GE
Energy

Substation Automation and Smart Grid

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IEEE Division VII Director
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POWERING POTENTIAL

The Smart Grid

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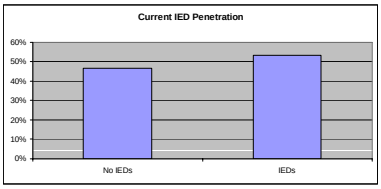
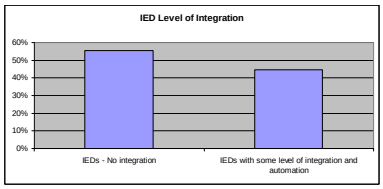
Current Situation



- A little more than half of existing T&D substations are equipped with IEDs

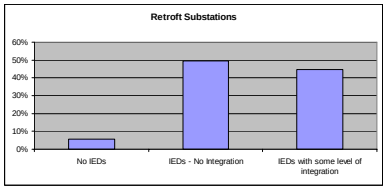
Source: "The World Market for Substation Automation and Integration Programs in Electric Utilities: 2005-2007"; Newton-Evans Research Company, Inc.

Current Situation (continued)



- 55% of IED substations have no integration (29% of total subs)
- 45% of IED substations have some integration (24% of total)

Plans for "Retrofit" Substations



- 97% of retrofit T&D substations will have IEDs
- 42% of retrofit T&D substations include IED integration and automation

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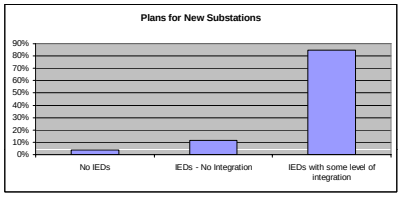
Plans for New Substations



- 97% of T&D substations will have IEDs
- 85% of T&D substations will include IED integration and automation

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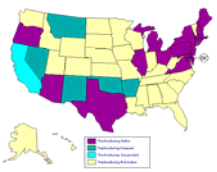
Why Needed? Why Now?

- ***DEREGULATION & COMPETITION***
  - *Deregulation driving actions of most utilities*
  - *Major driving forces:*
    - *Improved power quality and service reliability*
    - *New energy related services and business areas*
    - *Lower cost of service*
    - *Information needed for improved decision making*
  - *SA: A proactive response to these forces*



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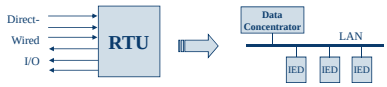
Why Needed? Why Now?

- ***DEVELOPMENT OF IEDs***
  - *Rapid development and deployment of Intelligent Electronic Devices (IEDs)*
    - *Protective relays*
    - *Meters*
    - *Equipment condition monitors*
  - *IEDs have become an integral part of Substation Automation systems*
  - *Technological developments have made SA Systems less expensive and more powerful*



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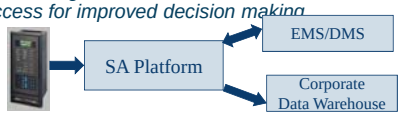
Why Needed? Why Now?

- ***ENTERPRISE-WIDE INTEREST IN INFORMATION FROM IEDs***
  - *"Operational" Data*
    - *Amps, volts, watts, VARs, fault location, switchgear status*
  - *"Non-Operational" Data*
    - *Equipment condition*
    - *Fault event and power quality data (waveforms)*
  - *Persons working outside the control room want access for improved decision making*



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Why Needed? Why Now?

- ***IMPLEMENTATION AND ACCEPTANCE OF STANDARDS***
  - *Confusion over industry communication standards is diminishing*
  - *International standards have become reality*

UCA2 ⟺ IEC61850

  - *Standards based implementation projects underway at <u>many</u> electric utilities*
    - *Widespread use of* ***de facto*** *standards for IED communications (DNP3, Modbus. Modbus+)*
    - *Some use of* ***de jure*** standards (UCA2/IEC61850)

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IED Level Benefits

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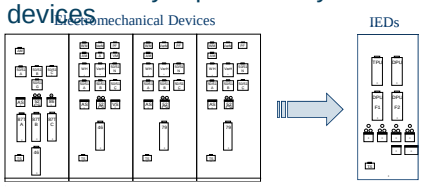
Construction Cost Savings

- Required functionality bundled in fewer components (21, 50/51, 79,…, metering, etc)
- One IED may replace many E-M devices



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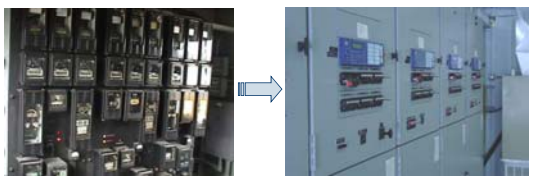
Construction Cost Savings

- **Reduction in Physical Complexity**
  - Less inter-device wiring
  - Fewer unique devices to inventory
  - Some traditional devices eliminated altogether



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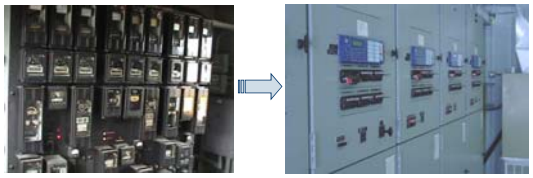
Construction Cost Savings

- **Relay/control house size (new construction only)**
- **Design & construction labor and materials**



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Integration Level Benefits

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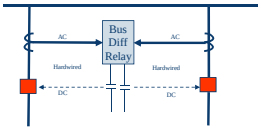
Integrated Protection Functions

- **Objective: Incorporate protection functions in the SA System**
  - Basic protection units (IEDs) exchange current/voltage data via high speed LAN
  - Relay trip signals exchanged over LAN

Traditional (Electromechanical) Approach



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Integrated Protection Functions

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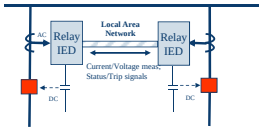
Integrated IED Approach



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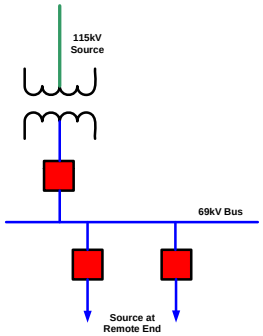
Integrated Protection – Breaker Failure



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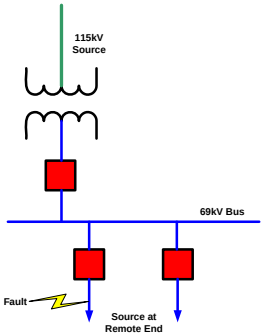

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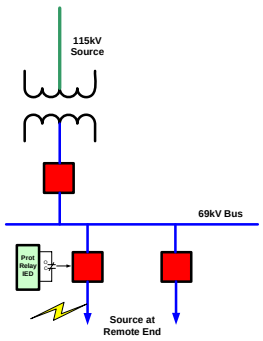

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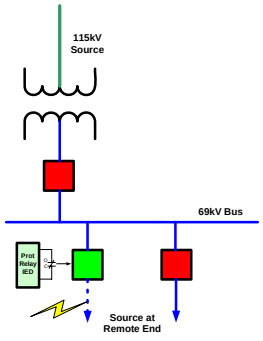

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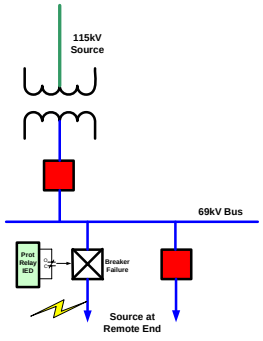

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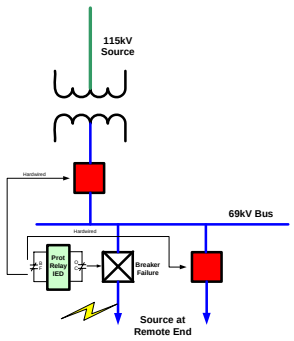

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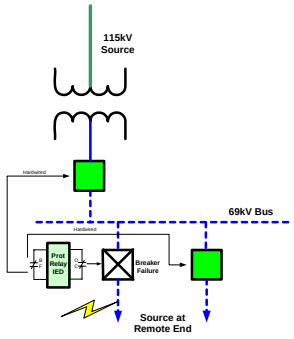

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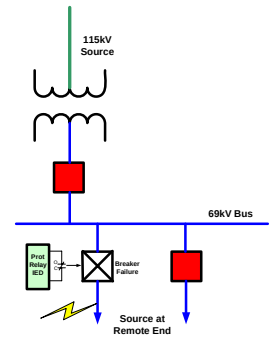

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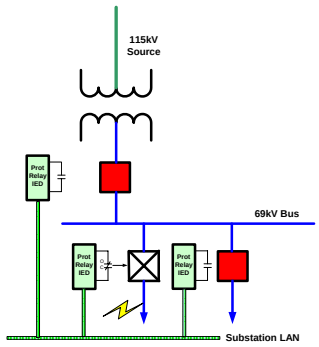

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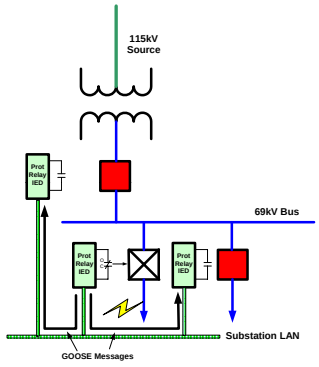

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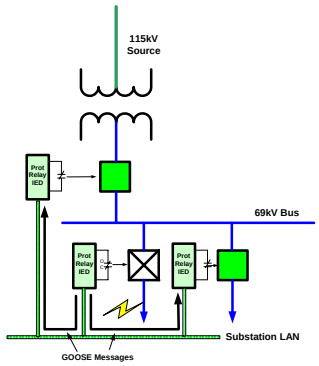

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Automation Functions

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Automatic Load Restoration: Supply Line Sectionalizing

- **Nature of the problem**
  - Distribution substations often tapped off supply line without high side breaker or high side protection
  - Considerable load may be out of service until field crews arrive on scene
- **Objectives**
  - Identify faulted section of supply line
  - Isolate faulted section
  - Restore supply to substations fed off unfaulted section of supply line

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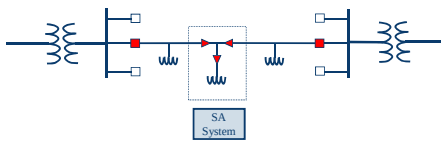
Supply Line Sectionalizing



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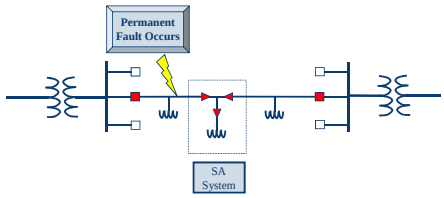
Supply Line Sectionalizing



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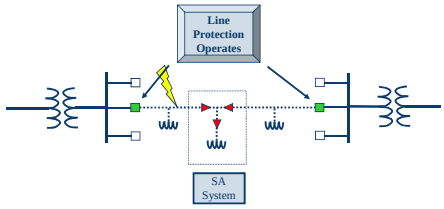
Supply Line Sectionalizing



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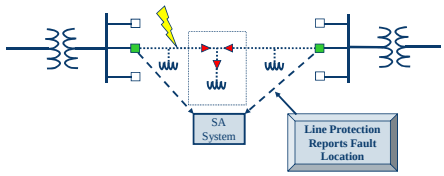
Supply Line Sectionalizing



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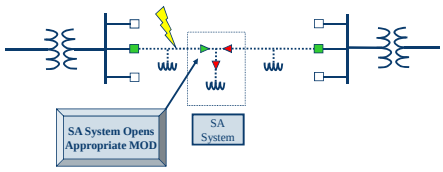

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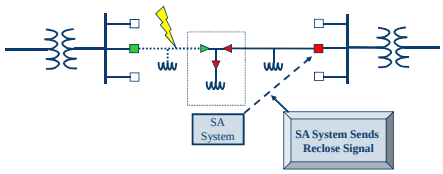


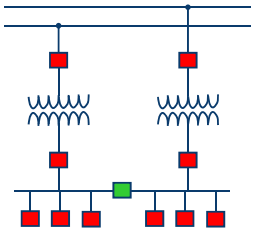
Automatic Load Restoration: "Intelligent" Bus Failover

- **Nature of Problem**
  - When a transformer failure occurs, "simple" bus failover scheme transfers load to healthy transformer
  - "Simple" failover scheme may overload healthy transformer, especially during peak load
  - Some schemes have been disabled because of this
  - Substation firm capacity limited by amount of load that can be carried if a transformer fault occurs

Automatic Load Restoration:
"Intelligent" Bus Failover

- **Objectives**
  - Transfer as much load as possible to 2nd substation transformer
  - If necessary, transfer portion of load to alternate substation
  - Shed portion of load if necessary

"Intelligent" Bus Failover:
How It Works



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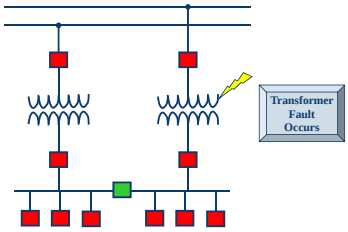
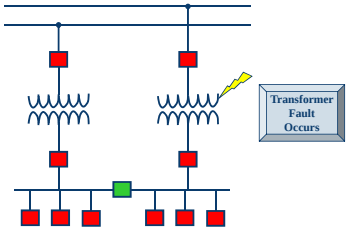


"Intelligent" Bus Failover: How It Works



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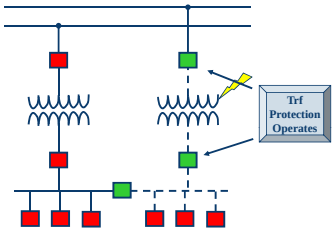
"Intelligent" Bus Failover: How It Works



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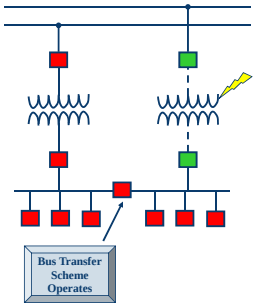

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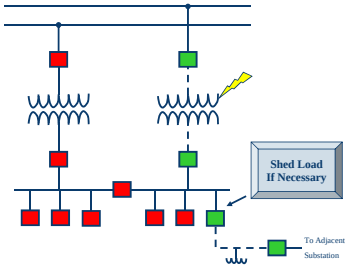

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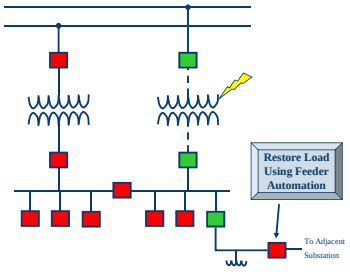
"Intelligent" Bus Failover: How It Works



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Enterprise Application Functions

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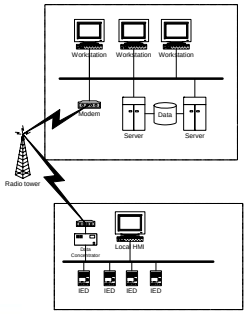
SCADA Data Path (Operational Data)



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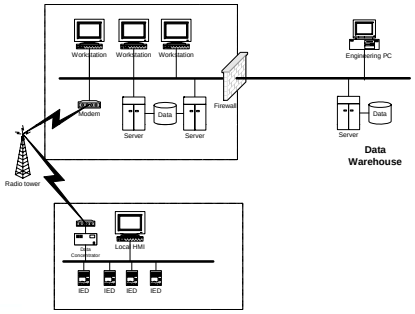
SCADA Data Path (Operational Data)



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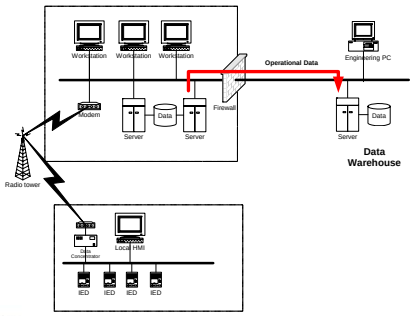
SCADA Data Path (Operational Data)



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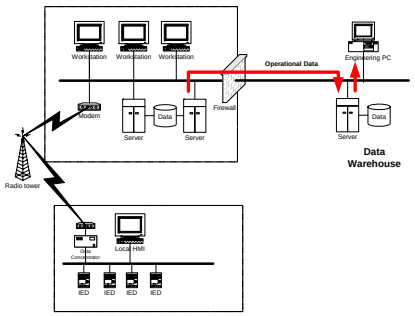
SCADA Data Path (Operational Data)



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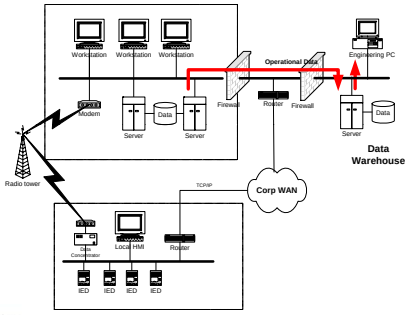
SCADA Data Path (Non-Operational Data)



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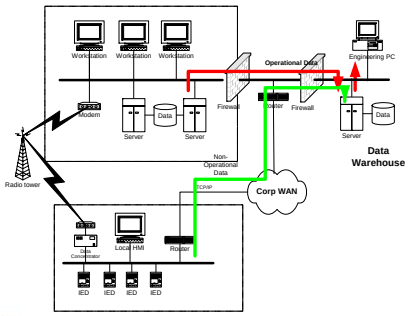
SCADA Data Path (Non-Operational Data)



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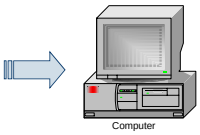
Disturbance Analysis

Exploit Inherent Capabilities of IEDs

- *Sequence of Event reporting*
- *Digital Fault Recorder (DFR)*
- *Fault Location*

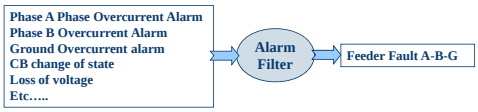
Disturbance Data from relay IED



Engineer's Desktop

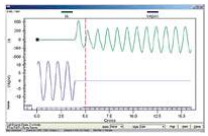
Intelligent Alarm Processing

- *Prioritize alarm information*
- *Eliminate duplicate & nuisance alarms*
- *Route alarm info to appropriate party*
- *"Expert" alarm processing*
  - provides more informative and useful alarm messages

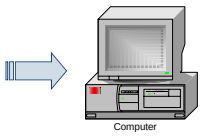


Power Quality Monitoring

- *SA System and IEDs able to detect power quality events and report the following information:*
  - Harmonic content of the voltage waveform
  - Total harmonic distortion
  - Oscillographic data (waveforms)



Power Quality Info from IEDs



Engineer's Desktop

Real-Time Equipment Rating

- *Base equipment ratings on actual conditions rather than conservative assumptions*
- *Squeeze more capacity out of existing equipment*
- *Example: Transformer "Hot Spot" Monitoring*
  - Monitor the true winding hot spot temperature
  - Derive loadability from the results
  - 5 - 10% additional loading can be achieved

Equipment Condition Monitoring

- **Continuous On-line Diagnosis of SS Equipment (HV breakers, Transformers)**
- Main objectives
  - Support reliability centered maintenance
  - Find/fix problems earlier
  - Avoid forced (unscheduled) outages
  - Reduce maintenance costs

Equipment Monitoring Devices

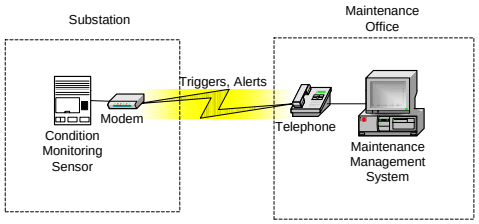
- **Dissolved Gas in Oil Monitors/Samples**
- **Moisture Detectors**
- **Load Tap Changer Monitors**
- **Partial Discharge/Acoustic Monitors**
- **Bushing Monitors**
- **Circuit Breaker Monitors (GIS and OCB)**
- **Battery Monitors**
- **Expert System Analyzers**
- **Protective Relay IEDs (I2t, Breaker timing)**

Equipment Condition Monitoring

- **Role of SA**
  - Monitor specialized sensors
  - Perform “expert system” analysis
  - Inform engineers or dispatchers of possible problems
  - Supply “non-operational” data

Equipment Condition Monitoring

- **Traditional approach:**



Equipment Condition Monitoring

- **SA approach – Use “Non-Operational Data Path:**