Use Case 25: State Estimation – T. Berry

Summary:

This use case is an alternative and expansion of the SCADA Data Update use case. It separates the Power System State Model between three subsystems: Data Acquisition, Topology Processor and State Estimator.

The State estimation application fetches data values from SCADA operations model, processes topology, estimates a new state, detects bad measurements and returns estimated states to SCADA operations model. It also makes a copy of the network state available for other network analysis applications.

Actor(s):

Name	Role description
System Operator (= Control Engineer)	(Human) Monitors and controls system operation
Telemetry System	(External System) Provides telemetry data in the form of analogue measurements, status, or accumulator data from substation, neighboring control center, or field device.
Data Maintenance Engineer	(Human) Creates, deletes and updates data defining network and telemetry. Does not participate in this use case but is shown on the diagram for reference.

Participating Systems:

System	Services or information provided
User Interface	Displays Data Acquisition data for the power system. Allows manual update of information.
Data Acquisition	A SCADA application that maintains latest measurements from Telemetry System and provides data for other subsystems in a form equivalent to CIM SCADA Package.
Alarm System	An application that forces notification of power system events to the human user's attention.
History/Logging	An application that records power system events.
Topology Processor	An application that processes switch states to determine TopologyNodes and TopologyIslands. This may be part of the SCADA package, part of the State Estimator package or stand-alone.
State Estimator	A Network application that holds a Power System Network Model equivalent to CIM Wires package. Creates the best estimate of current state of the power system. Includes state estimation and bad measurement detection.
Generic Network Application	Any Network application that contains a power system network model equivalent to CIM Wires package. Could be study load flow, contingency analysis or optimal power flow. Can use state estimator results as the base case.

Pre-conditions:

All participating subsystems are operational.
The Network Modification use case has ensured the internal data is consistent between the Data Acquisition, Topology Processor and State Estimator subsystems.

Assumptions / Design Considerations:

- The Data Acquisition subsystem, the Topology Processor susbsystem and the State Estimator subsystem have different internal representations of the power system network. They share the same identifiers for ConductingEquipment and Measurements. These identifiers may be numeric rather than character strings in order to improve performance.
- The State Estimator is assumed to have minimal user interface requirements but this includes the ability to manually trigger execution.
- The inputs to the Alarm System and History/Logging are essentially the same.
- Timing requirements: Timing for information exchanges is given for comparison purposes only.
- Frequency of use: Periodic state estimation is at intervals of 5 to 15 minutes.

Normal Sequence: Initiated by SCADA event
(This shows in time order, the sequence of information exchanges between the subsystems)

Use Case Step	Description
1	Telemetry System provides raw measurement set to Data Acquisition
2	Data Acquisition publishes ConductingEquipment state change events, if any, for Alarm Subsystem and History/Logging
3	Data Acquisition publishes analogue measurement limit crossings, if any, for Alarm Subsystem and History/Logging.
4	Data Acquisition publishes changed ConductingEquipment states and analogue measurements for user interfaces.
5	Data Acquisition notifies breaker status change event for Topology Processor.
6	Topology Processor calculates new topology and waits for settling period (typically 10s)
7	Topology Processor publishes events, if any, for Alarm Subsystem and History/Logging • Islands created or combined events • Branches open or closed • Equipment energized or de-energized
7a	Topology Processor sends changed topology information to State Estimator.
8	State Estimator fetches relevant analogue measurement values and quality attributes from Data Acquisition
9	State Estimator estimates all network states
10	State Estimator determines bad measurements
11	State Estimator publishes events, if any, for Alarm Subsystem • Network failed to solve • Measurement estimated quality change (bad/good) • Limit crossings
12	State Estimator sends estimated measurement values and quality to Data Acquisition.
13	State Estimator creates or overwrites network data set for export to other network applications.

14	Data Acquisition publishes estimated values for user interfaces.

Exception Sequence x: Multiple telemetry events

Use Case Step	Description
1-5	As normal sequence: Initiated by SCADA event Telemetry System detects breaker change leading to Data Acquisition notifies breaker status change event for Topology Processor
6	Topology Processor calculates new topology and waits for settling period (typically 10s)
1x-5x	Within settling period a second breaker changes state. As normal sequence: Initiated by SCADA event Repeat step 1-5 for second breaker
6x	Topology Processor calculates new topology and waits for settling period (typically 10s) Repeats step 6
7-14	As normal sequence: Initiated by SCADA event State Estimation runs to completion without further breaker changes.

Alternate Sequence a: Initiated by Timer

Use Case Step	Description
1a	Topology Processor is triggered by periodic timer (typically 300-900 s)
2-5	Omitted
5a	Topology Processor fetches relevant states for all ConductingEquipment from Data Acquisition to guarantee consistency.
6-14	As normal sequence: Initiated by SCADA event

Alternate Sequence b: Initiated by System Operator or after Network Modification

Use Case Step	Description
1b	System Operator uses User Interface to manually override a measurement in Data Acquisition
1b	System Operator uses User Interface to request Topology Processor to run.
2-5	Omitted
5b	Topology Processor fetches relevant states for all ConductingEquipment from Data Acquisition to guarantee consistency.
6	Topology Processor calculates new topology
7	Topology Processor publishes events, if any, for Alarm Subsystem and History/Logging • Islands created or combined events • Branches open or closed • Equipment energized or de-energized
7b	Topology Processor sends full topology information to State Estimator.
8-14	As normal sequence: Initiated by SCADA event

Post-conditions:

All subsystems have consistent internal data.

References:

This is an alternative to the SCADA Data Update use case.
This use case must be preceded by a Network Modification use case.

Information Exchanges:

This section lists the information exchanges described in the use case regardless of the step.

ID	Producer Actor/System	Consumer Actor/System	Information Content
A	Telemetry System (Actor)	Data Acquisition	Raw measurements – analogue measurements, status, or accumulator data Uses GOMSFE and/or other protocols
B	Data Acquisition	Alarm System	Changes in states for individual ConductingEquipment. Changes in individual analogue measurement limit crossings. 0-50 per second.
B	Alarm System	History/Logging	As above
C	Data Acquisition	History/Logging	Selected analogue readings. 2000 every 30 minutes
D	Data Acquisition	User Interface	Changed ConductingEquipment states and analogue measurements 0-100 per second
E	User Interface	System Operator (Actor)	ConductingEquipment states and analogue measurements. Refresh in 5 seconds
F	Data Acquisition	Topology Processor	Individual breaker status change event (initiated by Data Acquisition) 0-10 per second
G	Data Acquisition	Topology Processor	Full network ConductingEquipment states. (initiated by Topology Processor) 10000 every 5 minutes
H	Topology Processor	Alarm System History/Logging	Changes in Islands, energization status, open/closed branches 0-20 per minute
I	Data Acquisition	State Estimator	Relevant analogue measurement values and quality attributes (initiated by State Estimator) 6000 every 3 minutes
J	State Estimator	Alarm System History/Logging	Events such as • Network failed to solve • Measurement estimated quality change (bad/good) • Limit crossings 0-20 per minute
K	State Estimator	Data Acquisition	Estimated measurement values and quality 10000 per 3 minutes

L	Data Acquisition	User Interface	Estimated values for active views 0-100 per view
M	User Interface	System Operator (Actor)	Estimated values for active views Refresh in 5 seconds
N	Alarm System	User Interface	Alarm status 0-40 per second
O	State Estimator	Generic Network Application	Network data set with solved state 5000 items every 5 minutes
P1	Data Definition	Topology Processor	Connectivity data set with identifiers of ConductingEquipment and Measurements in Data Acquisition. 35000 items every 30 days
P2	Data Definition	State Estimator	Network data set with identifiers of ConductingEquipment and Measurements in Data Acquisition. 5000 items every 30 days
Q	System Operator (Actor)	User Interface	Manual override of telemetered data 1 item per hour
R	User Interface	Data Acquisition	Replacement value for manually overridden data 1 item per hour
S	Data Definition	Data Acquisition	Telemetry modification data set. 100 items every 30 days
T1	Topology Processor	State Estimator	All TopologicalNode and TopologicalIsland relationships with ConductingEquipment. 5000 items every 3 minutes
T2	Topology Processor	State Estimator	Changes in TopologicalNode and TopologicalIsland relationships with ConductingEquipment. 10 items every 30 minutes

Information Exchange Classification:

This section classifies the information exchanges according to their complexity.

Type	**Description of Information Exchange Messages**	**Ids**
Fast Data Event	Single CIM entity class per message Single CIM entity instance per message Subset of CIM entity attributes Initiated by Producer application Typically a changed telemetered value	D,F,L
Slow Data Event	Single CIM entity class per message Single CIM entity instance per message Subset of CIM entity attributes Initiated by Producer application Typically a user entered or displayed value	Q,R
Alarm Text Event	Formatted as text for user interface Based on Simple Event plus additional information e.g. Substation.name, ConductingEquipment.name,	B,H,J,N

	Measurement.unit, MeasurementValue.value Initiated by Producer application	
Array Data Set	Single CIM entity class per message Many CIM entity instances per message Subset of CIM entity attributes Initiated by Producer or Consumer application	C,G,I,K
Full Complex Data Set	Many CIM entity classes Many CIM entity instances Probably all attributes per CIM entity Includes relationships defined by keys	O, P1,P2, T
Modification Complex Data Set	Many CIM entity classes Many CIM entity instances Probably all attributes per CIM entity Includes relationships defined by keys Each instance marked delete, insert, update	S

Issues:

ID	Description	Status
1.		

Revision History:

No	Date	Author	Description
0.	13-Jan-99	T. Berry	Original
1.	15-Jan-99	T. Berry	Internal review – moved Startup, added exchange classification.
2	18-Jan-99	T. Berry	Aligned with IEM_notes document.
3	24-Apr-99	T. Berry	Add separate Topology Process. Merge analogue state changes into ‘B’ Make Alarm Subsystem responsible for archiving events of type B and H. Redefine ‘C’ as periodic archiving Add ‘T1’ for full topology data set Add ‘T2’ for changed topology set Use line width/style to show type of exchange in use case diagram.

Use Case Diagram:

The information exchanges between subsystems and actors do not form part of the CCAPI standard and are thus shown as dotted lines.

Information exchanges P1,P2 and S are part of the Network Modification use case.