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
Schematic Representation of Power System Relaying

Source → Schema → Results

Schematic Representation of Power System Relaying
1/15/2015
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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

Alpha Substation

Alpha-Gamma CB

CB100

Gamma Substation
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.

MUC12:C1
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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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.
DC Schematic Detail
DC Schematic Detail
Alternatives to Show Available Microprocessor Relay Resources
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

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<th>Test Switch</th>
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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 to 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

Schematic Representation of Power System Relaying

1/15/2015
Front View Rack Layout
Front View Rack Layout Easter Eggs

**PANEL 1**
BLACKBURN
LINE RM42

**PANEL 2**
LINE RM23 (FUTURE)
FORTESCUE
Front View Rack Layout Easter Eggs

PSRC

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

ELMORE

SCALE 1\(\frac{1}{2}''\)=1'-0"

JOB WO 20120

SUBSTATION

NCC-1701

05/26/06

05/26/06

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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?