Power System Engineering, Inc.

MIPSYCON 2016

Automating the OMS with the DMS - How To Get There

Nick Orndorff
Power System Engineering, Inc.
November 9, 2016

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www.powersystem.org

Important! – Please Read

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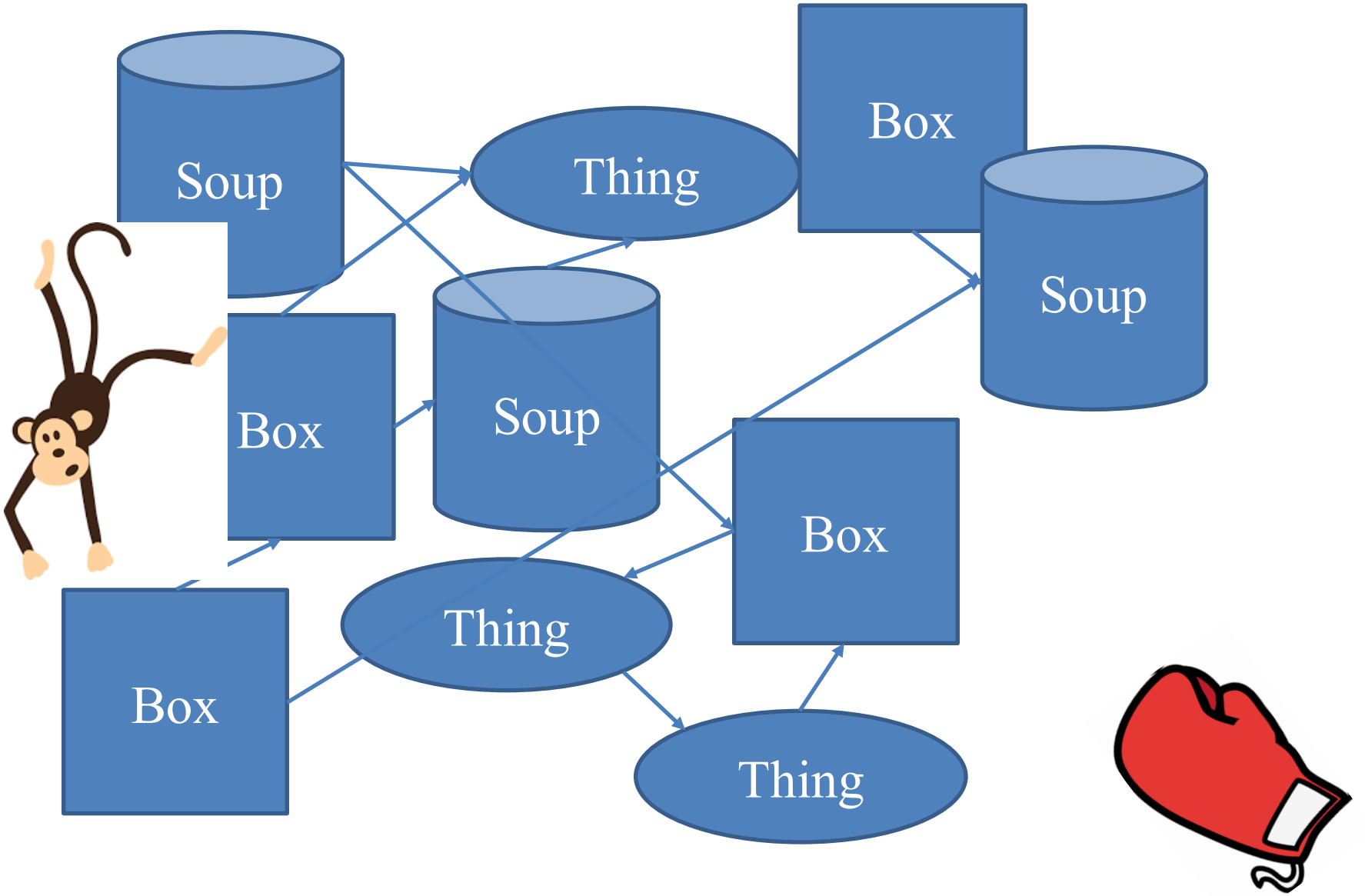
Animations!



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Automating Outage Management

Reliability

Customer Communication

Maximize Benefits

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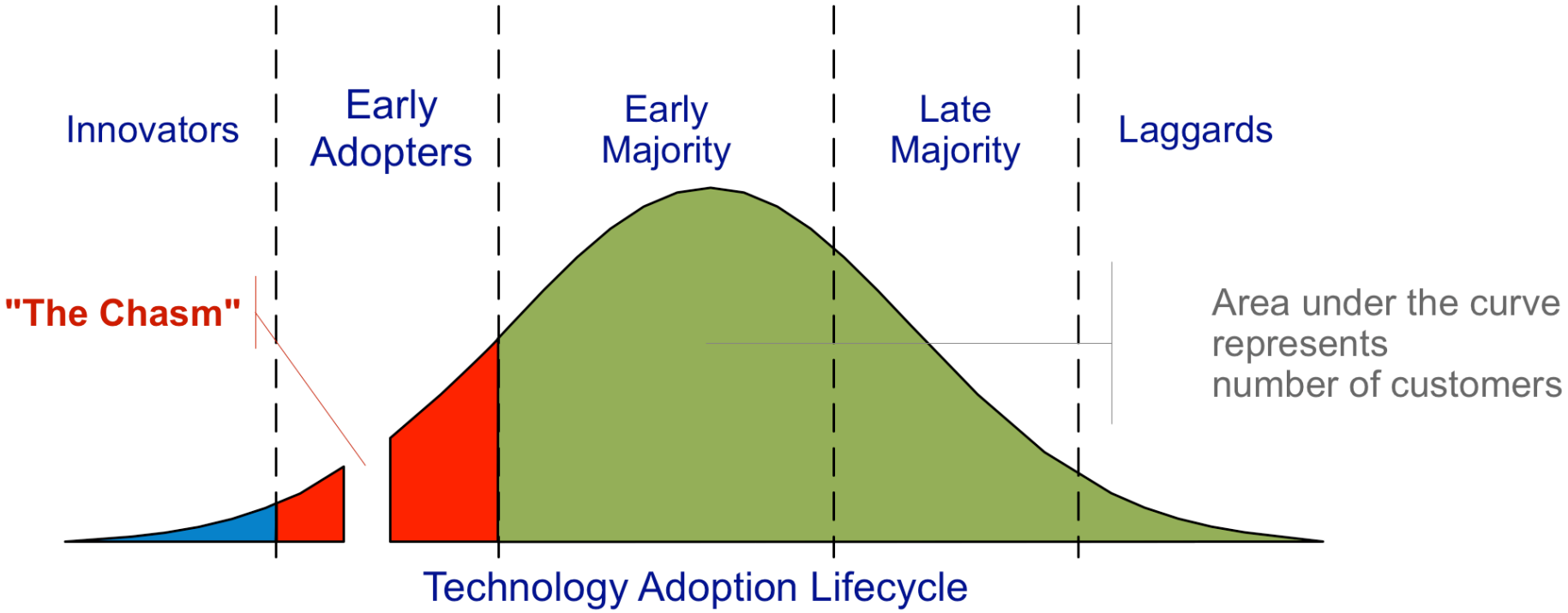
What type of company?



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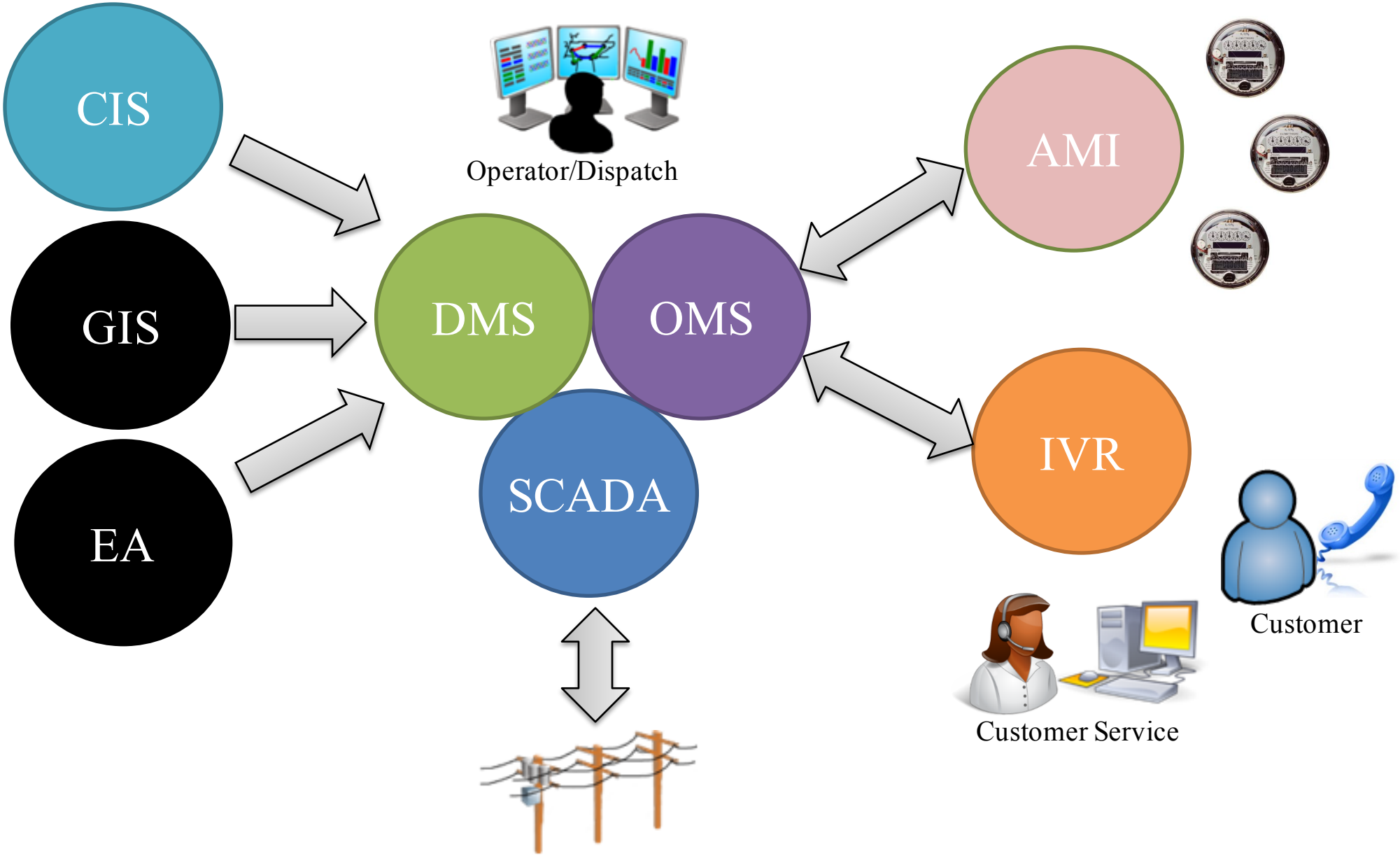

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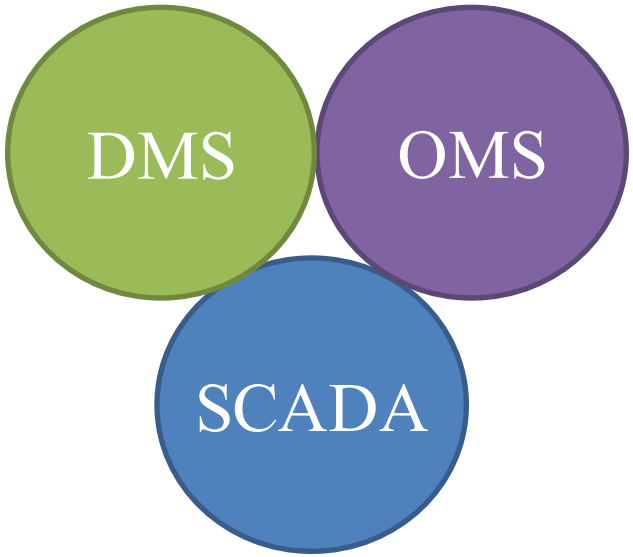
Operator/Dispatch



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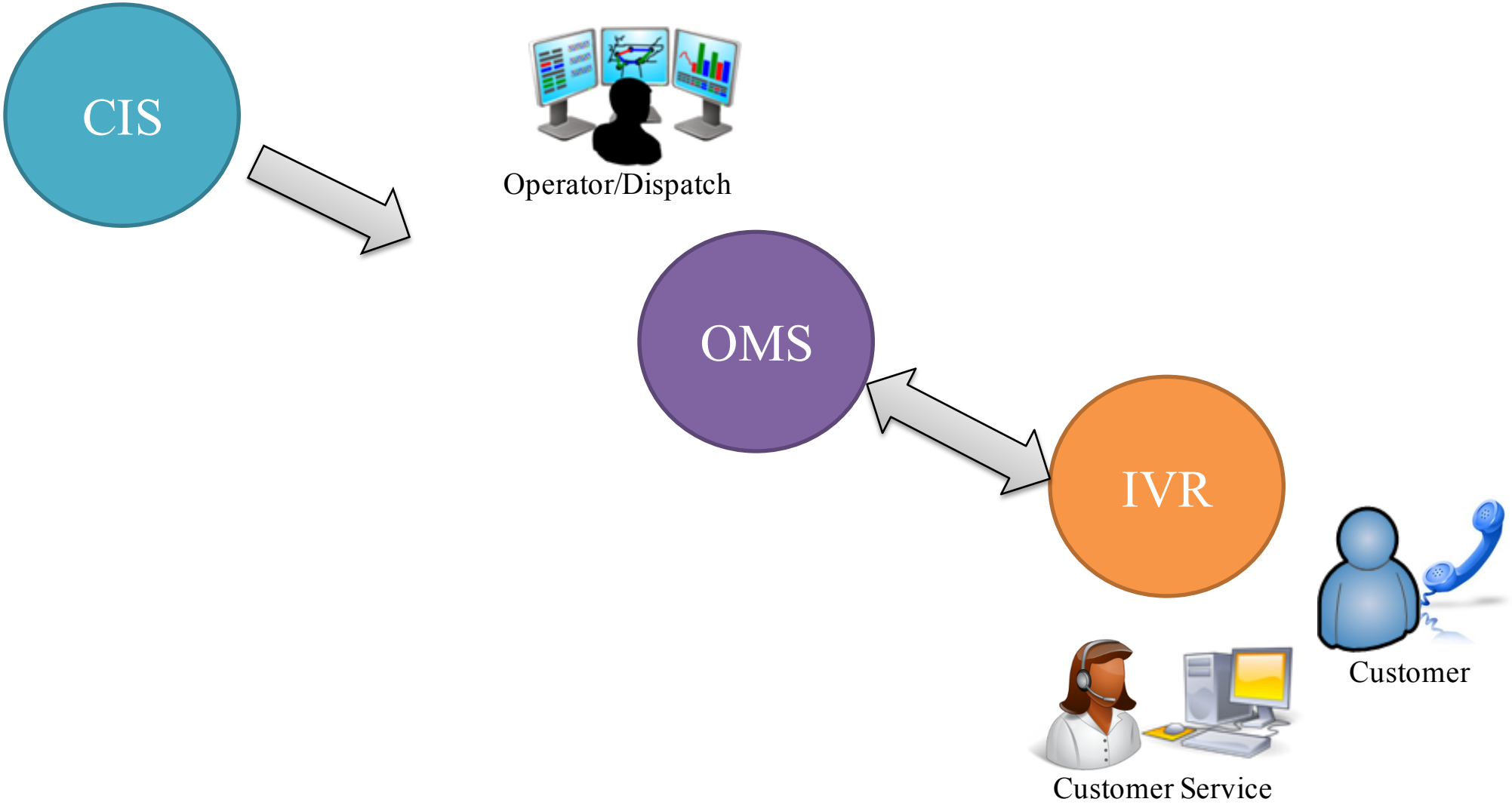

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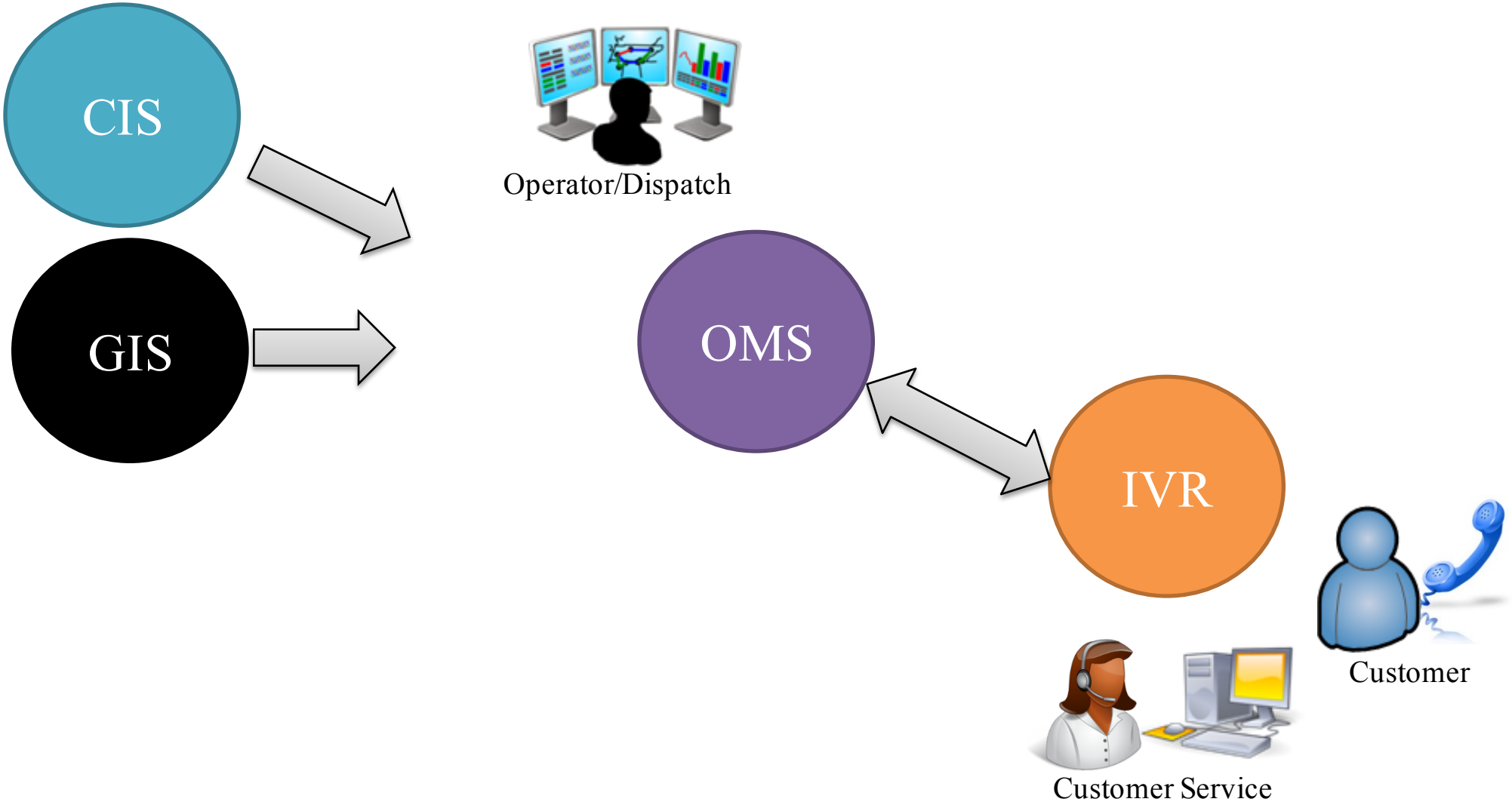

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GIS Notes

- Topology
  - Required for OMS outage prediction
  - Tool for real time distribution switching (OMS or DMS)
  - Phasing is important

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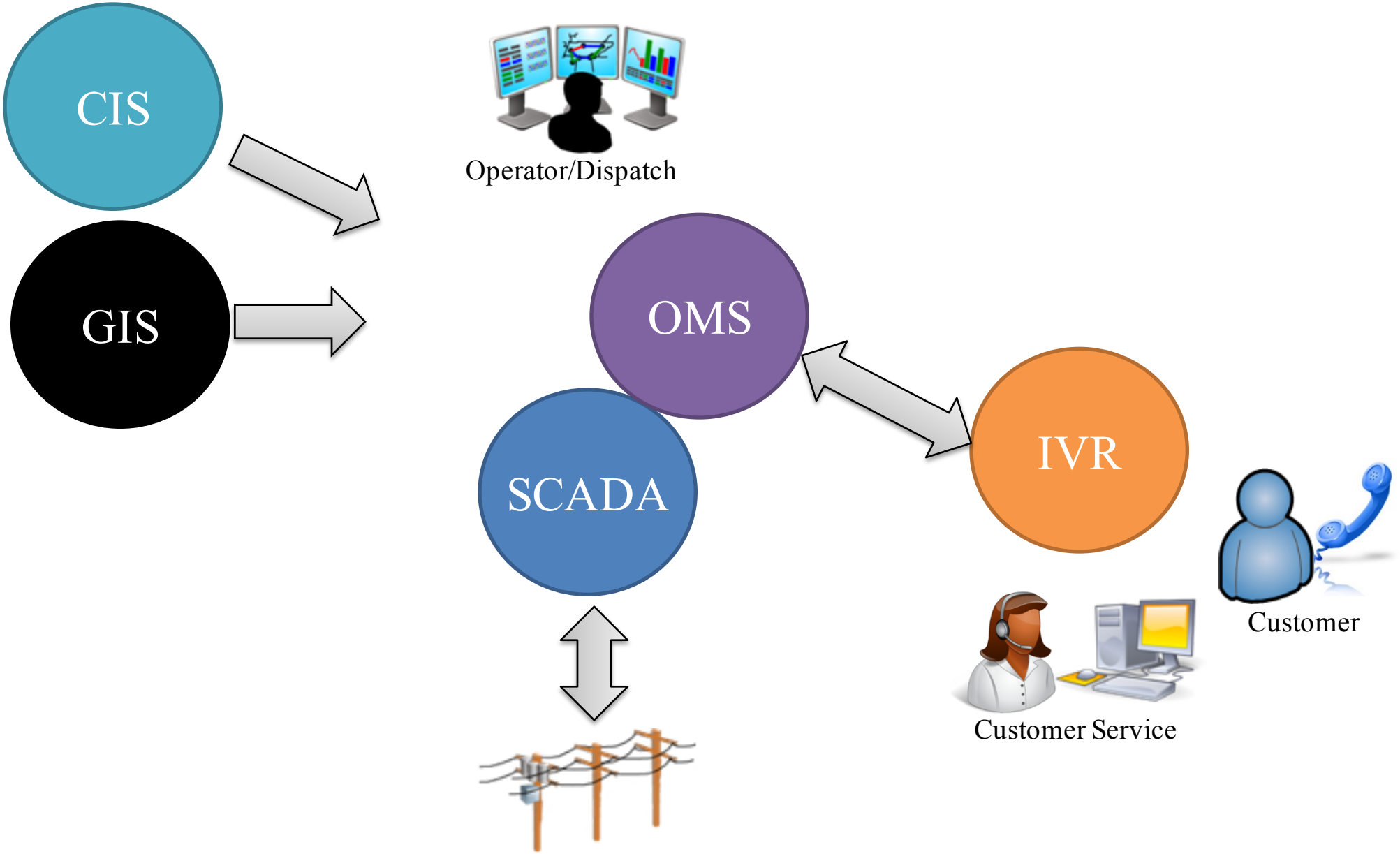

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SCADA Notes

- OMS Integration
  - MultiSpeak or ICCP typical
  - Switch status
  - Voltage/current values - Indicate when a sub is out
  - Fault currents or distances?

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Wolf

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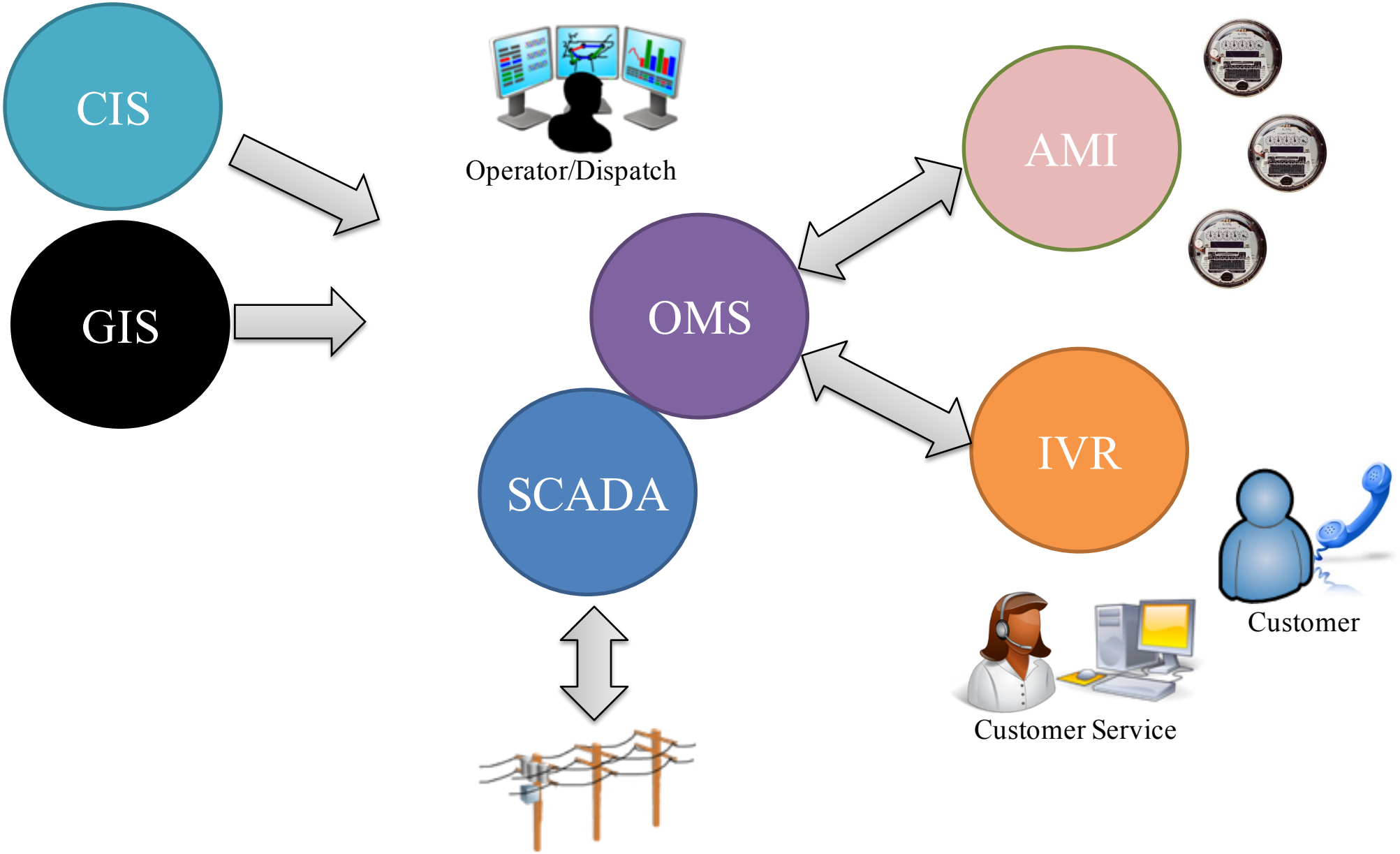

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AMI Notes

- Outage Management
  - Last gasp notifications
  - Meter pings – confirm out/restored
  - Remote connect/disconnect
- Distribution Management
  - Sag/swell notifications
  - (Near)-Real time EOL voltages
  - Meter pings - voltage
  - Load profiles

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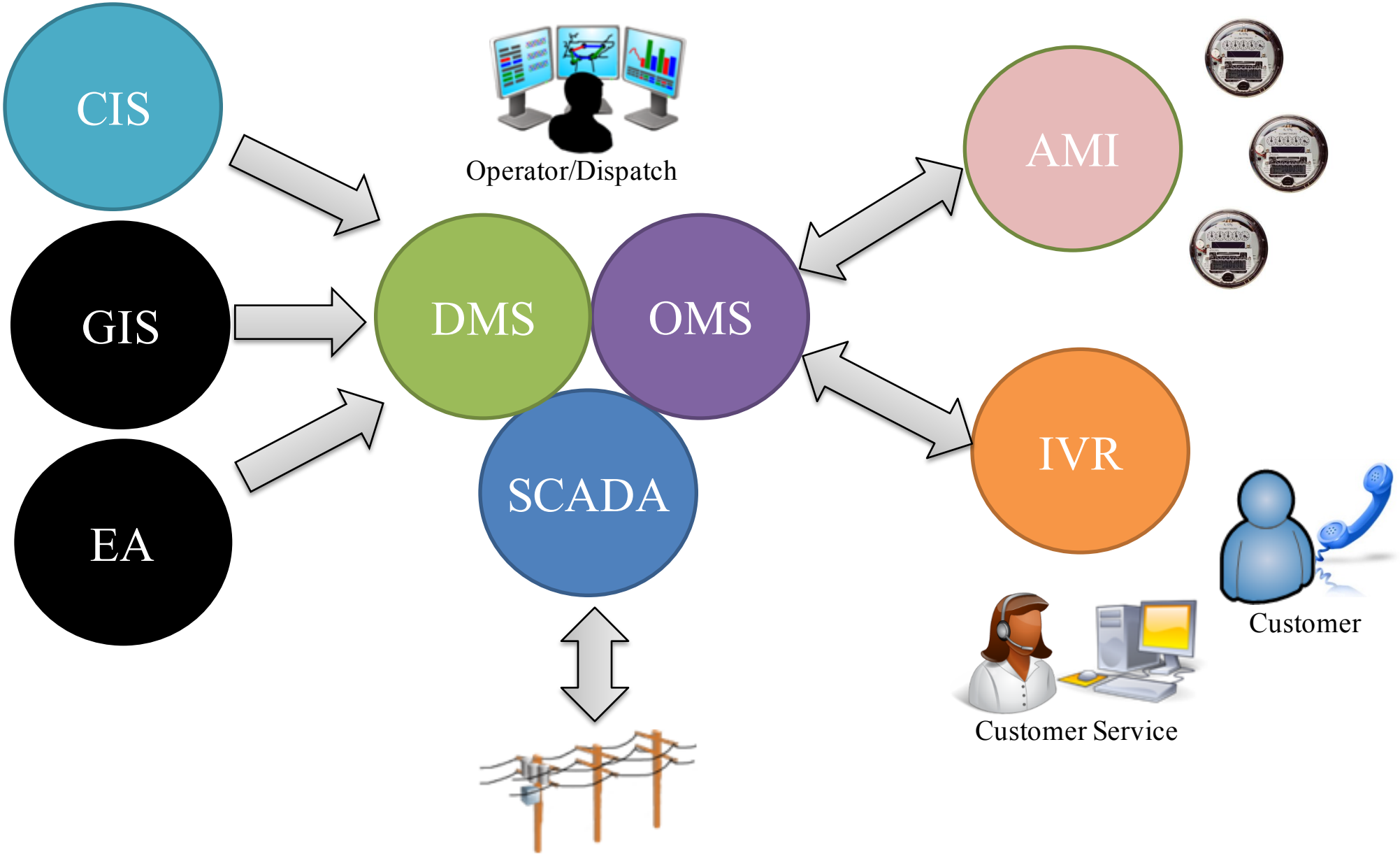
Automating Outage Management



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GIS Notes

- Topology
  - Required for OMS outage prediction
  - Tool for real time distribution switching (OMS or DMS)
  - Phasing is important
- Full electrical model
  - Device characteristics
  - Required for online load flow in DMS
  - Improves applications like Fault Location and Volt/VAR programs
- Substations?
- Business processes

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AMI Notes

- Outage Management
  - Last gasp notifications
  - Meter pings – confirm out/restored
  - Remote connect/disconnect
- Distribution Management
  - Sag/swell notifications
  - (Near)-Real time EOL voltages
  - Meter pings - voltage
  - Load profiles
- Communications requirements?

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Cliff Notes

- What type of company?
- Where are you today?
- Where do you want to go?
- GIS
  - Topology model with good phasing
  - Full electrical model
  - Drawn for operations
- SCADA
  - OMS Integration

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Cliff Notes

- AMI
  - Last gasp outage notifications
  - Sag/swell notifications
  - Pings
  - (Near)-Real time voltage values
  - Load profiles
  - Communications requirements

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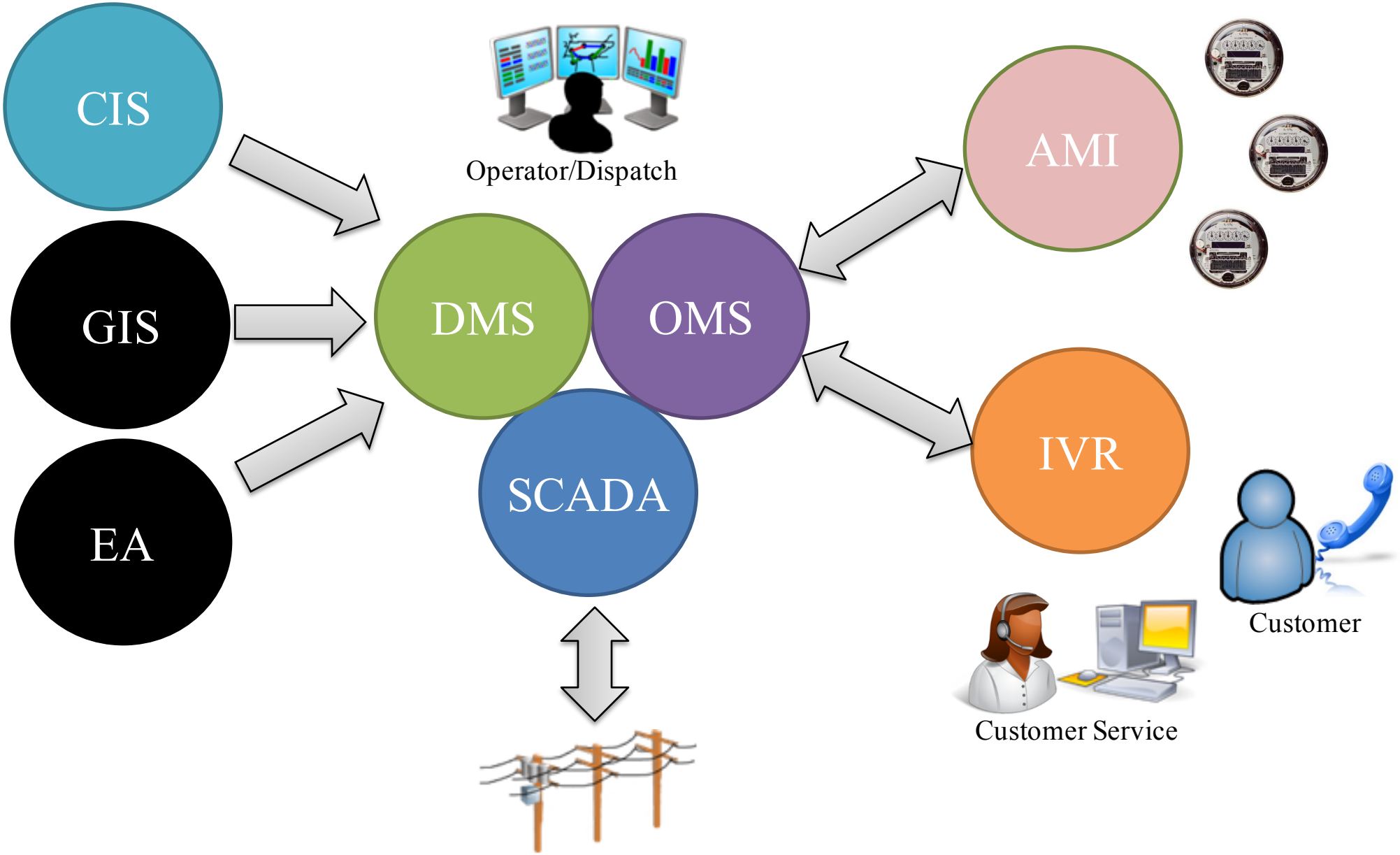
Automating Outage Management



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Questions?

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Thank You

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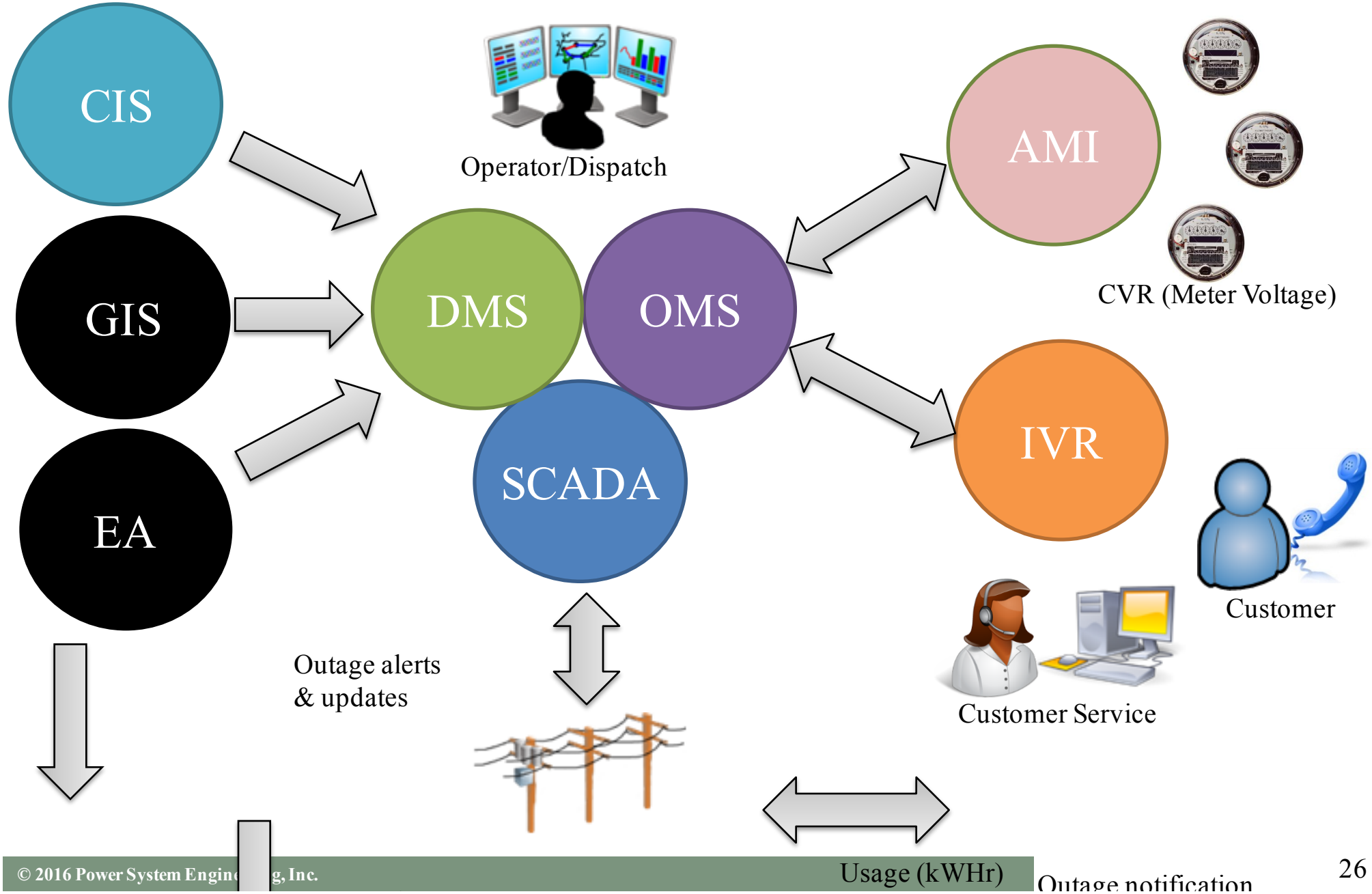
Automating Outage Management



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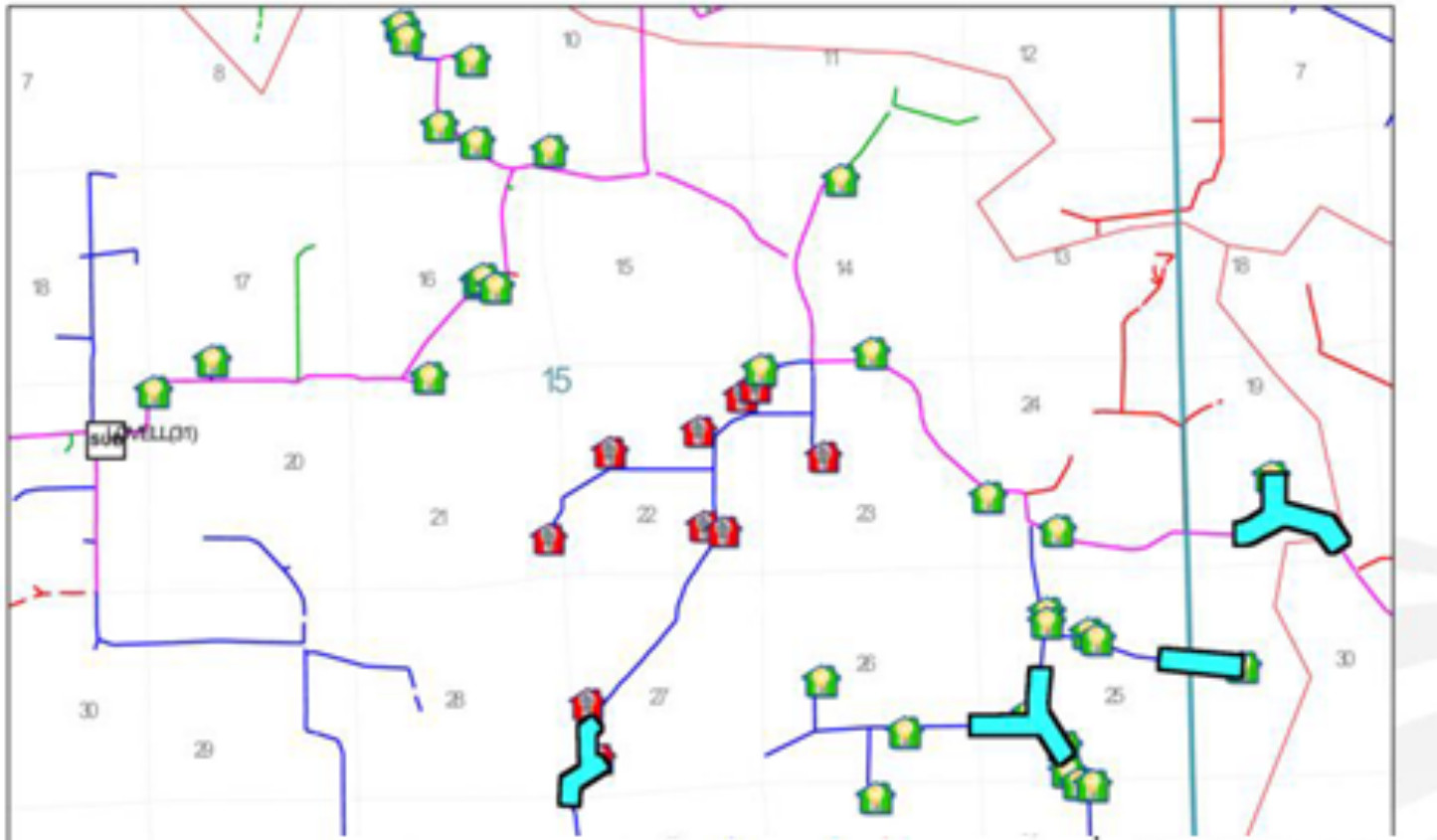

			Fault Currents		
Substation	Feeder	Time	Aph	Bph	Cph
Lovell	Ckt 3	1/10/2013 17:39:10	344		
Lovell	Ckt 3	1/10/2013 17:39:07	323		
Lovell	Ckt 3	1/10/2013 17:39:06	317		
Lovell	Ckt 3	1/10/2013 17:39:04	327		

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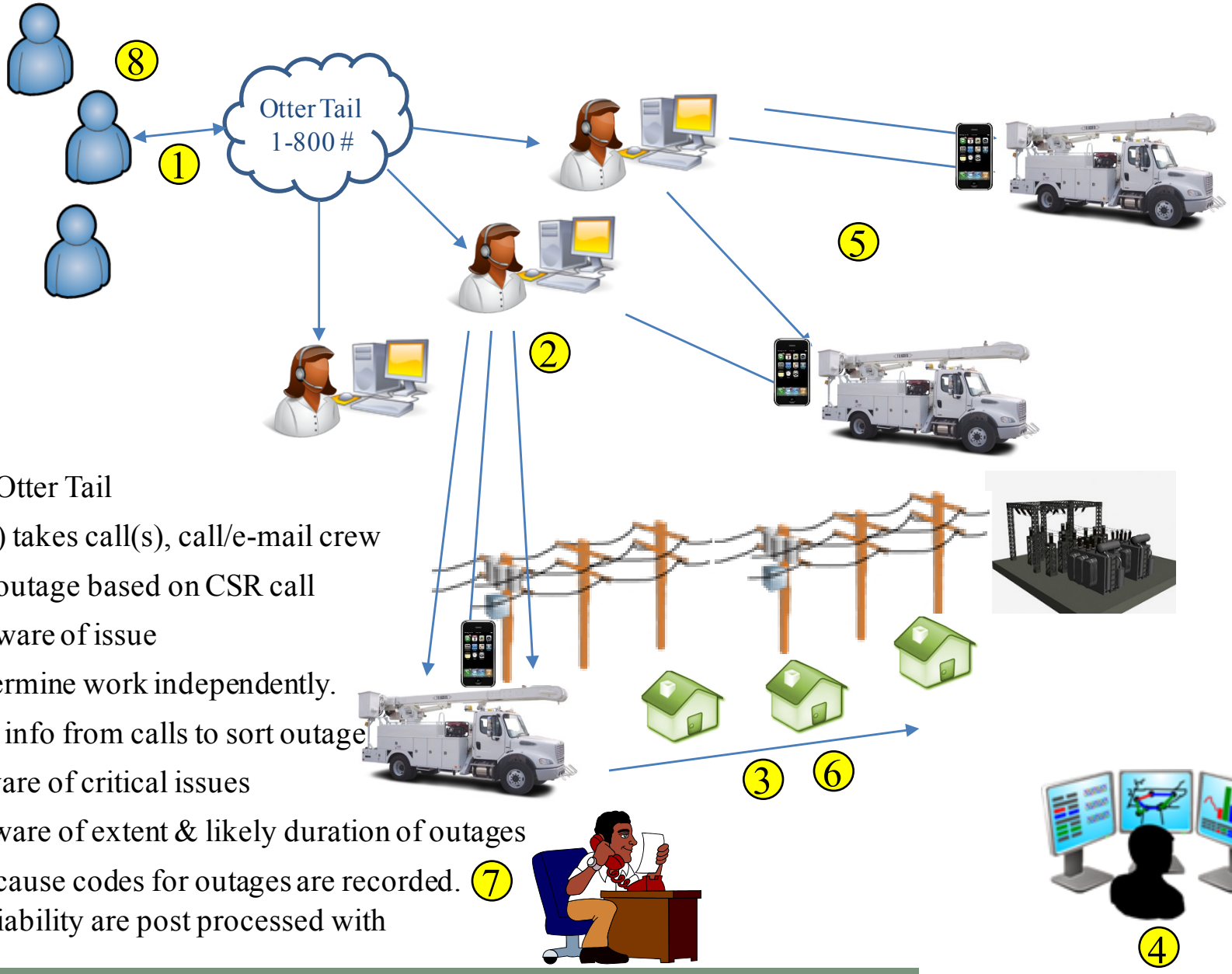
Outage Management – Traditional



1. Customer calls Otter Tail
2. CSR (Mgr, Ops) takes call(s), call/e-mail crew
3. Crew looks for outage based on CSR call
4. Operations unaware of issue
5. Individuals determine work independently.
6. Crews combine info from calls to sort outage
7. Managers unaware of critical issues
8. Customers unaware of extent & likely duration of outages
9. Uncertain how cause codes for outages are recorded.
10. Statistics for reliability are post processed with available data.

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Operational Transitions

- New methods can help us improve traditional operations.
- We're going to look at what it takes to support operational improvements in some of these areas,

	Traditional Operations	
Finding Faults	Drive the line to look for faults	Fault Location
Alarm Notification	SCADA Operator manning terminal 7-4, calls crews No SCADA Operator, checks SCADA when outage calls come in	Remote Notification
Crew Information	Crews get information over radio from dispatch	Mobile Crew Data
Phone Calls	CSRs hear about outages from customer calls, start to formulate picture of outage	AMI Integration
Back-feeding	Crews drive to isolation & tie points	Operator controlled
SOM & Testing		Testing switching

Can we overlay a day in the life discussion for an operations person with a discussion about what it takes to make these changes happen

- System Technical discussion – GIS prep, integration, Fault Data, Back-feeding
- Process Change discussion –

What utility examples can we include to make it more relatable?

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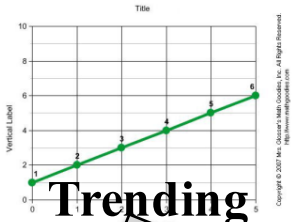
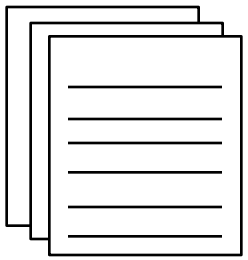
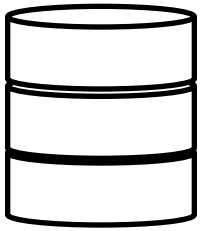
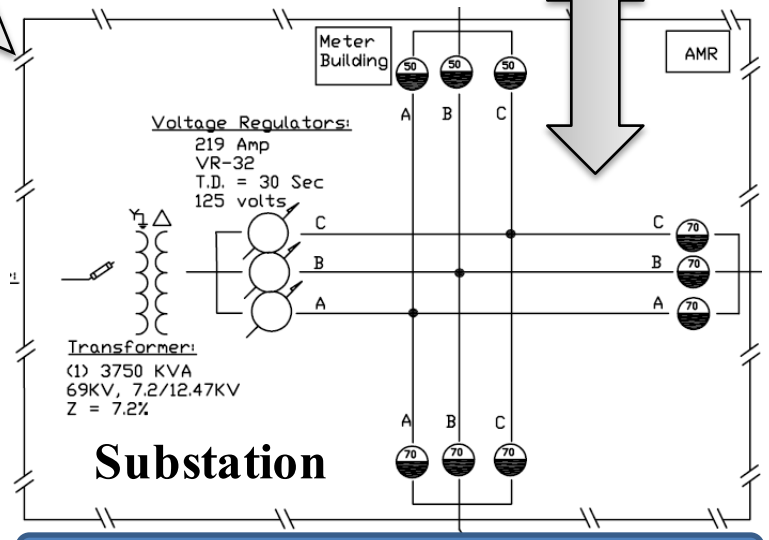
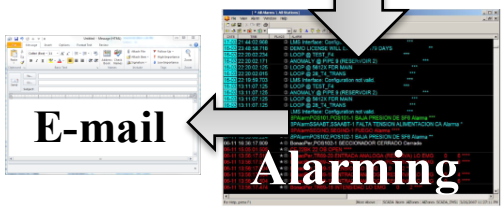
How are using SCADA today?











Switch Order Management

DG Monitoring

Fault Detection, Isolation & Restoration

Voltage Optimization

Data Acquisition

- Read Power, Current, etc.
- Status when Breakers Trip
- Notice of Blinks
- Fault Type & Distance
- MW Hours Peak Demand
- Winding Temperature

Control

- Trip Breakers
- Regulator Set Points
- Set Hot Line Tag, …

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SCADA Foundation Feature Review

How much benefit are you getting from your system today?

	Feature	Used Currently	Future Value
Foundational Features	**Substation One-Line**: Essential substation information such as status, power, and voltage is visible. Operators can perform basic trip / close and voltage raise / lower functions.		
	SCADA Alarm Handling: Operators have the ability to view alarms based on change of status or level of an analog value.		
	SCADA Alarm and Event Logs: Searchable logs of all alarms and operator initiated events such as control operations, alarm acknowledging, logging in and out.		
	Reporting: Managers and operators can easily generate reports of system performance over various periods of time.		
	Trending & Graphs: Ability to easily view both current and historical analog values in a graph.		
	Tagging: Ability to apply tags to perform scan inhibit, alarm inhibit and control inhibit.		
	Disaster Recovery: Ability to have redundant servers allowing operations to continue in the event of a hardware failure or site disaster.		
	Remote Notification: Personnel receive text messages, e-mails or voicemails when significant alarms occur.		
	Remote Access: Personnel can see SCADA screens remotely to understand alarm situations better or to verify system status.		
	Multiple User Access Rights: Ability to allow different users to have different authorization in the system and tracking of actions taken by users.		
	Fault Event Information: Operators can see the cause of breaker trips including phases involved, fault type and fault current magnitude to more easily diagnose causes.		
	Historical Archive: This feature entails an SQL searchable database that can be used to pull historical system information into Excel for reports or for planning studies.		

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SCADA Advanced Feature Review

Do you have need for some of these advanced features?

	Feature	Used Currently	Future Value
Advanced Electric SCADA Features	**Load Control**: Ability to send signals to disable A/C units, water heaters, etc. for a period of time as needed.		
	Outage Management System (OMS) Integration: Report breaker and switch status changes to the OMS to assist in outage prediction.		
	Automated Feeder Restoration: Communicate with substation and down-line feeder reclosers to automate detection, isolation and restoration of a fault.		
	Conservation Voltage Reduction: This entails the ability to reduce regulator and LTC set points in order to reduce demand.		
	AMI System Integration: Integration to AMI allows meter voltages to be brought into SCADA for controlling system voltage.		
	Inter-Control Center Protocol (ICCP) Connection: ICCP connections allow other utilities to share data from their system.		

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Expanding a Foundational SCADA Master

A foundational SCADA system can grow with CEC's use.

Base Features

Substation and Feeder Control
Fault Type and Distance to Fault
Trending & Graphing
Alarming including e-mail
Historical Archive
Corporate Dashboard

Integrations

OMS for Outage Notification
AMI for Voltage Measurement

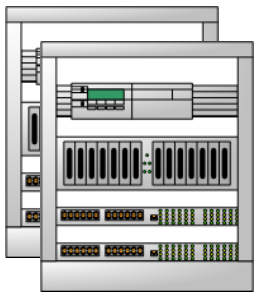
Expansion Features

Automated Restoration
Voltage Optimization
Switching Orders
Load Flow & Network Stability

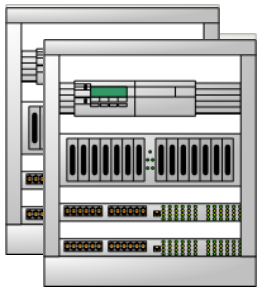
Main Operations Center

District Operations Centers

Remote Access



Redundant Servers



Triple & Quad Redundancy

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Improved Outage Handling and Protection

Many options are available today to assist with outages:

- **Outage Detection & Location**: Provide better information to line crews, customer service, and operations.
- **Fault Investigation**: Extract data easily to better recreate the source of the fault.
- **Quicker Restoration**: Reduce outage time for those who do not need to be affected by a fault.
- **Reduced Miscoordination**: Consider reclosers which can address miscoordination issues.

Build on proven protection principals you have trusted for years.

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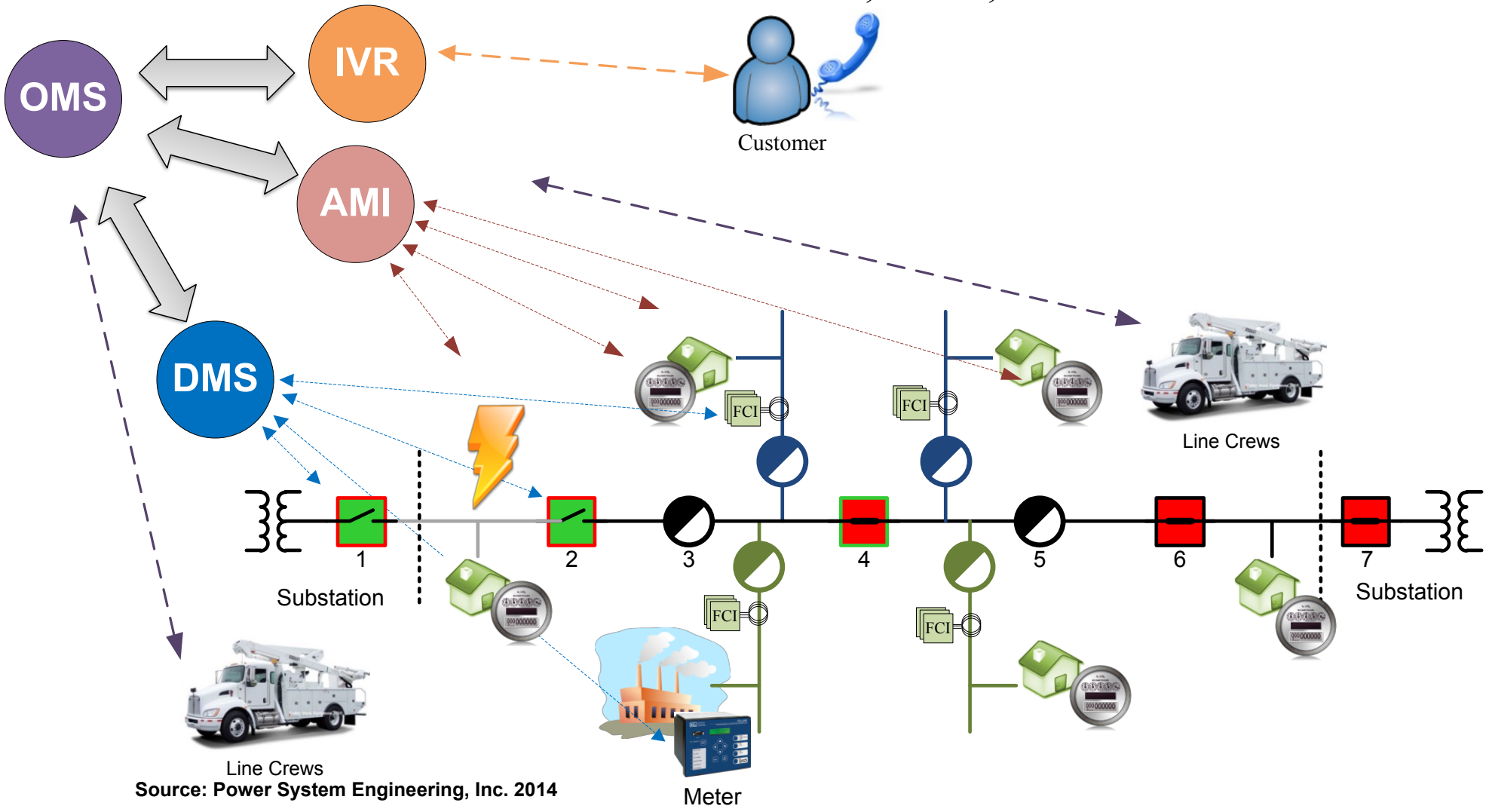
The Role of an OMS and DMS in Outage Handling

- OMS & DMS can both have network models of your distribution system.
- OMS has additional information from members, crews, and AMI.



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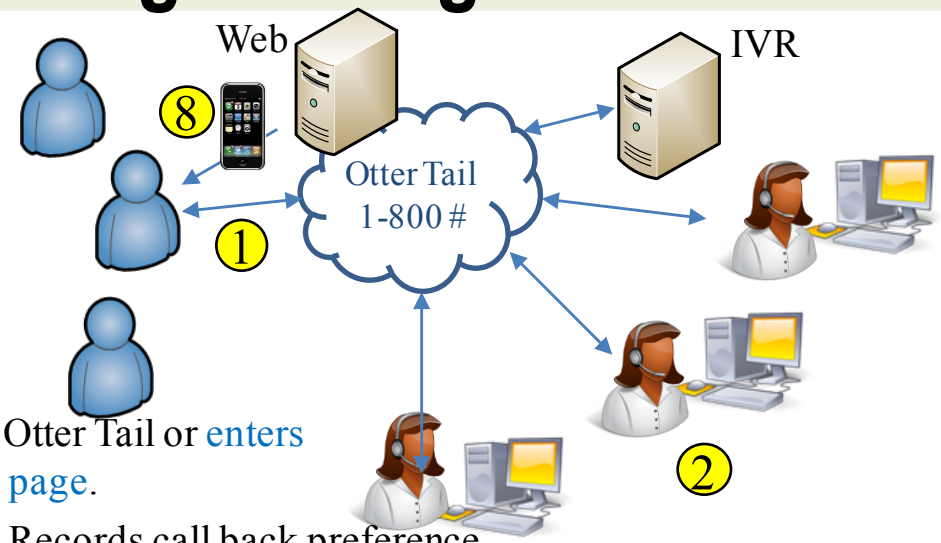
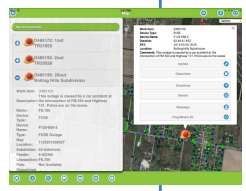
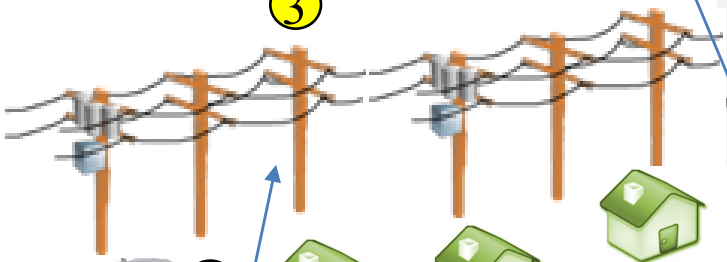
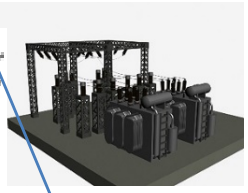
Outage Management – Industry Leaders









1. Customer calls Otter Tail or enters outage via web page.
2. CSR takes call. Records call back preference. Informs customer of outage extent and possibly estimated restoration time. IVR handles overflow.
3. OMS predicts outage location based on call(s) and SCADA breaker information. Fault location predicted based on fault current.
4. Operations sees outage areas on system map.
5. Operations sees all outages and works with crews coordinating priority restoration.
6. Crews receive outage location information and update status of the outage in the field.
7. Managers monitor system status.
8. Customers receive info from CSRs, monitor on web.
9. Outage causes recorded for each event.
10. Statistics calculated automatically.

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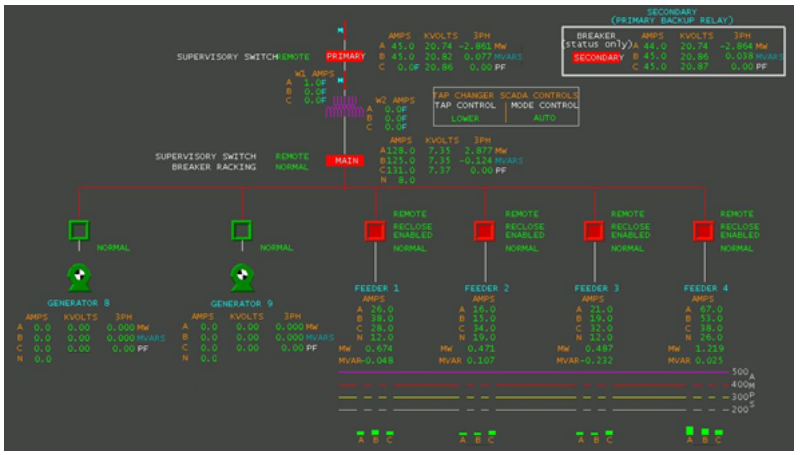
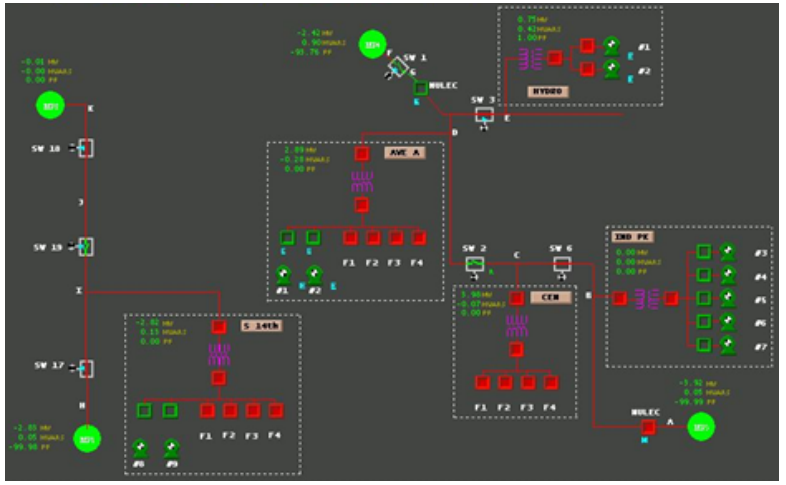
SCADA to a Distribution Management System

- Centralized FDIR expands SCADA into a DMS
- SCADA
  - Controlling your substations
  - Monitor line currents
  - Alarms indicating breaker trip, etc.



- Distribution Management System
  - Control your distribution system
  - Locate faults on distribution lines
  - Modeling your feeders
  - Feeder voltage prediction (network stability)
  - Feeder voltage management (VVO)



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Approach

Goal: Review the usability of GIS for DMS to,

- Offer feedback to on what effort may be required
- Better evaluate vendor's strengths given their ability to import GIS.

Process: We review two aspects of the GIS

- Inventory
  - DMS Fields: How well would the GIS fulfill the kinds of information needed by a DMS?
  - Completeness: How consistent and complete were the fields?
- Model
  - Connectivity Approach: What approach is used to build the device connectivity from substation to meter.
  - Network Model: Import the model into an Engineering Analysis package to evaluate the rules necessary to do so.

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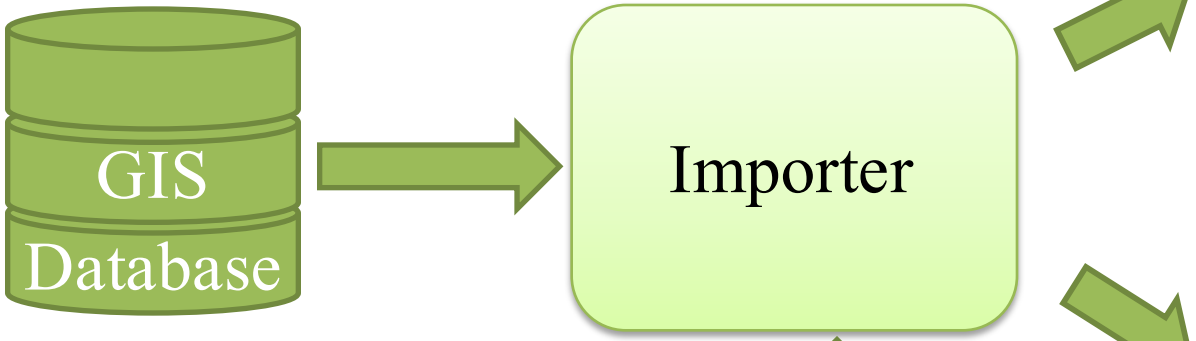
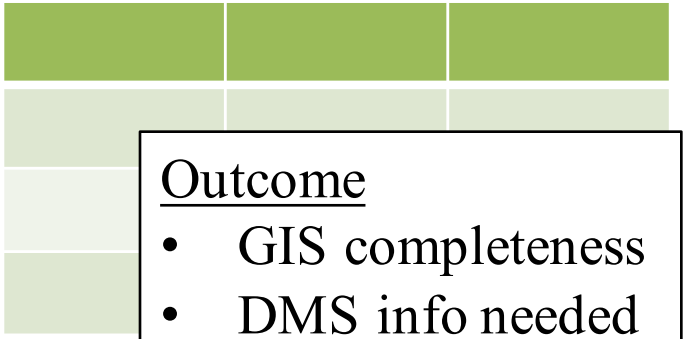
GIS Analysis Process

PSE analyzes your GIS database from the perspective of a DMS

- Compare against DMS data needs.
- Build an electrical network model.

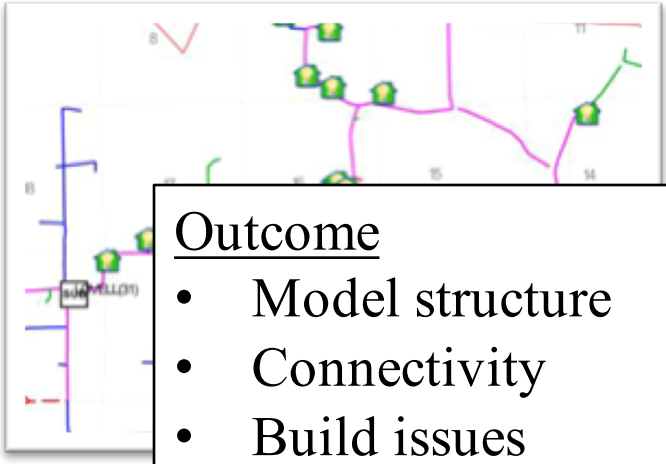


DMS/OMS Data Analysis



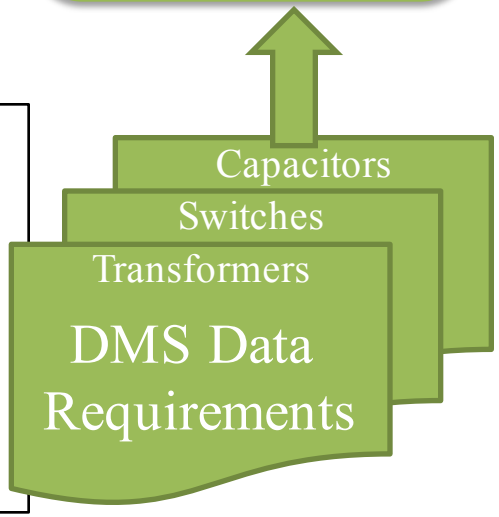
Outcome
- GIS completeness
- DMS info needed

Electrical Network Model



Outcome
- Model structure
- Connectivity
- Build issues

DMS Data
- Electrical ratings (interrupting current)
- Engineering Model Data (impedances)
- Device settings (trip settings, LDC)



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DMS Data Needs – Generic

- These base fields will be required for all feature classes
  - Common fields (ID, Name, GIS State, Phase) filled in well.
- Some fields may be inferred
  - Feeder: DMS will need to associate each device with a feeder.
  - Area of Responsibility: To optionally show sections of the system to an operator, DMS can infer AOR from substation.
  - Base KV: Nominal voltage a device should perform at.
  - Rated KV: Maximum voltage rating of a device.

ADMS Field Name	Description	LCEC GIS Column Name	Status	Comments
ID	GIS ID	FID	100% Full	Vendors may use different fields for the unique ID.
NAME	Device Name	EQUIPNUM	100% Full	
FEEDER	Feeder ID	-		Not explicit. Possibly derive from connected conductors.
GIS_STATE	GIS State	-	20% Full	Is S_RETIRED a possible match? (20% have value of 0)
PHASE	Phase of the device	PHASE	100% Full	
AOR	Area of responsibility	-		Typically this can be provided with an feeder to AOR mapping.
BASE_KV	Base voltage	-		Not explicit. Possibly derive from connected conductors.
RATED_KV	Rated voltage	-		Not explicit. Possibly derive from connected conductors.

Information may be inferred by DMS. Information will be required from GIS or elsewhere.

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DMS Data Needs – Switches

- Some fields will have to be added or alternate sources provided.
  - Rated Amps
  - Is Ganged: Are single-phase devices included as separate devices?
  - Load Break: Capable of breaking load?
  - Max Interrupting Current
  - Forward and Reverse Trip Amps

ADMS Field Name	Description	GIS Column Name	Status	Comments
NORMAL_STATE	Normal state	STATUS	100% Full	What is the definition of CT?
RATED_AMPS	Rated Amps	SIZE_R	59% Full	All data in this column is either 0 or null.
SWITCH_TYPE	Type of the switch (fuse, recloser, etc.)	LAYER	100% Full	LAYER or EQUIPID?
IS_GANGED	Is this gang operated?	-		Are single-phase devices included as separate devices? DMS may want to combine.
LOAD_BREAK	Can this switch break load?	-		
BYPASS_EXISTS	Can this switch be bypassed?	-		
MAX_INTERRUPT	Maximum interrupt capability	-		
FWD_TRIP_AMPS	Forward trip amps	-		
REV_TRIP_AMPS	Reverse trip amps	-		

Information may be inferred by DMS. Information will be required from GIS or elsewhere.

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DMS Data Needs– Loads (Service Transformers)

- Connection Type: Just verify definitions of 1 or 2
- Load Class
- Load Type: conforming or non-conforming
- KW_A/KVAR_A/KW_B…: May come from AMI/MDM.
- Customer Counts: Can be calculated

ADMS Field Name	Description	GIS Column Name	Status	Comments
SEC_BASE_V	Voltage meters will report	LO_VOLT	100% Full	HI_VOLT instead?
PF	Average PF	-		Usually defaulted based on load class (residential, commercial, etc.). May be known for large loads.
Conn_Type	Type ("Y", "D", or "YG")	MOUNTCODE	100% Full	All values are 1 or 2, what do they mean?
KW_A	Nominal kW for Phase A	-		For roughest estimate, can be defaulted based on xfmr size.
KVAR_A	Nominal kVAR for Phase A	-		For roughest estimate, can be defaulted based on xfmr size.
KW_B	Nominal kW for Phase B	-		For roughest estimate, can be defaulted based on xfmr size.
KVAR_B	Nominal kVAR for Phase B	-		For roughest estimate, can be defaulted based on xfmr size.
KW_C	Nominal kW for Phase C	-		For roughest estimate, can be defaulted based on xfmr size.
KVAR_C	Nominal kVAR for Phase C	-		For roughest estimate, can be defaulted based on xfmr size.
LOAD_CLASS	The type of load class	LOADTYPE		This field is mainly 0 or null with a few 1's. What is the intent?
LOAD_TYPE	conforming/non-conforming	-		
LOAD_PROFILE	Load profile for the device	-		
CUST_3PH	3-phase customers	-		May be calculated based on CIS provided data.
CUST_A	Number of customers on A	-		May be calculated based on CIS provided meter association.
CUST_B	Number of customers on B	-		May be calculated based on CIS provided meter association.
CUST_C	Number of customers on C	-		May be calculated based on CIS provided meter association.

Information may be inferred by DMS. Information will be required from GIS or elsewhere.

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What would we talk about here?

What MultiSpeak Supports and what that covers

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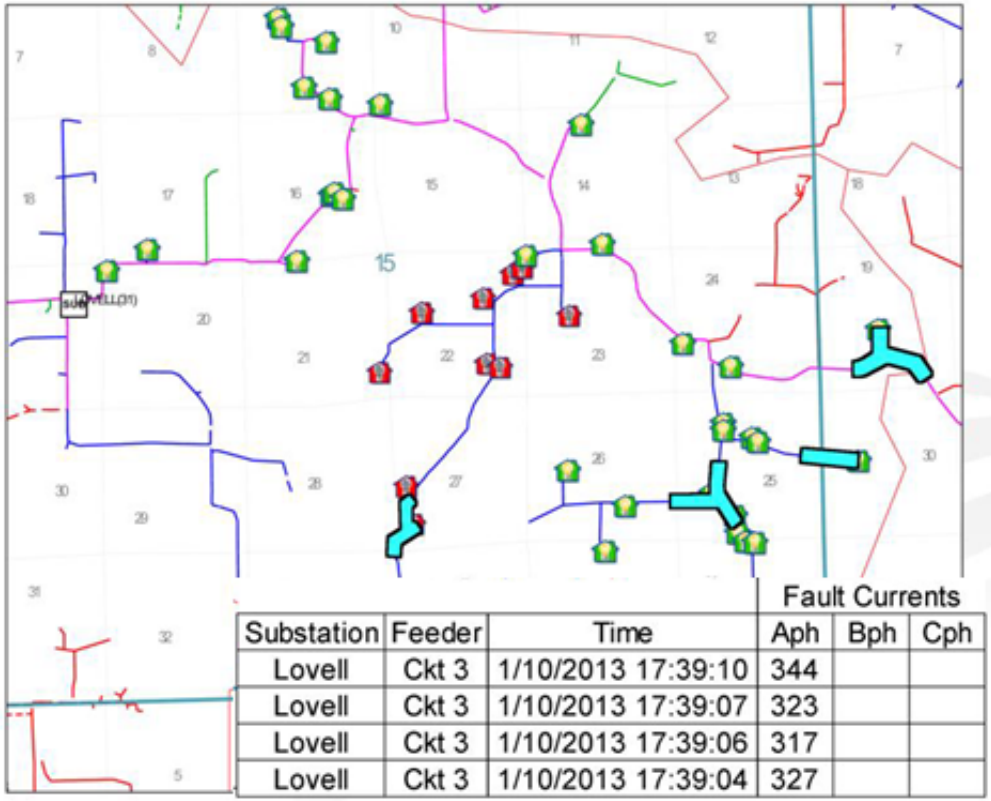
Operations – Using Fault Location to find outage

- SCADA sees fault, highlights the line sections based on engineering model where fault could be located.
- AMI pings meters by sub/ckt/ph to determine extent of outage. Green is on, red is out of power
- 2-3 minutes later, know what is out of power.
- This case, knew that an OCR was out and the fault was located in highlighted region.
- Can even restore outages before members call.

Downline Fault Location



			Fault Currents		
Substation	Feeder	Time	Aph	Bph	Cph
Lovell	Ckt 3	1/10/2013 17:39:10	344		
Lovell	Ckt 3	1/10/2013 17:39:07	323		
Lovell	Ckt 3	1/10/2013 17:39:06	317		
Lovell	Ckt 3	1/10/2013 17:39:04	327		

Courtesy: Maquoketa Valley Electric Cooperative

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Engineering – Improve Fault Investigation

Incredibly valuable relay data that uncovers whether your protection is performing as hoped.

- Fault Location: Operations Data – display in SCADA
  - Fault type: line-ground, line-line, phases involved
  - Fault current
  - Fault time
  - Distance to fault
- Event History: Engineering Data – Oscillography
  - ¼ cycle data from relay
  - All currents & voltages
  - 30 to 60 cycles of data around fault time
  - Analyze with relay/recloser vendors tool

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Line Sensors & Fault Indicators

Power Delivery Products

- Wireless to base station
- Fault data to SCADA
- 10 year battery powered

Cooper

- Cellular to control room
- Fault data to SCADA
- Line powered with battery backup.

Grid Sense

- Wireless to base station
- Fault data to SCADA
- Solar powered with battery backup.
- Waveform data saved when faults occur.

Sentient

- Cellular and other direct communications options.
- Fault data to SCADA
- Line powered with battery backup.
- Waveform data captured continually.

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Line Sensors / Fault Indicators

- Traditional fault indicators were visual indicators for line crews driving along a line.
- New fault indicators provide fault and normal operation information back to SCADA.

Category	Faulted Circuit Indicators			High Resolution FCIs / Sensors		
Company	PDP	Eaton	SEL	GridSense	Sentient	OptiSense
Product	Smart Navigator	Grid Advisor II	WSO	Line IQ	MM3	
Power Source	Battery	Line Current	Battery	Solar	Line Current	120VAC @ Base
Battery Life	15 Year	Several hour backup	> 10 Year	"x" hours w/o sunlight	Several hour backup	9 hour backup
Communications						
Sensor	Local Wireless (100 ft.)	Cellular from Sensor	L+G or On-Ramp Wireless from Sensor	Local Wireless (100 ft.)	Cellular, L+G, Silver Spring, Cisco	Fiber
Base Station	Ethernet			Ethernet		Ethernet
SCADA Support	DNP from Base Station	DNP from Sensor	DNP from Head End	DNP from Base Station	DNP from Sensor	DNP from Base Station
Current Accuracy	+/- 10% @ 20C +/- 20% over temp		+/- 25%	+/- 5%	+/- 10%	+/- 0.5% @ 25C +/- 1.5% over temp
Waveform Data	N/A	N/A	N/A	200ms / event (10 samples / cycle)	Continuous (130 samples / cycle)	Continuous (250 samples / cycle)
Fault Indication	High intensity LEDs	High Intensity LEDs	Reflective Target	High intensity LEDs	High intensity LEDs	N/A

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FCI Point Data Use

- Cooper FCIs have a lot of valuable data. How much of it is being used to your advantage today?

Point Type	Point Name	PDP FCI	Cooper	GridSense	Used Today
Status Values	FCI Red	Y			
	FCI Green	Y			
	Battery Voltage OK	Y	Analog	Analog	
	FCI Comm Loss	Y	Cellular		
	FCI Low Battery	Y	Analog	Analog	
	Battery Charger Status		Y		
	Power Flow Direction		Y		?
	Fault (Tripped)	Y	Y	Y	?
	Permanent Fault	Y	Y	Y	?
	Temporary Fault	Y	Y	Y	?
	Current Loss	Y	Y	Y	
	Overcurrent Detected	--	Y	Y	?
	Voltage Loss	Y	Sag & Swell	Y	
	Fault Direction		Y		?
Controls	Reset Targets		Y		
	Clear Counters		Y		

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FCI Analog Data Use

Point Type	Point Name	PDP FCI	Cooper	GridSense	Used Today
Analog Values	Phase Current	Y	Y	Y	?
	Phase Voltage	--	Y	Y	?
	Last Good Known Current	Y		Y	
	Average Current	Y	Y		
	Minimum Current	Y			
	Peak Current	Y			
	Temperature	Y	Y	Y	
	Conductor Temperature	Y		Y	
	Frequency	--	--	Y	
	Power	--	--	Y	?
	Reactive Power	--	--		
	Power Factor	--	--		
	VDC	Gateway	FCI	FCI	
	FCI Comm Status	Y	Cellular		
	FCI Low Battery	Y			
	Fault Current	Y	Y	Y	?
	Fault Duration	Y			
	Temporary Fault Counter	Y	Y		
	Permanent Fault Counter	Y	Y		
	AC Loss Counts		Y		
	AC Restore Counts		Y		
	di/dt Counts		Y		

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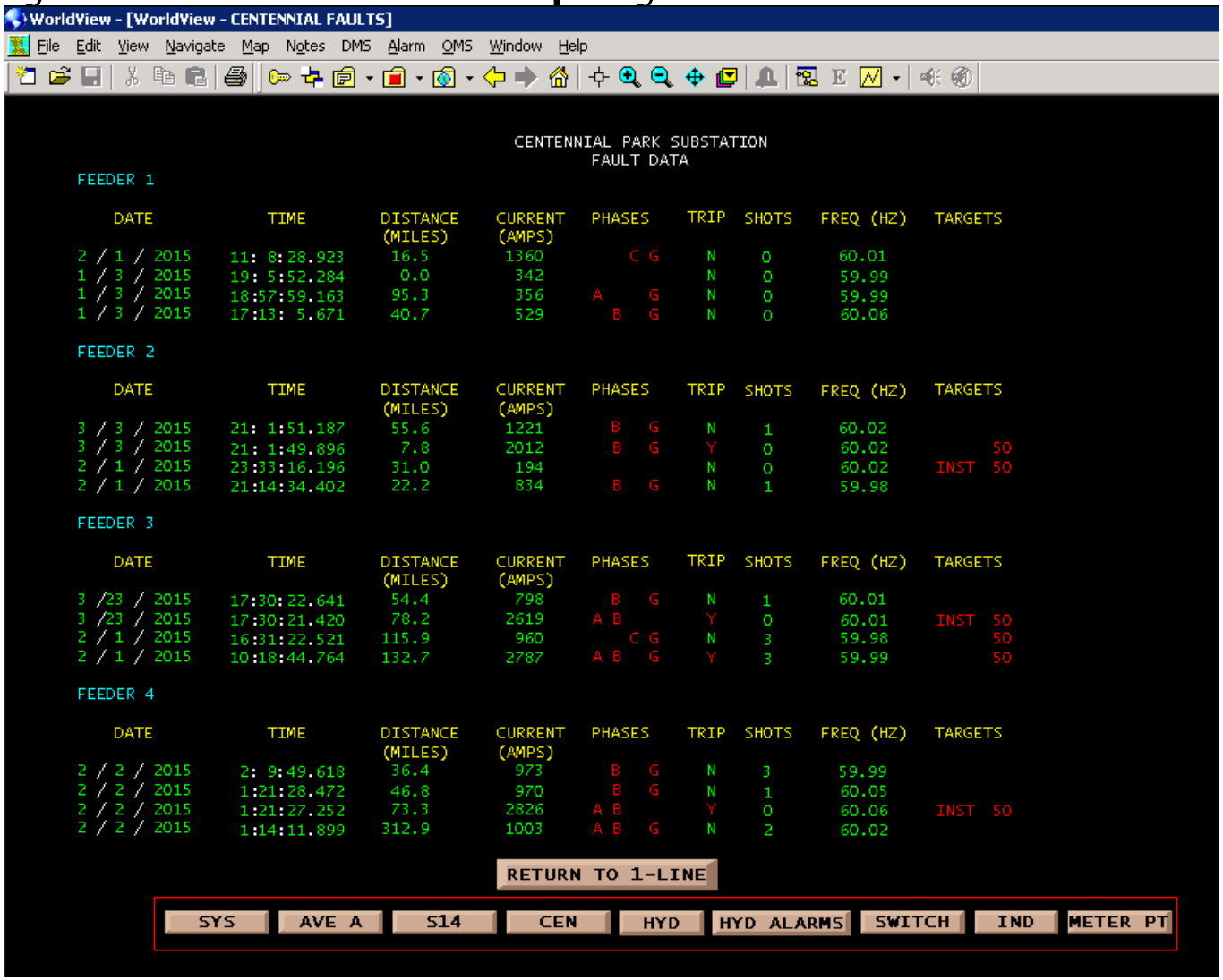
Fault Information

The screen below provides an example of fault data from a feeder relay that could be displayed on SCADA.



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Screens – Fault

- Eventually we want to make fault data easily visible to operators.
- Provide fault data to OMS as well as breaker status.

Source	Line (In/Out)	High Side	Feeder
	FCI or MO	Relay or FCI	Recloser
Analogs			
Fault Type	F	F	F
Fault Distance	F	--	F
Fault Current	F	F	F
Recloser Shot Count	--	--	F
Fault Time	F	F	F
Analogs			
Trip Target	--	F	F
50/51 Target	--	F	F
87 Fault	--	F	--
A/B/C Phase Targets	--	F	F
Breaker Failure	--	F	F
Close Failure	--	F	F
Lockout	--	F	F
Ground Fault	--	F	F
SEF Fault	--	F	F

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Coordinated Outage Management

- Advanced metering infrastructure (AMI), together with SCADA and outage management systems (OMS), can also be used to locate permanent faults that result in outages
  - SCADA detects fault current followed by current drop due to OCR operation.
  - SCADA informs OMS of likely fault location.
  - OMS sends command to AMI to ping "bellwether" meters at critical system junctions looking for an outage.
  - OMS receives meter status from AMI indicating extent of outage.
  - Operators use SCADA to isolate & restore other areas

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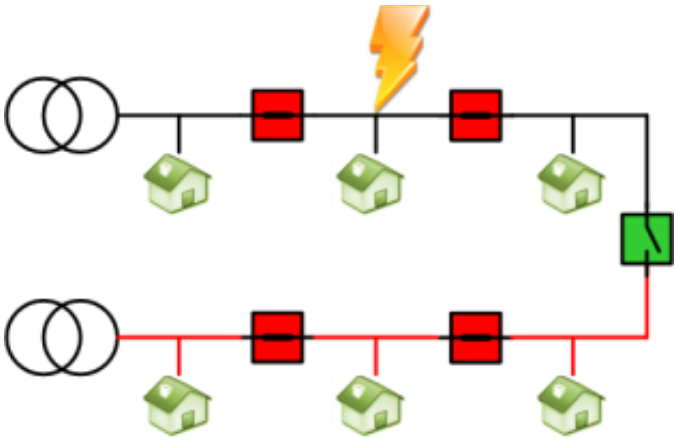
Benefits of Automated Restoration

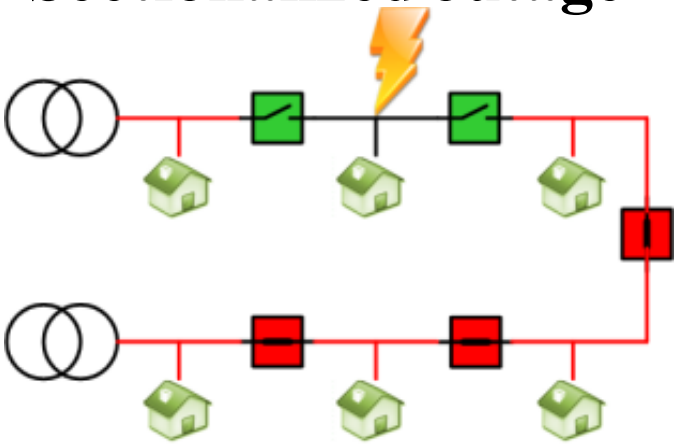
Best understood with an example:

- Outage occurs on a feeder with 1,000 meters
- Sequence of events without automation
  - Detect outage (5 min)
  - Crews drive from home to office (30 min)
  - Crews drive from office to outage (30 min)
  - Crews sectionalize outage (15 min)
  - Crews repair fault (60 min)
- Sectionalizing reduces outage to 300 meters
- Automation would allow operator to sectionalize while crews are in transit.

Original outage



Sectionalized outage



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Restoration Levels

It is critical to understand your end-goal for restoration before choosing an architecture to implement it.

- Level of operator intervention and automation
- Speed of restoration and available communications

Category	Process	Time Frame
Operator Activated Restoration	Detect trips with SCADA alarm, determine switching steps, coordinate with line crews, perform isolation & restoration	5 minutes
Centralized Automated Restoration	Software determines most likely fault location, isolation & restoration strategy.	30 sec – 2 min
Decentralized High-Speed Restoration	Products such as Siemens 7SC80 & S&C IntelliTeam coordinate amongst themselves	1-2 seconds
Automatic Source Transfer	Localized critical load source switching	~100ms (6-10 cycles)
Direct Transfer Trip	Transmission Line protection between separate substations	~100ms (6 cycles)

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Operator Interaction

- Key aspect to a centralized FDIR is the ability for operators to actively participate in the restoral process.
  - Verify Switching Orders
  - Red-line system changes
  - Planning & Operator Simulation
    - Indicate Faults and observe switching recommendations from system.
    - Perform switching and model system voltages under various loads.
  - Crew Interaction
    - Applying Hot Line Tags when crews are working on line segments.

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Centralized & Decentralized Considerations

- **Goals**
  - Operation Interaction: Control, approve or monitor
  - Speed of Restoration: Minutes or seconds
  - Model based or parameter based system
  - Multi-vendor recloser support

- **Situation**
  - Speed of communications
  - Distance between reclosers & coordination
  - Capabilities of your existing SCADA system
  - Coordination with your power supplier

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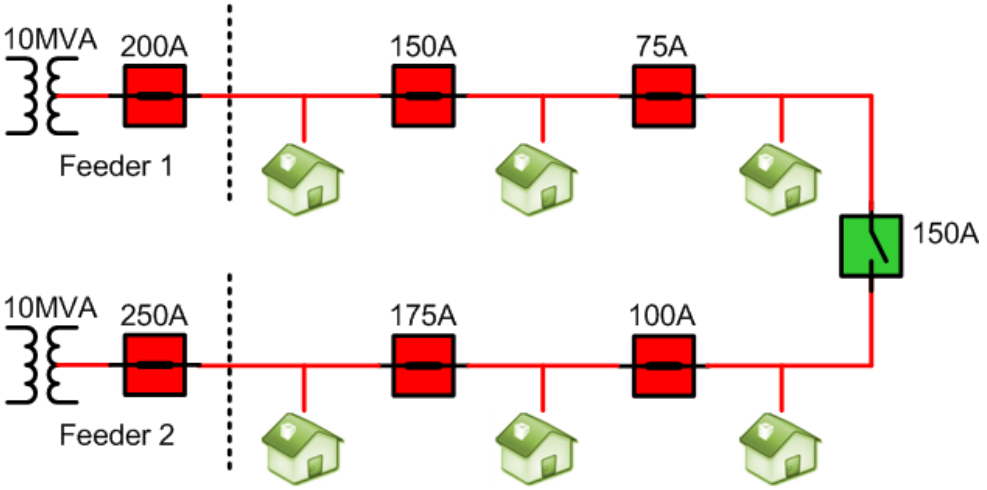
Modeling Automated Restoration

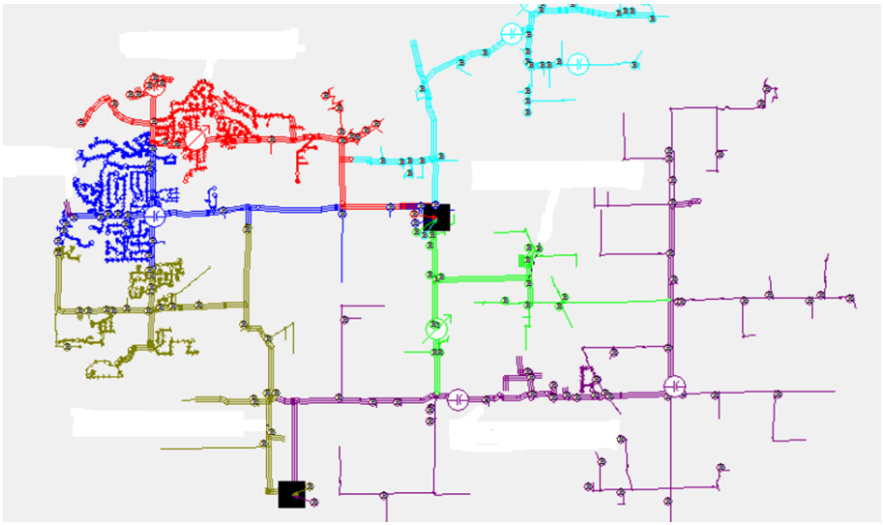
- The "model" is the set of information that the software uses to make decisions.
- It impacts what decisions the software can make.

Device Parameter Model



- Easier to configure.
- Can dynamically adjust load to allowable current levels.
- Cannot predict end-of-line voltage.

Full Electrical Model



- Import WindMil or other engineering model.
- Supports dynamic load balancing and end of line voltage prediction.
- Based on load prediction.

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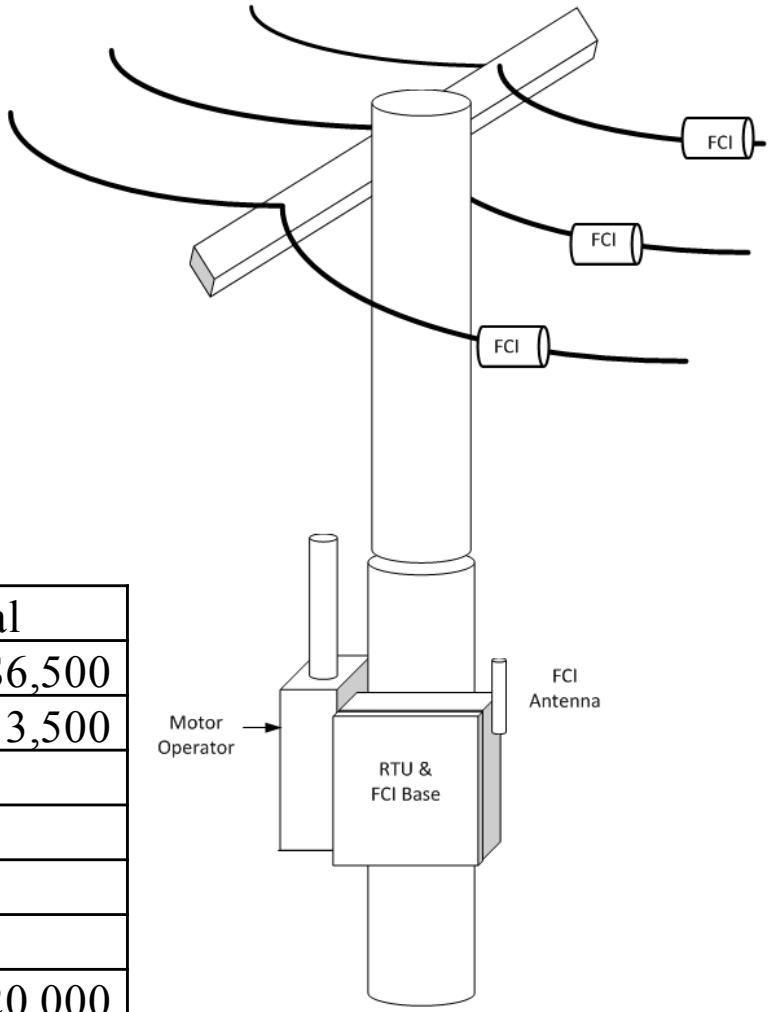
Automating Switches

- Typical recommendation is for reclosers at tie points to isolate and avoid outage on unfaulted feeder
- Load break and non-load break
- Make best use of existing switches
  - Motor operator (SEECO, Turner, …)
  - RTU
  - Faulted current indicators
    - Determine fault for isolating
    - Monitor demand for load balancing



Component	Component Cost	Total
Motor Operator		$6,500
Automation		$13,500
- RTU	$1,500	
- FCIs	$2,000	
- Communications	$5,000	
- Enclosure / Battery / Wiring	$5,000	
Equipment Total		$20,000

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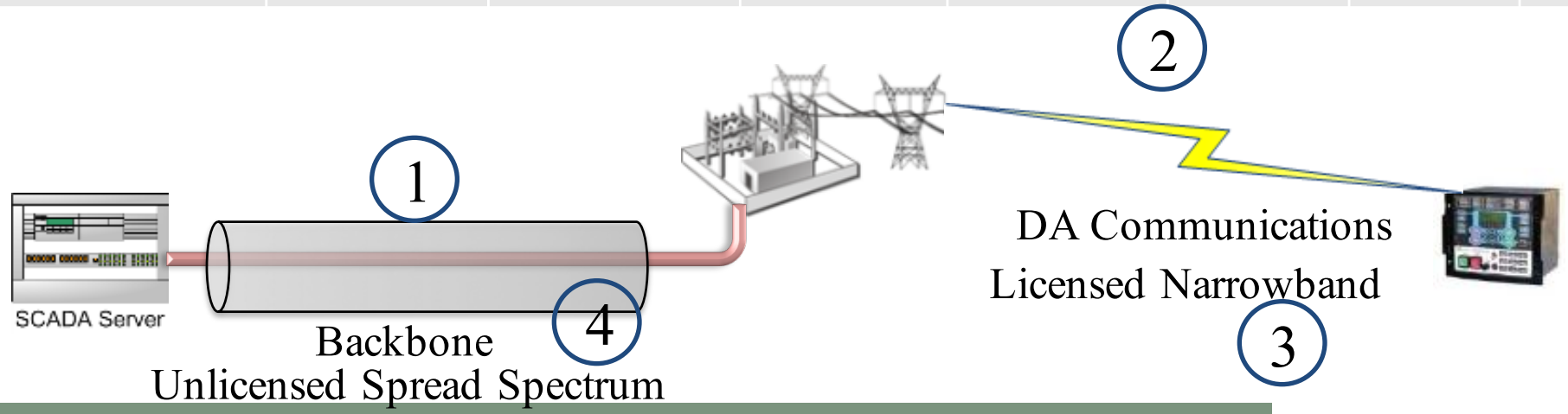
FLISR Latency & Bandwidth Considerations

- An example shows that latency (not bandwidth) drives system performance.
  - Turn-around time of the poll at 680ms sets time length
  - Last leg of DA communications throttles overall performance

			1	2	3	4	Total
Integrity Poll	Request	100 bytes	5ms	80ms	80ms	5ms	170
	Response	200 bytes	10ms	160ms	160ms	10ms	340
	Ack	100 bytes	5ms	80ms	80ms	5ms	170
	Total	400 bytes					680ms



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Bandwidth Study – Latency vs. Traffic Type

- Results below summarize predicted latency
  - 16 kbps is too slow for event polls with events
  - 64 kbps is acceptable for 25 to 50 devices
  - Round robin polling is more predictable

Legend

Latency	Indication
<3	Good
3-10	OK
10-30	Fair
30-90	Poor
>90	Horrible

Latencies (Avg / Max) in seconds for various traffic configurations

Protocol	Polling	Traffic Type	100kHz (256kbps) - CalAmp SD				25kHz /100kHz (64kbps) - CalAmp SD				25kHz (16kbps) - CalAmp SD			
			25	50	100	200	25	50	100	200	25	50	100	200
DNP Serial	Shot-gun	Event Poll - no events	0.1/0.5	0.2/1.1	0.4/1.8	0.9/2.7	0.1/0.6	0.2/1.3	0.6/1.9	1.2/3.2	0.2/1.3	0.5/1.5	1.1/2.8	2.4/5.1
		Integrity Poll	0.2/0.8	0.5/1.8	1.1/2.9	2.4/5.6	0.6/1.6	1.5/3.5	3.6/7.1	7.7/13	2.0/4.8	5.2/9.7	13/21	28/44
		Event Poll - events	0.7/2.2	1.9/4.6	4.7/8.8	10/17	2.7/6.8	7.2/13	18/29	39/61	11/23	28/53	68/116	148/231
		Issue Control	0.1/0.5	0.2/1.1	0.4/1.8	0.9/2.7	0.1/0.6	0.2/1.3	0.6/1.9	1.2/3.2	0.2/1.3	0.5/1.5	1.1/2.8	2.4/5.1
DNP UDP	Round Robin	Event Poll - no events	0.1	0.3	0.5	1.1	0.5	1.0	2.1	4.2	2.0	4.1	8.3	16.6
		Integrity Poll	0.3	0.6	1.2	2.4	1.2	2.4	4.8	9.7	4.8	9.5	19	38
		Event Poll - events	1.0	2.1	4.1	8.3	4.2	8.3	16.6	33.2	16.3	32.6	65.2	130.4
		Issue Control	0.1	0.3	0.5	1.1	0.5	1.0	2.1	4.2	2.0	4.1	8.3	16.6
	Shot-gun	Event Poll - no events	0.1/0.7	0.3/1.3	0.7/2.4	1.4/3.5	0.3/0.9	0.7/2.1	1.7/4.1	3.7/7.0	0.9/2.1	2.3/4.9	5.8/10	13/21
		Integrity Poll	0.2/0.8	0.6/1.7	1.5/3.3	3.2/6.2	0.7/1.9	2.0/4.3	4.9/9.3	11/18	2.8/6.2	7.3/14	18/31	39/63
		Event Poll - events	0.8/2.1	2.0/4.1	4.9/9.4	11/18	2.9/6.6	7.5/14	18/31	39/62	11/24	29/55	71/117	154/242
		Issue Control	0.1/0.7	0.3/1.3	0.7/2.4	1.4/3.5	0.3/0.9	0.7/2.1	1.7/4.1	3.7/7.0	0.9/2.1	2.3/4.9	5.8/10	13/21

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Bandwidth Study – Summary

- **Latency**
  - Operators receiving data back from reclosers within 15 seconds is reasonable given 45+ seconds for reclose cycle.
  - Control operations within 5 seconds is a good goal.
- **Number of devices**: Each network should limit to 25-50 devices.
- **Polling Scheme**
  - Devices currently communicate via unsolicited report by exception. While this is efficient during times of low traffic, caution should be used to insure packets aren't lost during events.
  - FDIR system should verify it hears from all devices before deciding on restoration options.
- **Ethernet** is preferable for programmability and device access.
- **Over-air Rates**
  - Rates of 64kbps to 128 kbps should be the design goal for the wireless network.

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Summary Principles for FDIR Design

- **Control Topology Decisions**
  - Centralized vs. Decentralized
  - Operator Control and Automation Level
- **Protection Fundamentals**
  - Crew safety remains paramount
  - Apply protection principles as network adapts
- **Integral to SCADA or Add-on**
- **Network modeling**
  - Desire to integrate load flow and voltage optimization into FDIR
- **Communication**
  - Design with network capabilities in mind.
- **Vendor Offerings**

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