AMI Performance Requirements and Testing

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Principal Technology Engineer

Key (and Bee) material by:
Jeff Hendrickson – AMI Project Lead
Manager – Customer Operations
Member owned electric cooperative

• Largest in Minnesota
• One of the largest in US

131,000 member customers
  92% residential by customer

1,000 square miles territory
44 substations
9,000 miles of line

System peak demand 550 MW
Wholesale Power Supplier – Great River Energy
Discussion outline

- Basis for decision making – “Stage Gate” process
- Specifications development
- Pre-contract vetting
- Contract – compliance requirements
- “SAT” – GO / NO-GO decision making
- Results, on-going work....
## Business Development & Deployment - Stage-Gate Approach

<table>
<thead>
<tr>
<th>Stages</th>
<th>Go/Stop</th>
<th>Purpose</th>
<th>Confidence level/Filter</th>
<th>Deliverable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategy / feasibility assessment</td>
<td>Gate 1</td>
<td>Prepare high-level business case</td>
<td>Strategic Fit, initial financial eval</td>
<td>Stage 1 Worksheets</td>
</tr>
<tr>
<td>RFP process, vendor vetting</td>
<td>Gate 2</td>
<td>Prepare detailed business case</td>
<td>80% confidence – will yield ROI</td>
<td>Fully evaluated costs, savings, IRR over life cycle of system</td>
</tr>
<tr>
<td>Contract</td>
<td>Gate 3</td>
<td>Spec, RFP, review vendors, shortlist</td>
<td>short list meets requirements, maintain IRR</td>
<td>Review and comparison of vendors:  • Meets requirements  • Performance  • “Fit”</td>
</tr>
<tr>
<td>Partial launch, SAT 1</td>
<td>Gate 4</td>
<td>Negotiate purchase with top pick</td>
<td>Parties agree to design and terms</td>
<td>Inked contract</td>
</tr>
<tr>
<td>System update, added function, SAT 2</td>
<td>Gate 5</td>
<td>Limited field install - system testing for all components</td>
<td>System performs as specified</td>
<td>Identify / resolve issues. Determine if performance meets requirements.</td>
</tr>
<tr>
<td>Full deployment</td>
<td>Gate 6</td>
<td>Version upgrade, added functions, full test</td>
<td>System performs as specified</td>
<td>Identify / resolve issues. Meet gatekeeper requirements? YES – GO NO – fix or cancel</td>
</tr>
</tbody>
</table>

### Stage 1: Full system launch
- Parties agree to design and terms
- System performs as specified
- Test GO / NO-GO key performance metrics
- Identify / resolve issues.
- Meet gatekeeper requirements? YES – GO NO – fix or cancel

### Gate Approach
- **Gate 1:** Go/Stop
- **Gate 2:** RFP process, vendor vetting
- **Gate 3:** Contract
- **Gate 4:** Partial launch, SAT 1
- **Gate 5:** System update, added function, SAT 2
- **Gate 6:** Full system launch
Pre-contract vetting

- Corporate goals / strategy
- Definition & of needs – specifications and RFP process
- Review of vendor response – fit requirements?
- Validation prior to contract:
  - Vendor interviews
  - Vendor demonstration
  - Vendor customer interviews
  - Vendor customer site visits
System Design – “Business Driver” Strategy

Required Today (primary business case)
• Master System and Integration
• Master System Reporting/Inquiry
• Pre-paid Meter Support
• C&I Metering
• Disconnect and Reconnect
• AMI System Security

Additional Applications (desired, but not primary business case)
• Demand Response and Home Automation
• Distribution Automation
Contract requirements (or, targets...)

System Design – System Attributes

- Software head end (data processing, user interface)
- Integration into enterprise network
- Meter hardware
- Communications WAN
- % meters read / read rate (business-based performance)
- Suitability to leverage for other DA applications
Key System Design Elements....

- Fits within existing CE IT environment
  - MultiSpeak 3.x/4.0
  - SQL DB
- IPV6
- Compatible with cellular base communications
- Allow for fixed IP address per collector/router
- Communication protocol convertible to DNP via TCP/IP for DA device interface
- Security – NIST SP800-64 (& other requirements too numerous to list...)
- “FAN” Communications:
  - Mesh – 900 MHz unlicensed – vendor proprietary system
  - Backhaul – Fiber, Microwave, or Cellular from 55 routers

- Meter Reading Functionality
- Communications System`
Key “Specified” Performance Metrics:

Meter coverage requirements
- 99.6% - can be read by request upon demand
- 100% read rate – within three day billing cycle
- Bandwidth (No. bytes per hourly meter read)
- Outage reporting within specified time
- Over-the-air firmware upgrades

Questions asked for Information:
- Time to perform on-demand reads
- Min, max and average number of “hops” per proposed design
- Maximum number of hops system will support
- Latency
- Voltage monitoring accuracy
SAT2 Critical Functionality Testing

Head End Software System
(data provided by system...)

Interfaces to Connexus Systems:
• CIS
• OMS

Internal (Connexus) processes supporting the above...
18-Member, Cross-Functional Core Team
- Strong Leaders & Knowledge Experts
- Supported by Outside Experts
  - Vendor Project Management & Support
  - Consulting Resources
# SAT Honeywell Testing

## SAT 2 - HONEYWELL TESTS

<table>
<thead>
<tr>
<th>Test Areas</th>
<th>Purpose</th>
<th>Status</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Setup</td>
<td>Adding Routers &amp; Meters</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>4.1.3 Device Reports</td>
<td>Search, View, Axis Detect</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>4.1.4 Remove Test Meters</td>
<td>Removing meters from AMI</td>
<td>Pass</td>
<td>Will use AUS and Metersync process</td>
</tr>
<tr>
<td>4.2 Electricity Metering</td>
<td>On Request Reads, Push Data, Disc/Reco</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>4.3 Schedule Reports</td>
<td>Meters not reporting or assigned</td>
<td>Pass</td>
<td>Changes in 11.0</td>
</tr>
<tr>
<td>4.4 Performance</td>
<td>Read Performance &amp; Metrics</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>4.5 Alarms and Events</td>
<td>View, Ack, Custom, Clear Events &amp; Alarms</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>4.6 Communication</td>
<td>Power Status, NOC Ping, Router Reconfig</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>4.7 Security</td>
<td>WAN, NMS Security</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>4.8 Meter Configuration</td>
<td>Configure meters in MeterCat &amp; Push Out</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>4.9 Firmware Upgrades</td>
<td>NMS &amp; Meter Firmware</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>4.10 User Administration</td>
<td>User profiles in Connexo</td>
<td>Pass/Fail</td>
<td>GUI is correct, docs are not. Update in 11.0</td>
</tr>
<tr>
<td>4.11 Outage &amp; Restoration</td>
<td>Push Outage Alarm &amp; Restoration event</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>4.12 TOU Special Features</td>
<td>TOU special dates</td>
<td>Pass</td>
<td></td>
</tr>
</tbody>
</table>

- Confirmed 10.4 Updates to Connexo (Head-end)
  - Push midnight self-reads for billing (eliminates scheduled reads)
  - Push Outage Alarms & Restoration Events
  - TOU special dates
  - OTA Meter updates
- Re-Confirmed base functionality (same testing as 10.3 SAT)
**SAT Interface Status**

**KEY SAT 2 INTERFACE STATUS**

<table>
<thead>
<tr>
<th>System</th>
<th>Interface</th>
<th>Business Group User(s)</th>
<th>Status</th>
<th>Comments</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUS-HW</td>
<td>On-Demand Reads</td>
<td>COS, SYS Ops, MSR</td>
<td>Not Tested</td>
<td>AUS to HW MultiSpeak calls failing</td>
<td></td>
</tr>
<tr>
<td>AUS-HW</td>
<td>Meter Disconnect</td>
<td>COS, Credit</td>
<td>Not Tested</td>
<td>AUS to HW MultiSpeak calls failing</td>
<td></td>
</tr>
<tr>
<td>AUS-HW</td>
<td>Meter Reconnect</td>
<td>COS, Credit, MSR, Sys Ops</td>
<td>Not Tested</td>
<td>AUS to HW MultiSpeak calls failing</td>
<td></td>
</tr>
<tr>
<td>AUS-HW</td>
<td>Billing Reads</td>
<td>COS</td>
<td>Pass</td>
<td></td>
<td>Y</td>
</tr>
<tr>
<td>AUS-HW</td>
<td>MeterSync (Test)</td>
<td>All</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUS-HW</td>
<td>MeterSync (Prod)</td>
<td>All</td>
<td>Pass</td>
<td></td>
<td>Y</td>
</tr>
<tr>
<td>HW-MDM</td>
<td>Interval Data</td>
<td>COS, MSR, Metering</td>
<td>Pass</td>
<td>Alarms look there but desc missing</td>
<td></td>
</tr>
<tr>
<td>HW-MDM</td>
<td>Alarms</td>
<td>COS, Metering</td>
<td>Pass/Fail</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUS-MDM</td>
<td>Customer Changes</td>
<td>COS, MSR</td>
<td>Not Tested</td>
<td>NISC Development needed, 3-4 weeks out</td>
<td></td>
</tr>
<tr>
<td>AUS-MDM</td>
<td>Location Changes</td>
<td>COS, MSR</td>
<td>Not Tested</td>
<td>NISC Development needed, 3-4 weeks out</td>
<td></td>
</tr>
<tr>
<td>AUS-MDM</td>
<td>Meter Changes</td>
<td>COS, MSR, Metering</td>
<td>Not Tested</td>
<td>NISC Development needed, 3-4 weeks out</td>
<td></td>
</tr>
<tr>
<td>AUS-MDM</td>
<td>Usage Monitoring</td>
<td>COS, MSR, Metering, Credit</td>
<td>Not Tested</td>
<td>Unit testing is good, test in week 2</td>
<td></td>
</tr>
<tr>
<td>AUS-HW</td>
<td>Meter Change</td>
<td>COS, MSR, Metering</td>
<td>Pass/Fail</td>
<td>(Change meter info i.e. bill cycle. Add route to bill)</td>
<td></td>
</tr>
<tr>
<td>AUS-HW</td>
<td>Meter Exchange</td>
<td>COS, MSR, Metering</td>
<td>Fail</td>
<td>New meter was not added to location</td>
<td></td>
</tr>
<tr>
<td>AUS-HW</td>
<td>Meter Remove</td>
<td>COS, MSR, Metering</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUS-HW</td>
<td>Meter Install</td>
<td>COS, MSR, Metering</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUS-SGS</td>
<td>Meter Exchange</td>
<td>All</td>
<td>Pass/Fail</td>
<td>All changes confirmed in earlier testing</td>
<td></td>
</tr>
</tbody>
</table>

- Billing reads passed from HW to AUS (it takes seconds)
- CIS and HW systems in sync daily
- Meter exchange process between AUS and SGS needs to be re-confirmed
### SAT Key Processes Status

#### KEY SAT 2 PROCESS STATUS

<table>
<thead>
<tr>
<th>Area</th>
<th>Process</th>
<th>Status</th>
<th>Comments</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>COS</td>
<td>Meter Reading Uploads for Billing</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COS</td>
<td>Meters Not Read in Billing File</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COS</td>
<td>Pre-exception Processing of AMI readings</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COS</td>
<td>Meter Change</td>
<td>Not Tested</td>
<td>Waiting for AUS-HW multispeak</td>
<td></td>
</tr>
<tr>
<td>COS</td>
<td>Load Mgmt Meter Change</td>
<td>Not Tested</td>
<td>Waiting for AUS-HW multispeak</td>
<td></td>
</tr>
<tr>
<td>COS</td>
<td>Move in/out</td>
<td>Not Tested</td>
<td>Waiting for AUS-HW multispeak</td>
<td></td>
</tr>
<tr>
<td>COS</td>
<td>Meter Disconnect</td>
<td>Not Tested</td>
<td>AUS to HW MultiSpeak calls failing</td>
<td></td>
</tr>
<tr>
<td>Metering</td>
<td>Meter Change</td>
<td>Pass</td>
<td>Process in Place</td>
<td></td>
</tr>
<tr>
<td>Metering</td>
<td>Daily Monitoring - Meter Health</td>
<td>Pass</td>
<td>Filters Created in Prod, ready to monitor</td>
<td></td>
</tr>
<tr>
<td>Metering</td>
<td>Daily Monitoring - Meter Communications</td>
<td>Pass</td>
<td>Filters Created in Prod, ready to monitor</td>
<td></td>
</tr>
<tr>
<td>Metering</td>
<td>Daily Monitoring - Meter Tamper</td>
<td>Pass</td>
<td>Filters Created in Prod, ready to monitor</td>
<td></td>
</tr>
<tr>
<td>Metering</td>
<td>TOU &amp; Bi-Directional Metering</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sys Ops</td>
<td>Voltage Reading &amp; Intervals</td>
<td>Pass</td>
<td></td>
<td>Included in Bill Files</td>
</tr>
<tr>
<td>Sys Ops</td>
<td>Power Status Check</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sys Ops</td>
<td>Outage &amp; Restoration Alarms &amp; Events</td>
<td>Pass</td>
<td>Filters in place to monitor as needed</td>
<td></td>
</tr>
<tr>
<td>Sys Ops</td>
<td>Meter Reconnect</td>
<td>Not Tested</td>
<td>AUS to HW MultiSpeak calls failing</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Meter Disconnect</td>
<td>Not Tested</td>
<td>AUS to HW MultiSpeak calls failing</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Meter Reconnect</td>
<td>Not Tested</td>
<td>AUS to HW MultiSpeak calls failing</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Failed Meter Reconnect</td>
<td>Not Tested</td>
<td>Need process defined b4 change</td>
<td></td>
</tr>
<tr>
<td>MSR</td>
<td>Meter Reconnect</td>
<td>Not Tested</td>
<td>AUS to HW MultiSpeak calls failing</td>
<td></td>
</tr>
<tr>
<td>MSR</td>
<td>High Bill</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- ✔ Meters not read via AMI and Exception process of AMI reads
- ✔ Daily Monitoring of Meter Health, Communications, and Tamper
- ✔ Outage and Voltage visibility for Sys Ops
- ✔ High Bill research via MDM for Member Services
SAT Network Test Status

**KEY SAT 2 NETWORK TESTS**

<table>
<thead>
<tr>
<th>System</th>
<th>Process</th>
<th>Business Group</th>
<th>User(s)</th>
<th>Status</th>
<th>Comments</th>
<th>Go / No</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOC</td>
<td>Patching &amp; Updates</td>
<td>IT</td>
<td></td>
<td>Pass</td>
<td>Patching and MS Updates applied Jan-Feb</td>
<td>Go</td>
</tr>
<tr>
<td>AMI</td>
<td>Patching &amp; Updates</td>
<td>IT</td>
<td></td>
<td>Pass</td>
<td>Patching and MS Updates applied Jan-Feb</td>
<td>Go</td>
</tr>
<tr>
<td>NOC</td>
<td>Router Failover</td>
<td>IT</td>
<td></td>
<td>Pass</td>
<td>Excellent Test Results</td>
<td>Go / No</td>
</tr>
</tbody>
</table>

- ✔️ Patching and Updates on AMI & NOC confirmed
- ✔️ Router Failover test passed (See next slides)
  - Network issues related to Firewall upgrade created challenges
  - Excellent support from IT staff & Honeywell to resolve
SAT2 Router Failover Testing

Test #1 - Shut down Ramsey Tower (Anoka)
SAT2 Router Failover – Close Up of SAT Area

BEFORE

Anoka Tower

Energy Park

After

Anoka Tower

Enterprise Park
SAT Router Failover – Active Meters

- Baseline - Meters were reporting 77% Anoka Tower, 20% to Energy Park
- Meters delay 15-30 minutes after a router outage to start looking for a new path
- Within first hour, 42% found a new router and 64% by 2nd hour
- By hour 5, 100% of meters were able to migrate to a new path and start reporting
- The new router loading was 80% on Energy Park and 18% on Enterprise
SAT2 Router Failover Testing

Test #2 - Shut down EnergyPark
SAT2 Router Failover – Overview of SAT Area

BEFORE

Anoka Tower
Energy Park
Enterprise Park

After

Anoka Tower
Energy Park
Enterprise Park
SAT2 Router Failover – Close Up of SAT Area

- 2.04 Mile meter to meter hop
- 1.9 Mile meter to meter hop
- 1 Mile first hop meters
Baseline - Meters were reporting 79% Energy Park, 18% to Enterprise Park, 3% to Daytonport
Meters delay 15-30 minutes after a router outage to start looking for a new path
Within first hour, 23% found a new router and 36% by 2nd hour (Half as fast as earlier test)
By hour 6, 80% of EnergyPark meters migrated to a new path and 20% appeared to dropped off
By 8:AM the next morning, 100% of meters were reporting w/97% to Enterprise Park
Go / No Go Recommendation:

Summary:
- Product delivery schedules (meters & routers) remain on plan
- Software delivery schedules remain within tolerance of plan
- The successful results of SAT 1 and SAT 2 testing
- Status of system integrations
- Critical business process testing & documentation
- Performance of the AMI networks within the SAT area

The AMI team is recommended a **Go** decision.
Pole Shadow
**Lessons Learned & “continuing improvement”**

- Did not specify maximum allowable hop count
- Did not specify n-1 contingency (loss of router)

**“Tweaking” router placement to optimize:**
- Hop count performance
- Achieve N-1 reliability

- “Standard” protocols are not always “standard”

**AMI to SCADA interface**
Non-compatible flavors of MultiSpeak
Questions / Discussion