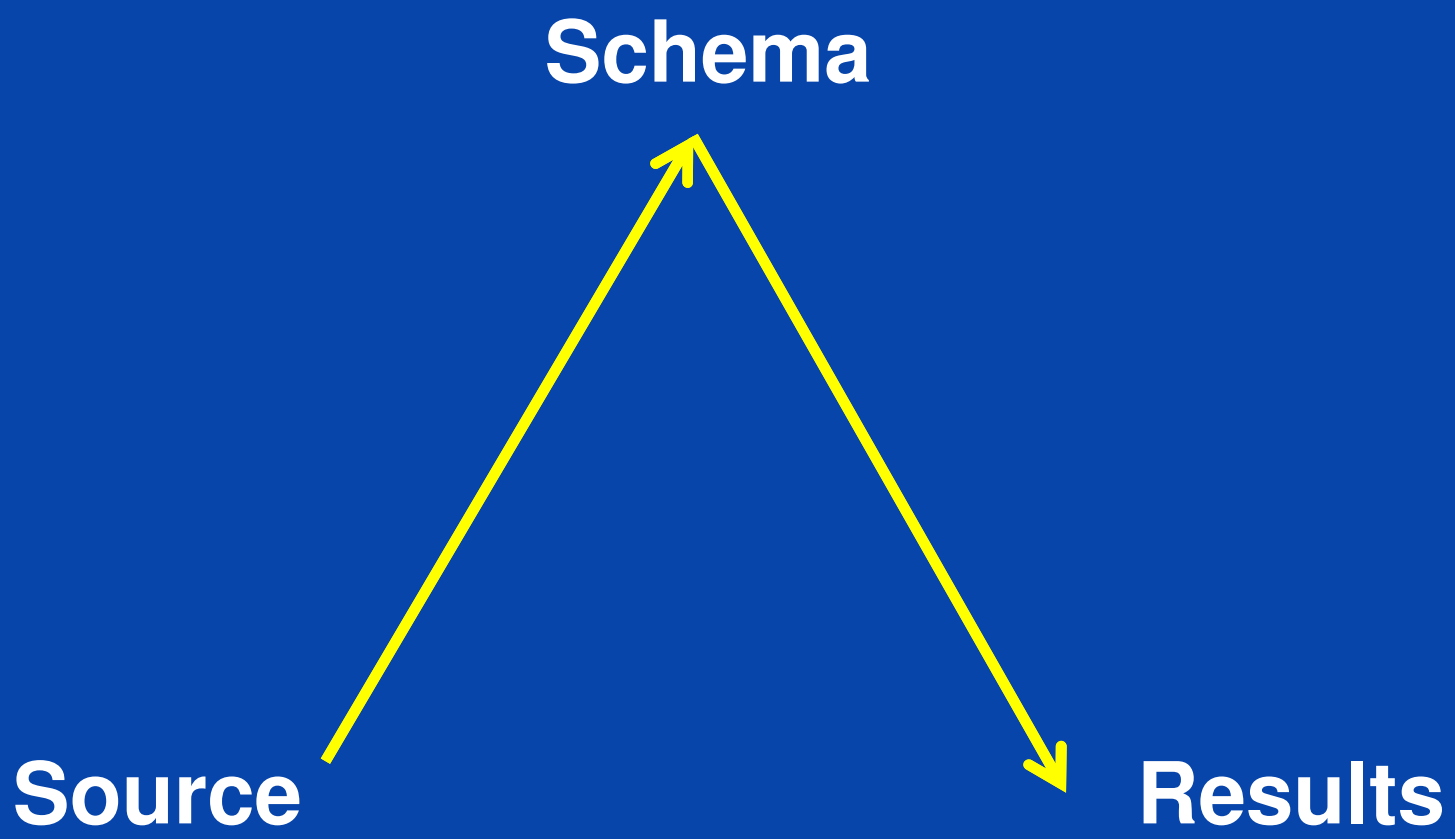
Sign vehicle-sense-referent

Symbol-thought-object

Office-drawing-field



Semiotics
Ferdinand de Saussure
dyadic


Schema
Source
Results

Working Group I5 Members

Kevin Donahoe – chair

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Matt Black

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John Csisek

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Jack Jester

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Bruce Mackie

Dean Miller

Adi Mulawarman

Shyam Musunuri

Jim Niemira

Craig Preuss

Tony Seegers

John Tengdin

Joe Uchiyama

Andre Uribe

Dolly Villasmil

Don Ware

Roger Whittaker

Karl Zimmerman

IEEE PES Power & Energy Society

Why Write the Paper?

Things are changing at the source of schematics

Transformative technologies will redefine long-standing practices

Considerable investment in updating technologies, transmission assets and energy resources

What are Schematics?

A schematic is a diagram that represents the elements of a system using abstract, graphic symbols rather than realistic pictures.

Schematics communicate function.

Schematics omit details not relevant to the info it is intended to convey…

And may add unrealistic elements that aid comprehension.

What are the “Results” of Schematics?

Installation

Commissioning

Troubleshooting

Equipment Maintenance

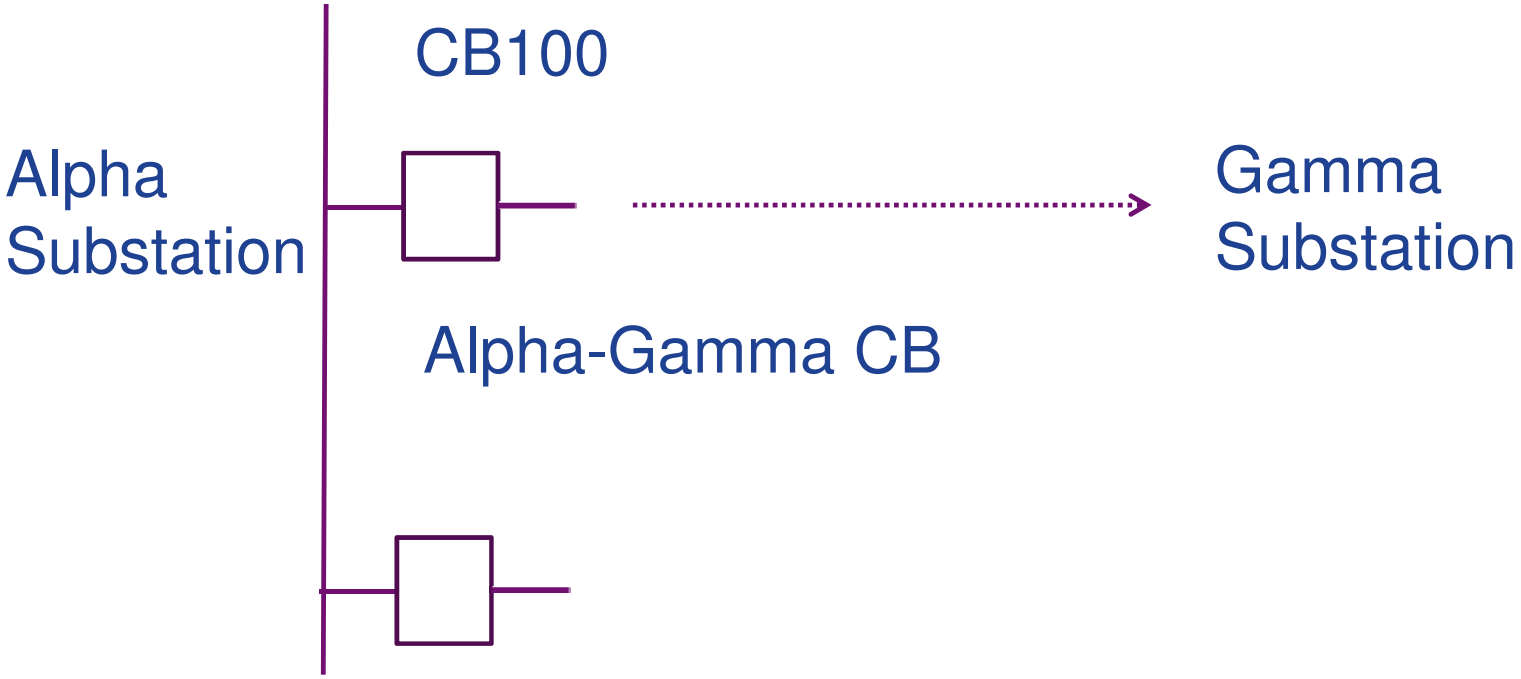
Power System Operation

Legal Records

Estimating

Example of how a Schematic Addresses Different Functions

Operating and Maintenance



Hierarchy of Drawings

Hierarchy of detail between drawings

Single line diagram is the least detailed, uses basic symbols

AC & DC schematics at the next level of detail, necessary connection and function details

Remaining drawings greatest level of detail. Maintain the connection details from schematics & add physical details. Indicates precise location & connections.

Types of Schematics

Protection Zone Diagram

Single-Line Diagram

AC Schematics

DC Schematics

Logic Diagram

Other Forms of Documentation

Wiring Diagram

Panel Layout Diagram

Communication Diagrams

Design Philosophy Documents

Commissioning Documentation

Protection Zone Diagram

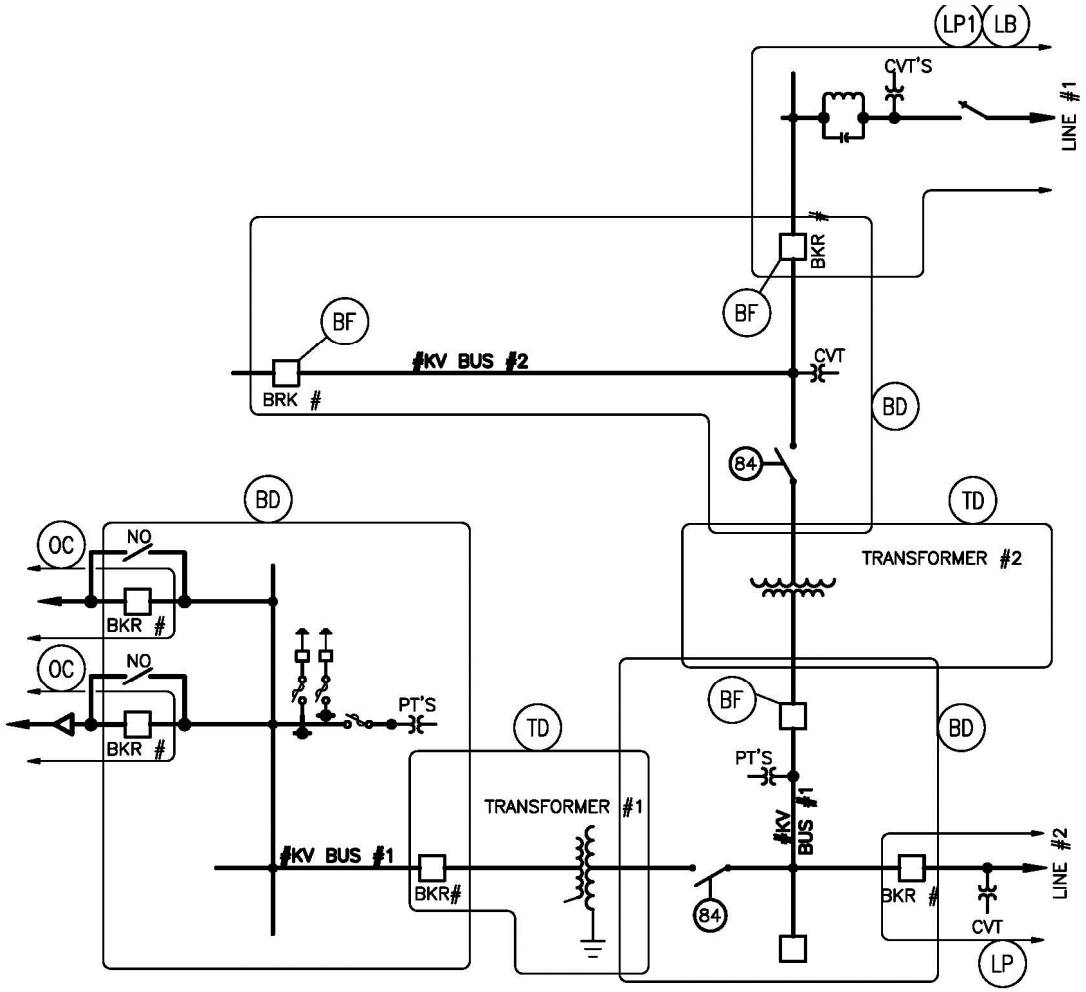
Labeled zones indicate type and area of protection

Easily identify functional protection scheme

Any fault or “X” should land inside a protected area

Protected areas should always overlap to provide full coverage

Protection Zone Diagram



Single Line Diagram

The three phase equipment and connections are shown with a single line

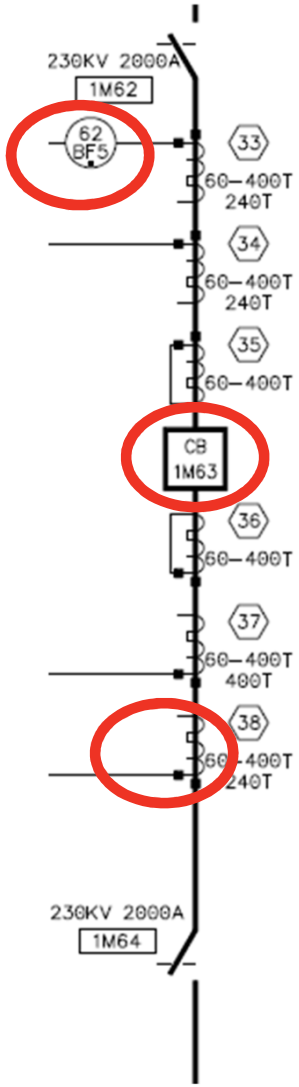
Highest level view of electrical and physical design of substation

Details primarily communicate function (i.e. polarity of CTs, transformer Wye or Delta winding, etc.)

Shows primary substation equipment as well as current & voltage transformers & their secondaries

Dashed lines with arrows indicate action commands which can be sent to equipment

Single Line Diagram Details



Single Line Diagrams & Process Bus

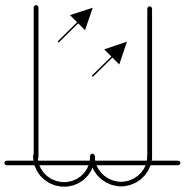
Process bus uses merging units (MU)

MU collects voltage, current and digital inputs and converts to IEC61850 protocol

The fiber connection alone between the MU and IEDs does not indicate what data is being used

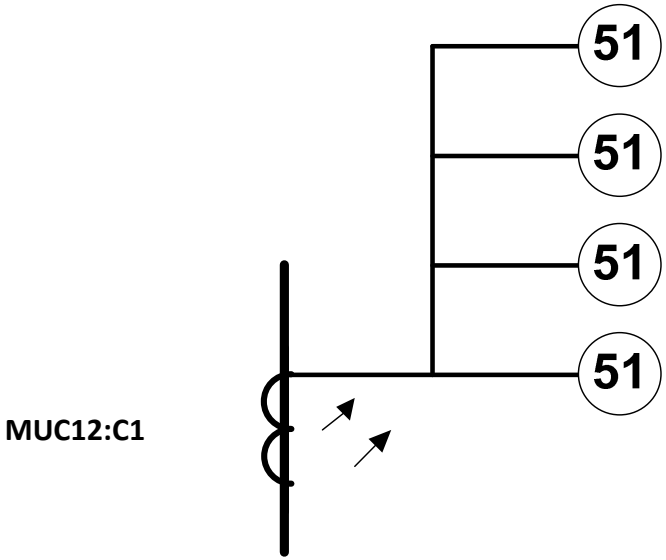
The protective function the IED is performing will be less obvious since it isn't clear what input it is getting from the MU

Theoretical Example

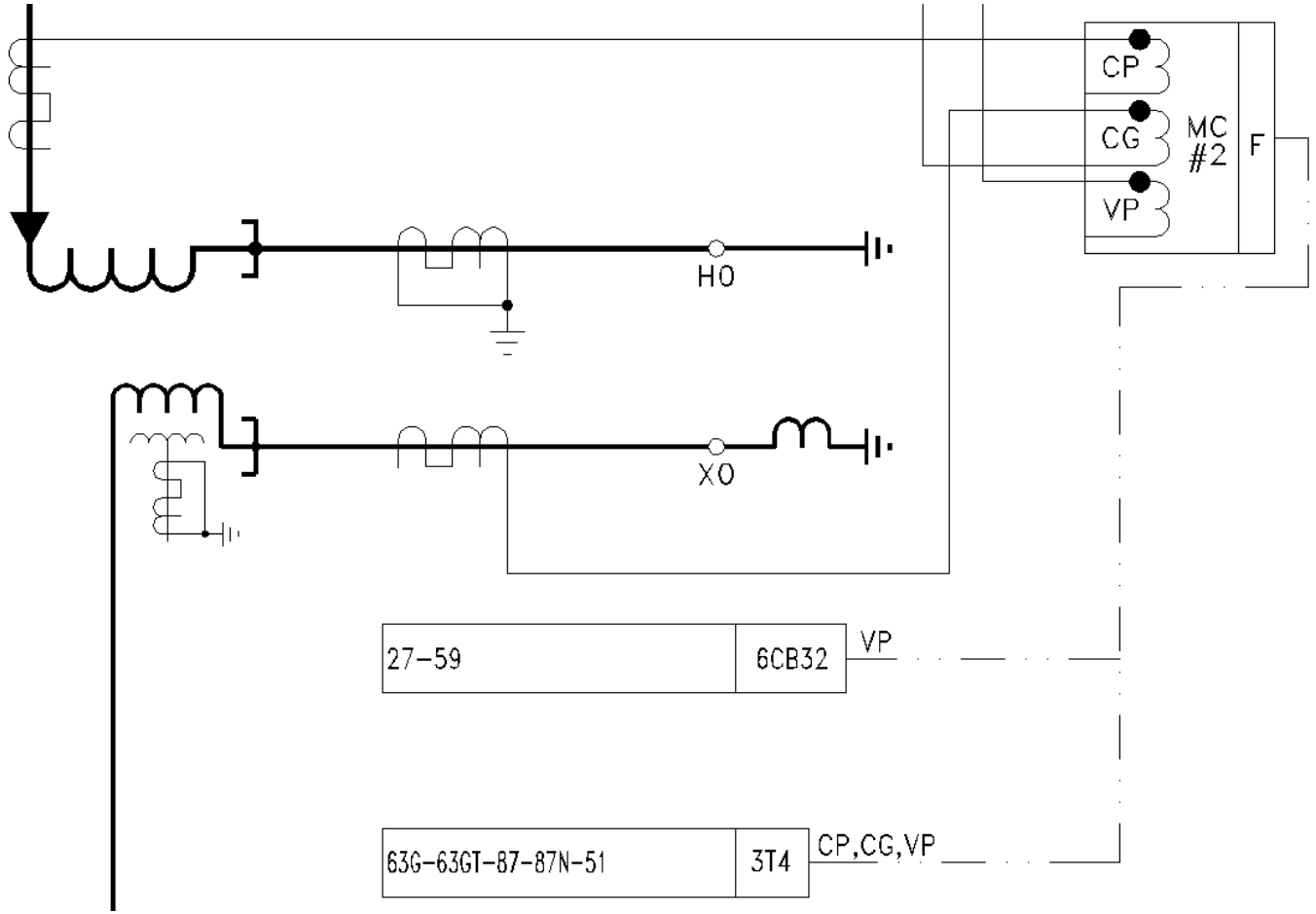


Current data from merging unit.

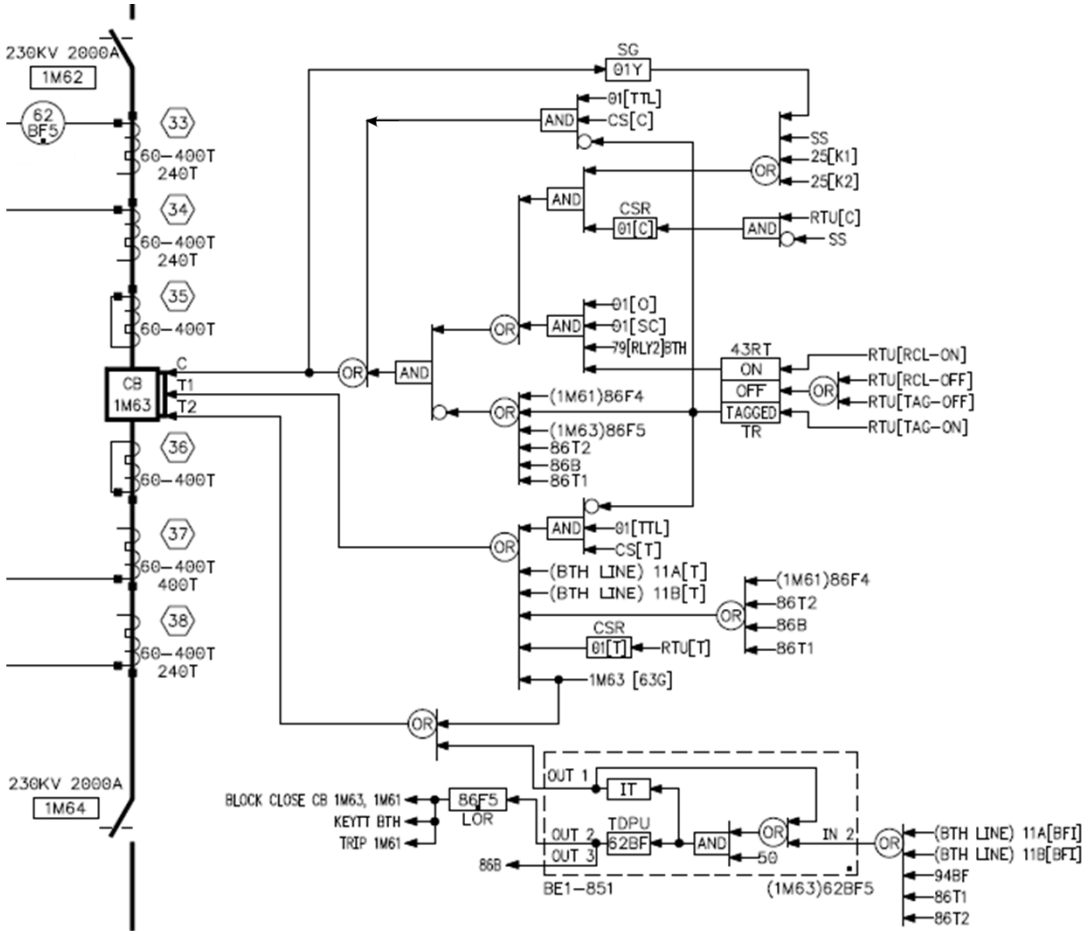
Voltage data from merging unit.



Example in Use



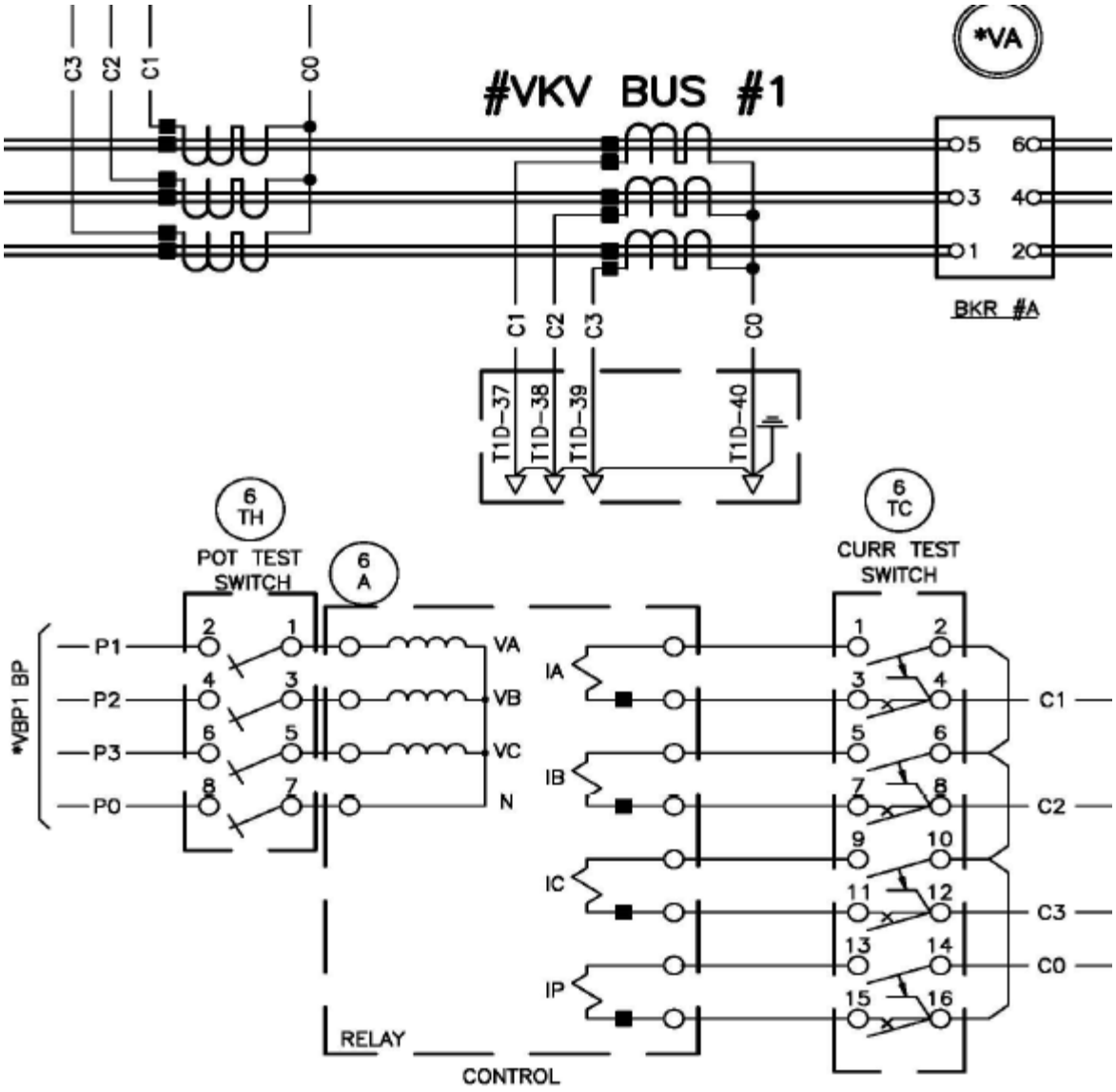
SLD with explicit logic



AC Schematics (Three-Line Diagrams)

- Shows all three phases of primary system
- All significant equipment shown
- Includes equipment thermal ratings, circuit breakers in amperes, and transformers in MVA
- Also include VTs, PTs, and CTs, as well as protective relays and meters with their respective wiring
- Test switch details

Example AC Schematic



DC Schematics

DC typically depict the protection and control functions of substation equipment

Sometimes those control functions are supplied by AC

Typically, DC source shown on left with initiating contacts located above operating elements

Many utilities have developed their own standards regarding symbology

Nuances DC Schematic

- Example: Difference between black triangles representing transitions verses triangles representing diodes

With widespread use of IEDs, it is advantageous to use DC schematics to show what functions are being used and which are available on each microprocessor relay

Nuances DC Schematic

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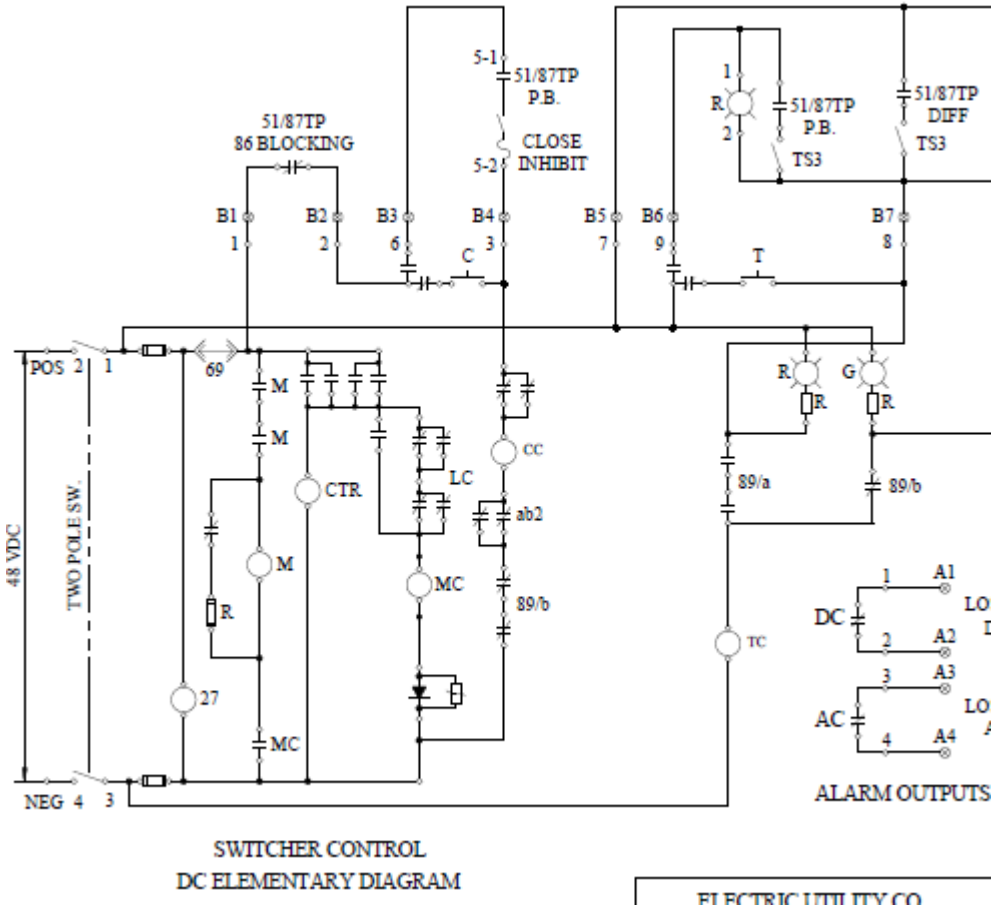
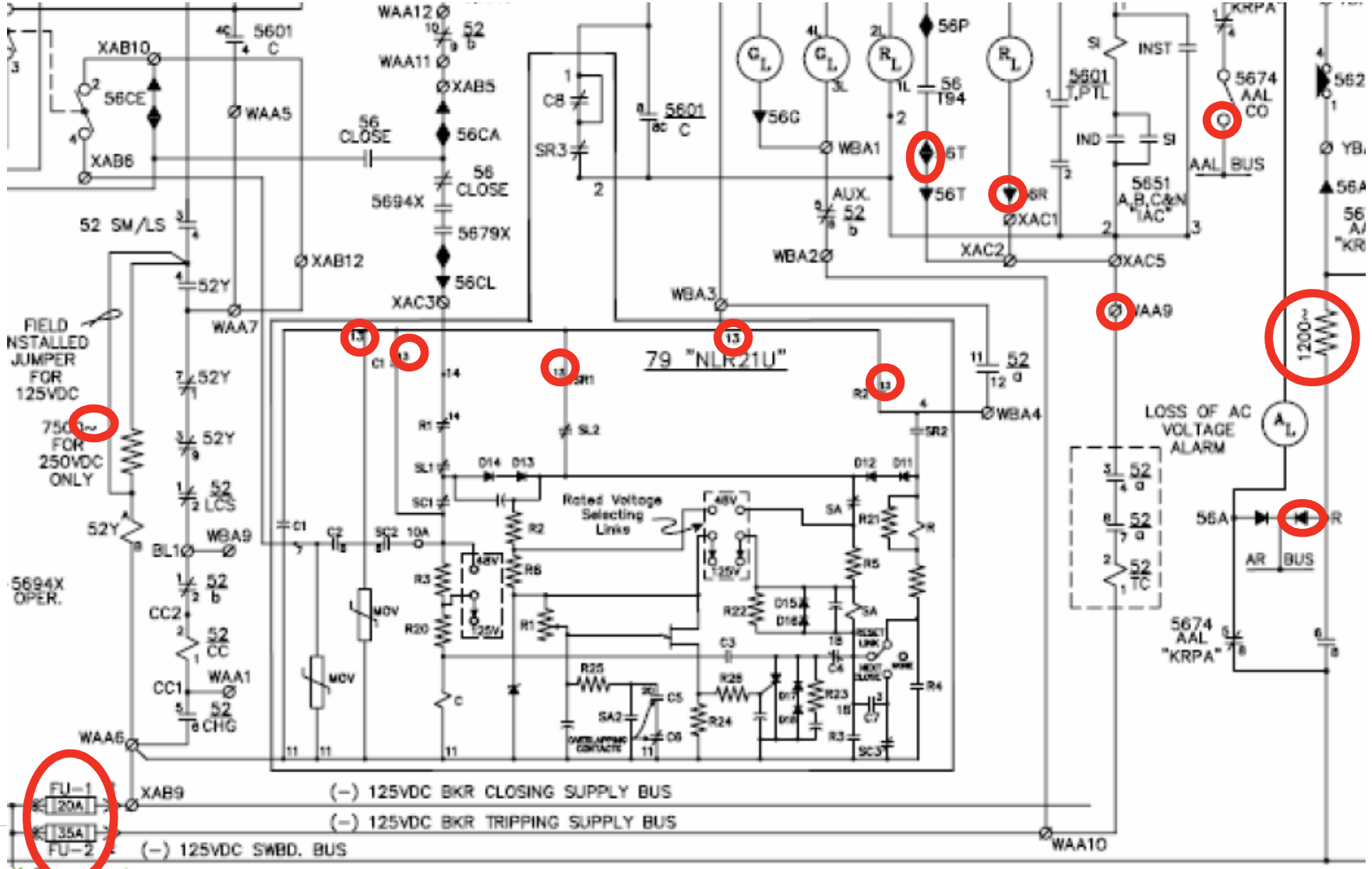
DC Schematic Detail



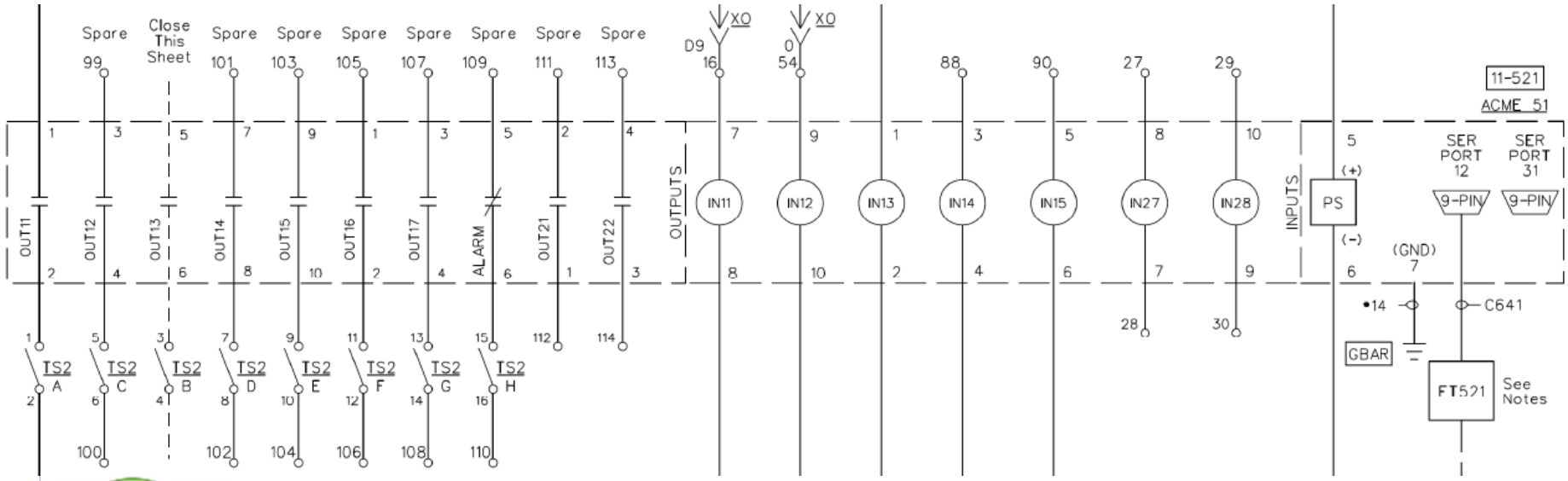
DC Schematic Detail



Alternatives to Show Available Microprocessor Relay Resources

11T3
ACME 51

Connections	Name	Function
7O—□—O8	IN11	SW 23 Close Position
9O—□—O10	IN12	SW 23 Open Position
1O—□—O2	IN13	SW 23 Trip Coil Monitor
3O—□—O4	IN14	Loss of Emergency Station Power
5O—□—O6	IN15	SW 23 Lockout, Urgent SF6 Alarm
7O—□—O8	IN16	SW 23 Low SF6 Pressure Alarm
5O—□—O6	IN21	
7O—□—O8	IN22	Transformer 3 Device Alarm
9O—□—O10	IN23	Transformer 3 Gas Alarm
1O—□—O2	IN24	Transformer 3 Moisture Alarm
3O—□—O4	IN25	
5O—□—O6	IN26	
7O—□—O8	IN27	
9O—□—O10	IN28	
1O—||—O2	OUT11	Trip SW 123
3O—||—O4	OUT12	Close SW 123
5O—||—O6	OUT13	
7O—||—O8	OUT14	
9O—||—O10	OUT15	
1O—||—O2	OUT16	
3O—||—O4	OUT17	
5O—|/|—O6	ALARM	



DC Schematics & Microprocessor Programming

Hardware only documentation

Software shown as part of the elementary diagram

Logic diagram on the elementary

DC Schematics & IEC61850 Station Bus

Eliminates most dedicated control wiring between relays

Typical DC schematic not enough

Point-to-point list or spreadsheet format

GOOSE MESSAGES OUT TS LI VERIFIED IN RECEIVING RELAY ARCH ONLY VERIFIED IN SOURCE RELAY QUICKSET

INITIATING RELAY	dataset name	CCOUT##	ELEMENT	Test Switch	TEST SW	97 SWITCH	BKR/MOD FUNCTION	COMMENTS	21P/ABC 50BFP- 79/9P999 Relay-Type-A	21S/ABC 50BFS/9P999 Relay-Type-A
87T2P_Relay Type - C	GooseDSet2	A2.phsA.C	A AMPS					A AMPS ,		
87T2P_Relay Type - C	GooseDSet2	A2.phsB.C	B AMPS					B AMPS ,		
87T2P_Relay Type - C	GooseDSet2	A2.phsC.C	C AMPS					C AMPS ,		
87T2P_Relay Type - C	GooseDSet13	MsgQuality	Goose Message Quality					Goose Message Quality ,	CCIN111	CCIN111
87T2P_Relay Type - C	GooseDSet2	PhV.phsA.C	VOLTAGE					VOLTAGE ,		
87T2P_Relay Type - C	GooseDSet13	S1LT2	97T2P				S	97T2P STATUS,		
87T2P_Relay Type - C	GooseDSet13	S3V1T	86T2	TS-A	S3	97T2F	BK	T 86T2P TRIP, BFI, RECL WAIT, BKR 5P	CCIN050	CCIN050

Logic Diagrams

Variety of types including

- Timing diagrams
- Boolean logic diagrams
- Karnaugh Map
- Structured Text
- Functional Description
- Flowcharts

Considerations for Logic Diagrams

How should logic be organized in drawing sets?

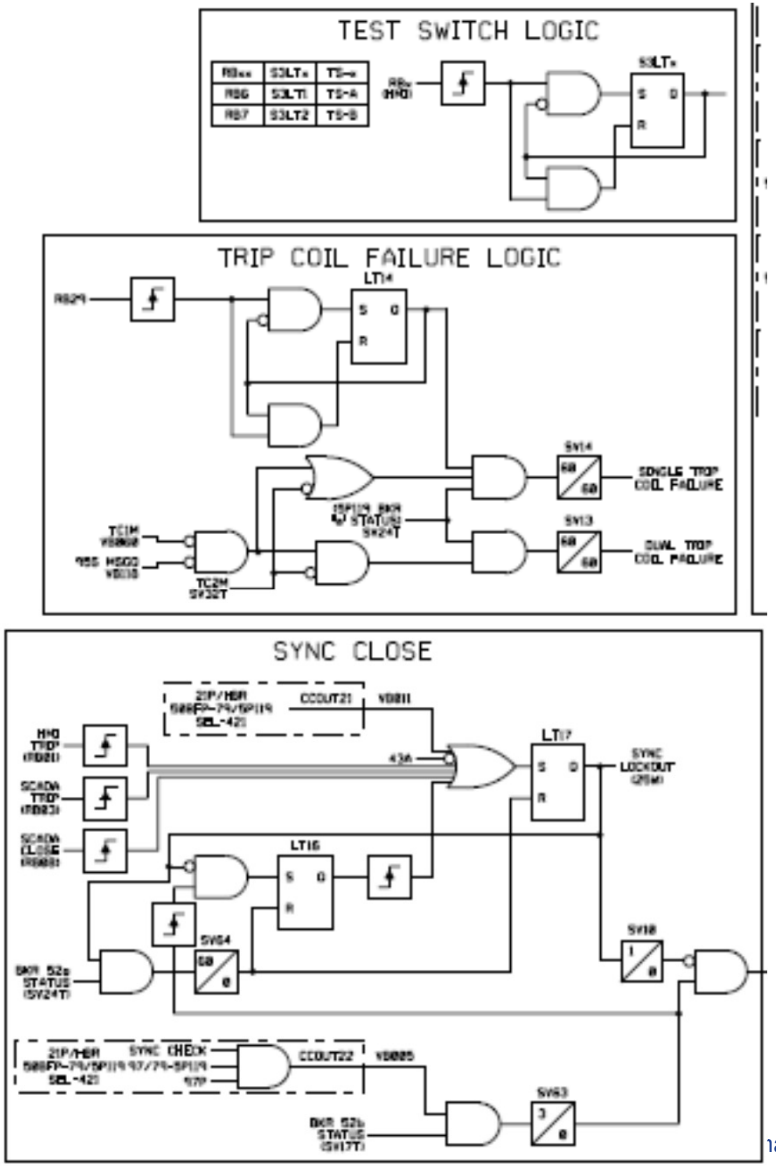
What reference system will be used connect logic with other drawings?

Will duplication of manufacturers' drawings create copyright issues?

How much of the included logic representations ought to be tested? How will it be verified?

What is the best way to create logic diagrams?

Example Logic Diagram



Other Forms of Documentation

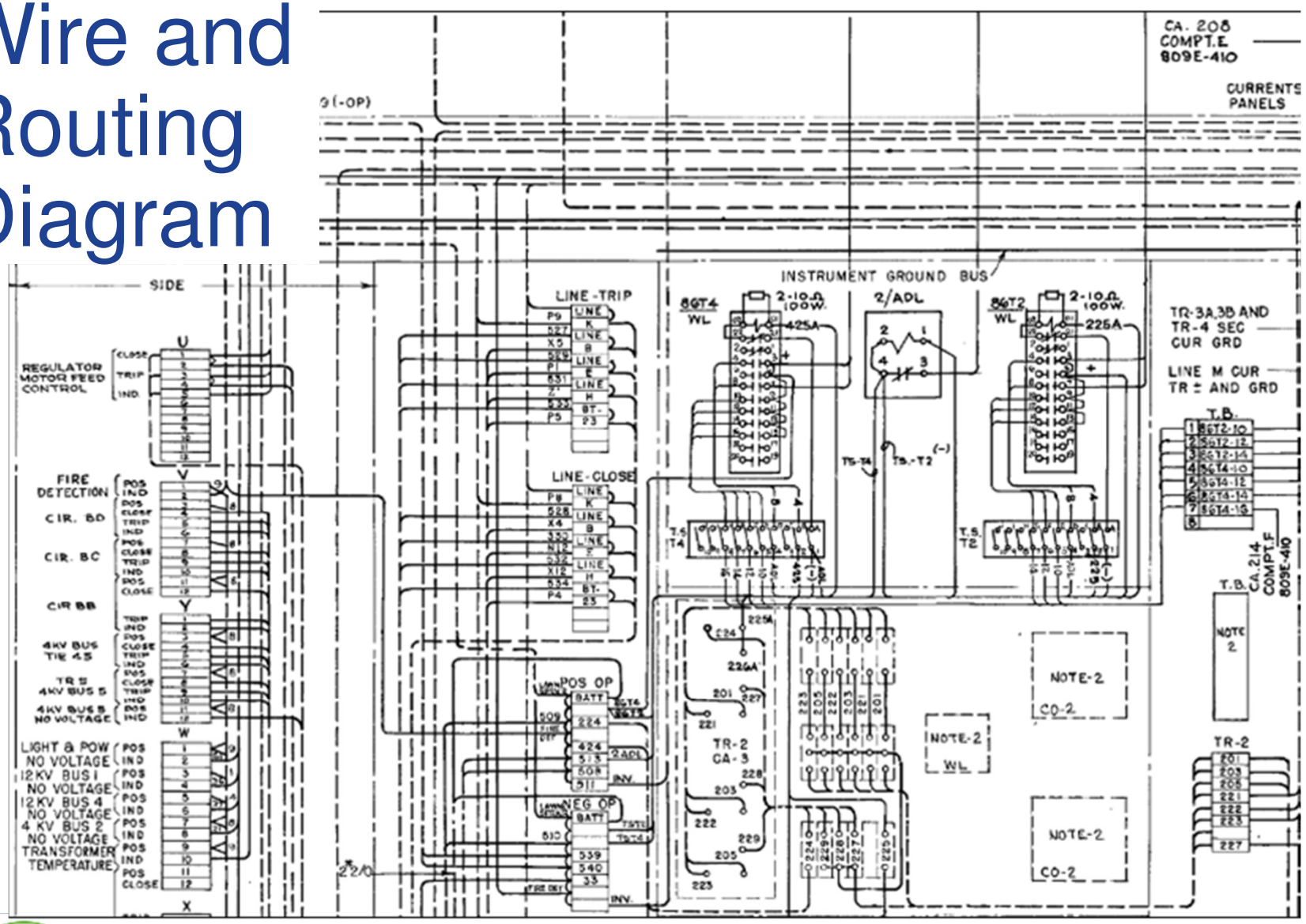
Wiring Diagrams and Rack Layout

Communication Diagrams

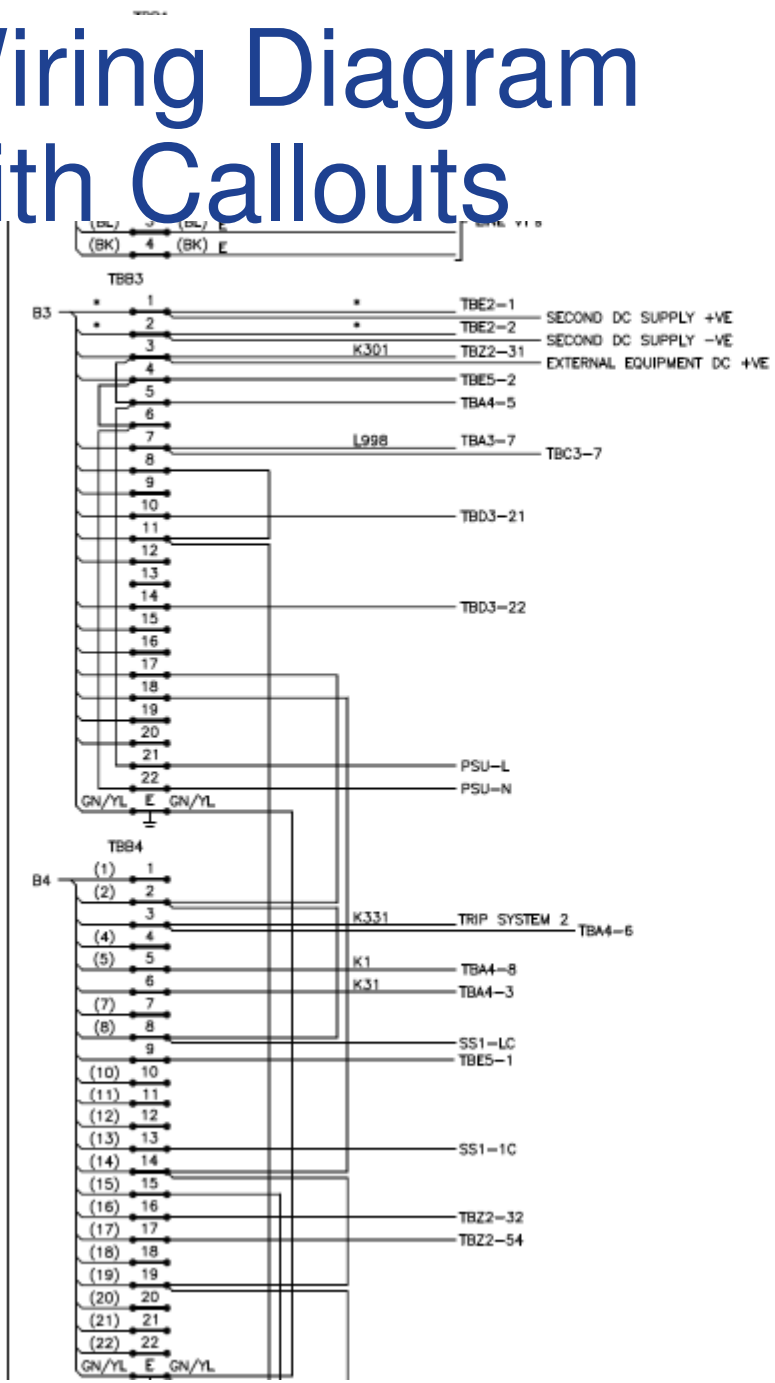
Design Philosophy

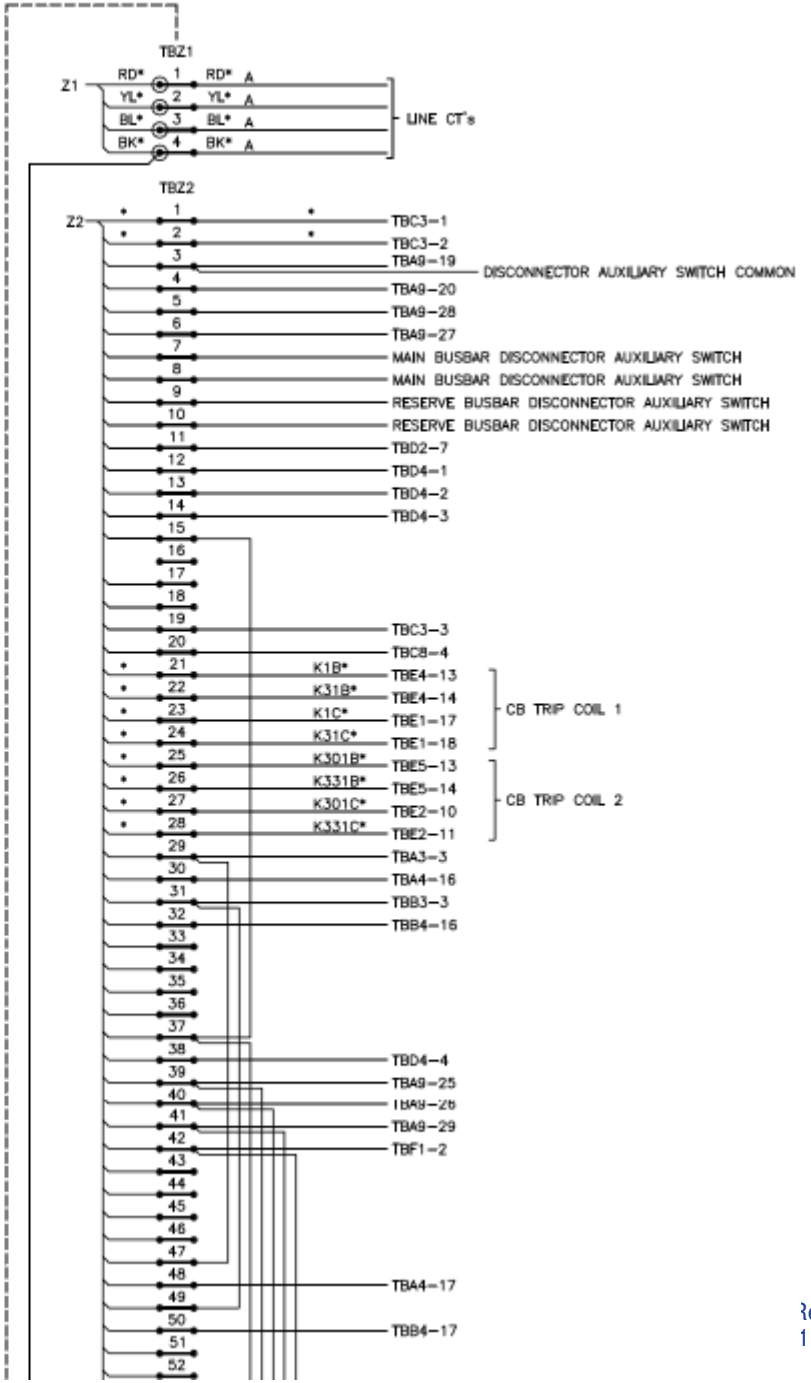
Commissioning Documentation

Wire and Routing Diagram

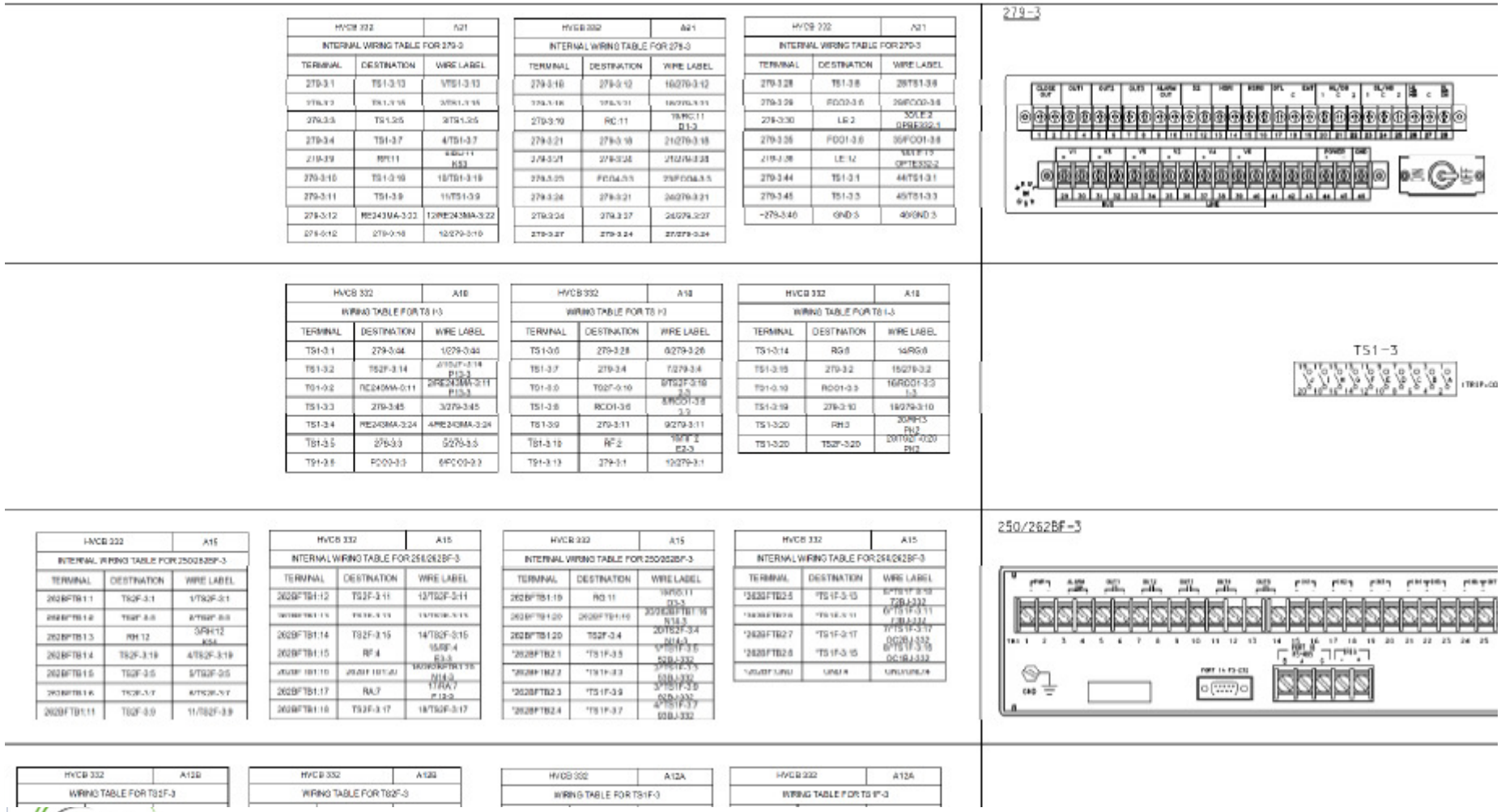


Wiring Diagram with Callouts

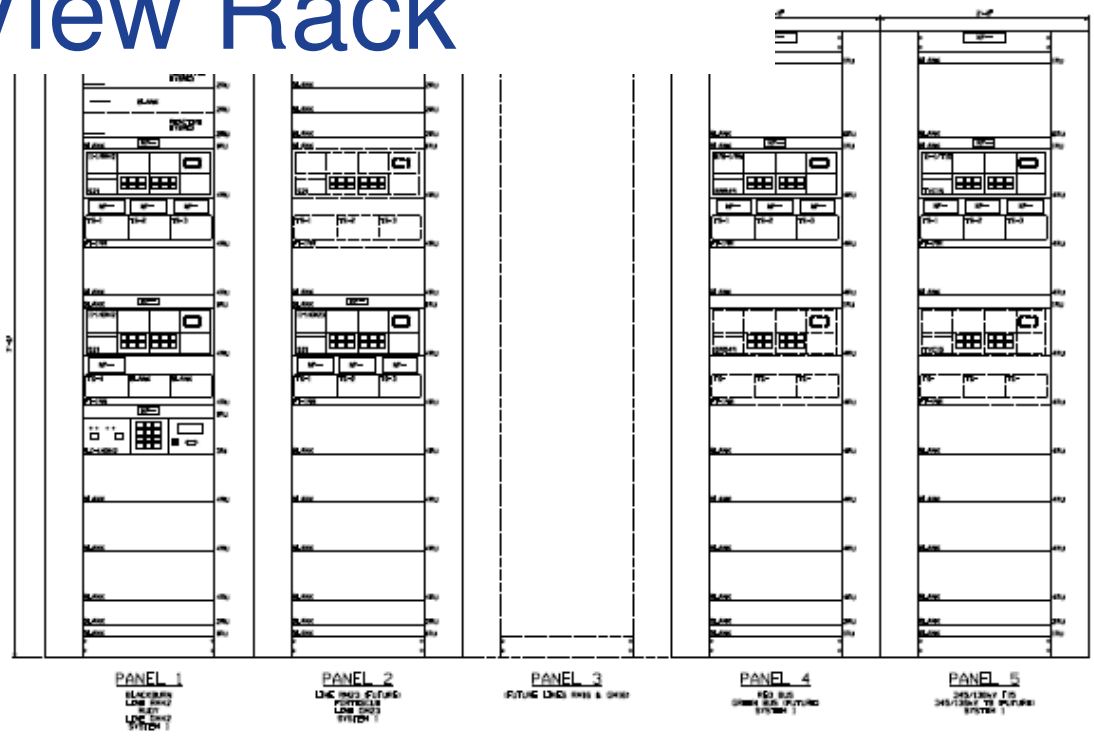




Wiring Diagram with Connection Tables



Front View Rack Layout



345 & 138kV SYSTEM I PANEL LINEUP

PSRC

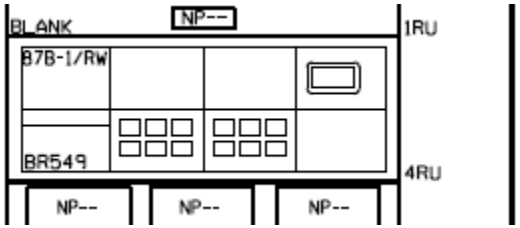
345 & 138kV SYSTEM I RACKS 1, 2, 3, 4 & 5 FRONT VIEWS

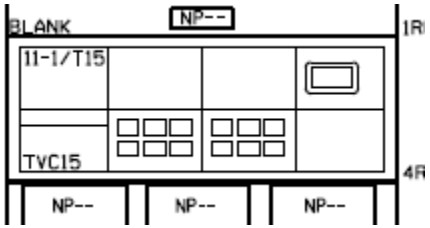
ELMORE

NCC-1701

108

Front View Rack Layout Easter Eggs





PANEL 1

BLACKBURN
LINE RM42

PANEL 2

LINE RM23 (FUTURE)
FORTESCUE

Front View Rack Layout Easter

DR. O.U. TRIPDIT 05/26/06	PSRC	345 & 138kV SYSTEM 1 RACKS 1, 2, 3, 4 & 5 FRONT VIEWS	
CK. PAUL DeTRIPS 05/26/06			
SECTION HEAD APP. / /			
DIVISION HEAD APP. / /			
DEPARTMENT HEAD APP. / /			
		ELMORE SUBSTATION	
		SCALE 1½"=1'-0"	DRAWING NO. NCC-1701 / SHEET 108 / REV.
		JOB WO 20120	

345 & 138 RACKS
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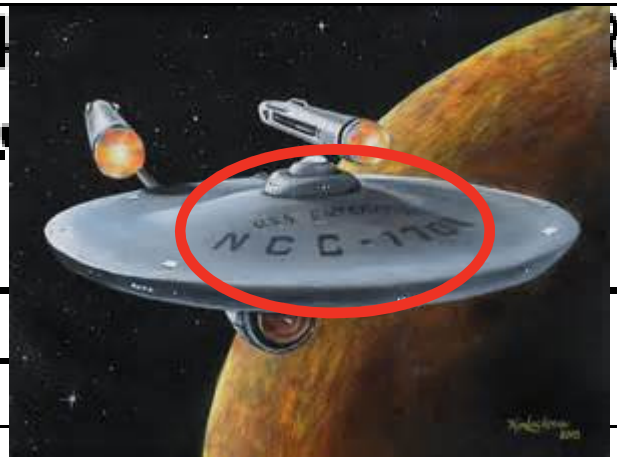

ELMORE SUBSTATION

SCALE 1½"=1'-0" SHEET 108 REV.

JOB WO 20120

DATE

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Communication Diagrams

- Internal – system within substation which feeds into external communications
- SCADA – system used to communicate system properties and controls to remote location
- External – system used for inter-substation communication

Substation Internal Communication

IEEE Std C37.1-2007 discusses importance of block diagrams. Block diagrams should include:

Remote SCADA communications to one or more entities and/or utilities for operational data

Remote communications to one or more entities and/or utilities for non-operational data

Inter-substation protective relay communications via various transport methodologies

Local telco circuits for substation phone and/or data circuits

Revenue metering data circuits

Substation Internal Communication

The block diagram should detail the following connections for each IED:

Device designation

Device part number (optional)

RS-232 serial communication ports with connector type (terminal block, DB9 male/female) and port number with front or rear indicated as necessary

RS-485 serial communication ports with connector type (terminal block, DB9 male/female) and port number or terminal block number with front or rear indicated as necessary

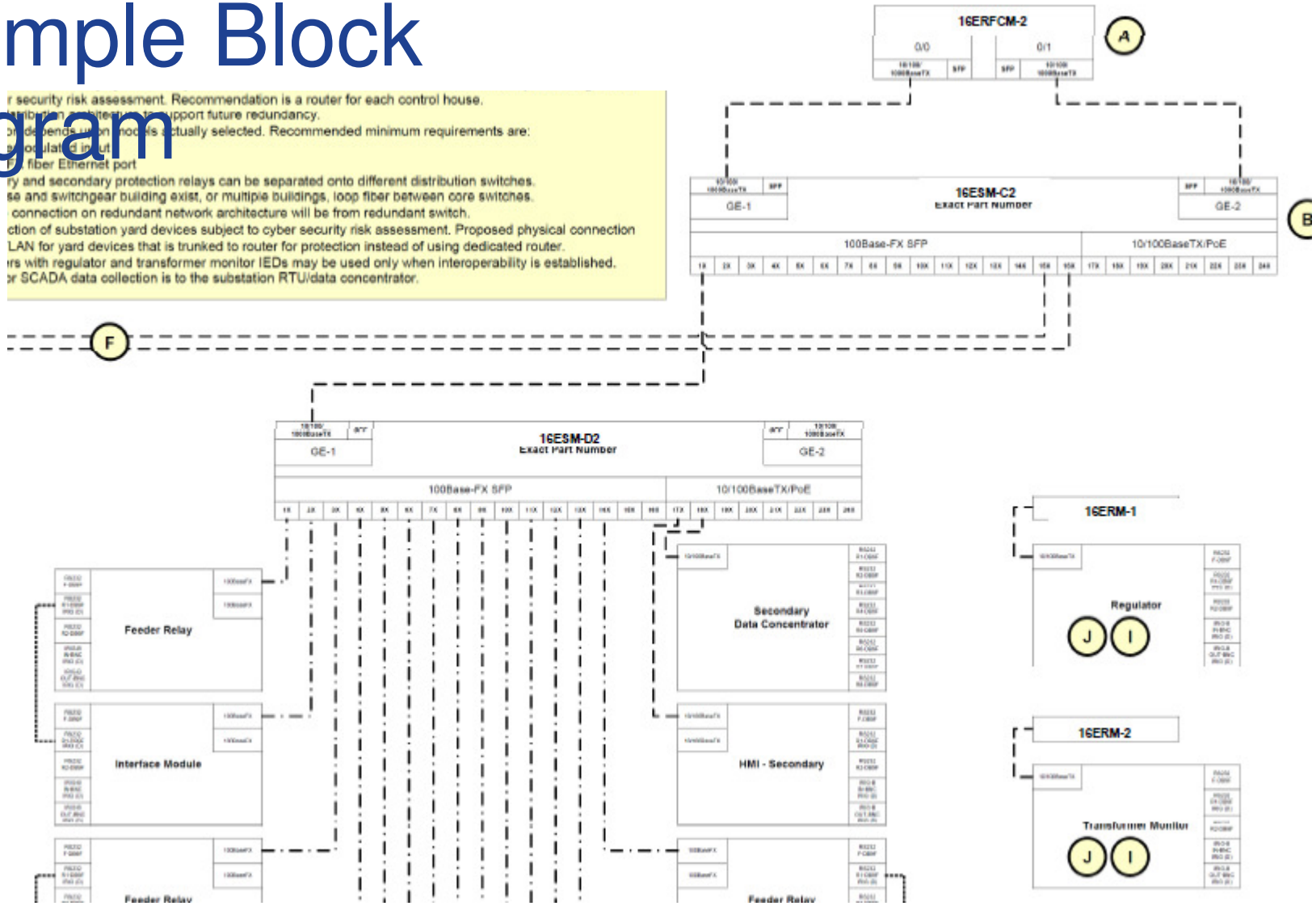
Substation Internal Communication

The block diagram should also detail the following connections for each IED:

Ethernet ports with connector type and speed (RJ45: 10/100BaseTX, 10/100/1000BaseTX; ST, MTRJ, LC: 10BaseFX, 100BaseFX) and port number with front or rear indicated

IRIG-B port with connector type (coax, terminal block) and modulation, with port number or terminal block number with front or rear indicated as necessary

Example Block Diagram



Substation SCADA Communication

Representing substation SCADA related control/equipment in the schematics

Necessary parts of the points list

Possible worksheet columns in points list

Substation External Communication

Communication System Map

Communication System Layout Diagram

Microwave Radio and Fiber Optic Communication System Diagram

Communication Channel Circuit Diagram

Database Documentation

Other Forms of Documentation

Design Philosophy Document

Commissioning Documentation

Conclusion

Established methods, though updating, have proved effective, safe, and reliable

The net loss of expertise challenges the continuation of best practices so more papers like this one will be needed

As relaying and communication technologies advance this will require a close relationship between manufacturer and user to facilitate assimilation into existing methods of documentation

Shift from meaning being conveyed by wiring to meaning being conveyed by programmed logic. This can leads to opportunities for translation error

Expertise required to maintain these new systems is different from that needed for older systems

It cannot be overstated how important it will be to the adoption of new relay system technologies that for the maintenance of these systems, documentation is available that emphasizes transparency to the functions that the system is performing. It is crucial that the technology of power system relaying does not outstrip the industry's ability to safely, reliably and effectively implement these technologies into its daily operations.

Questions?