



BOUNDLESS ENERGY™

A CIM based Incremental Approach for Real-time System Model Update

Yidan Lu

EMS Advanced Applications, AEP

BOUNDLESS ENERGY™

Grid Modeling in AEP

Internal Grid Modeling

Every Three Week

Changes on AEP
service area

Manually via ETS
Projects

External Grid Modeling

Every Quarter

Changes in
neighboring Entities

Automatically via
CIM based Procedure

AEP External Grid Modeling— Background

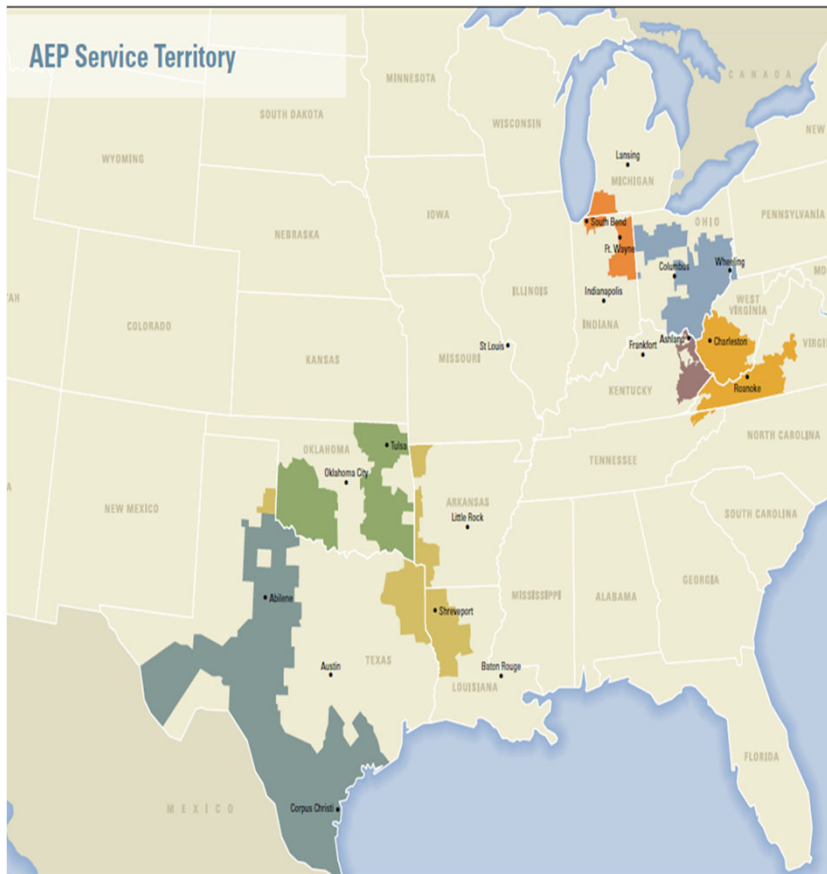
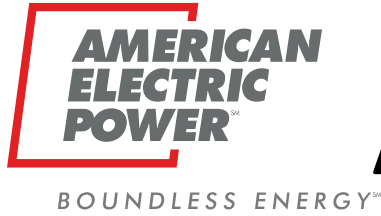


Fig. 1. AEP Footprint

- AEP operates in 11 states. Our footprints are modeled as internal part in EMS and maintained by our modelers.
- External models are maintained by other utilities who submit model changes to regional RTO.
- RTO releases regional model in CIM format periodically that includes changes submitted by all utilities .
- Recurring effort needed to bring those device to AEP’s EMS model



AEP External Grid Modeling— Objective

- To simplify the recurring effort and reduce human error in the external model update.
- To enable easy data exchange and customization in EMS model maintenance.
- To promote smart grid interoperability by using CIM standards as recommended by FERC and National Institute of Standards and Technology (NIST)

*BOUNDLESS ENERGY*SM

AEP External Grid Modeling— Methodology

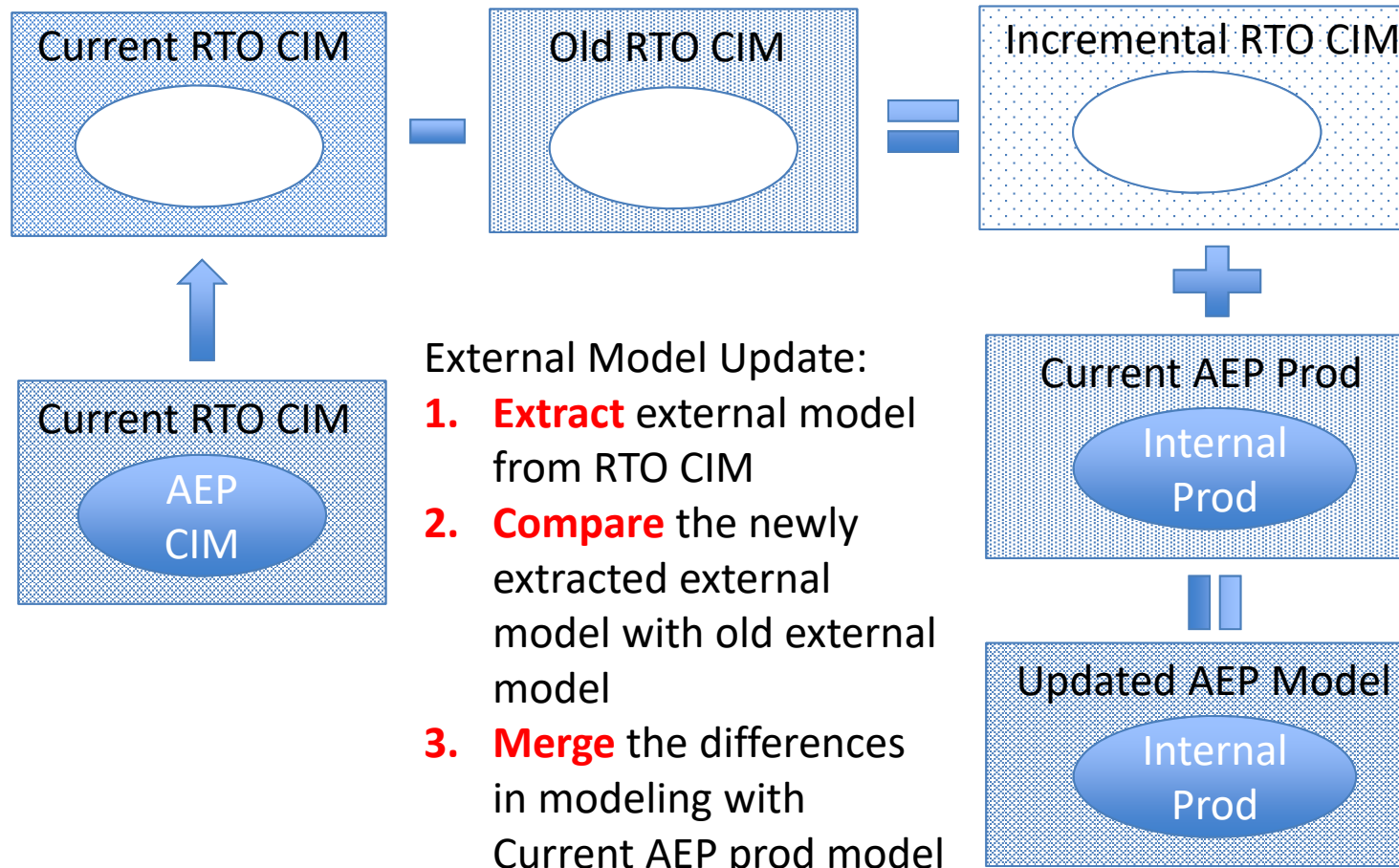


Fig. 2. AEP External Grid Modeling-CIM Incremental Method

AEP External Grid Modeling- Architecture

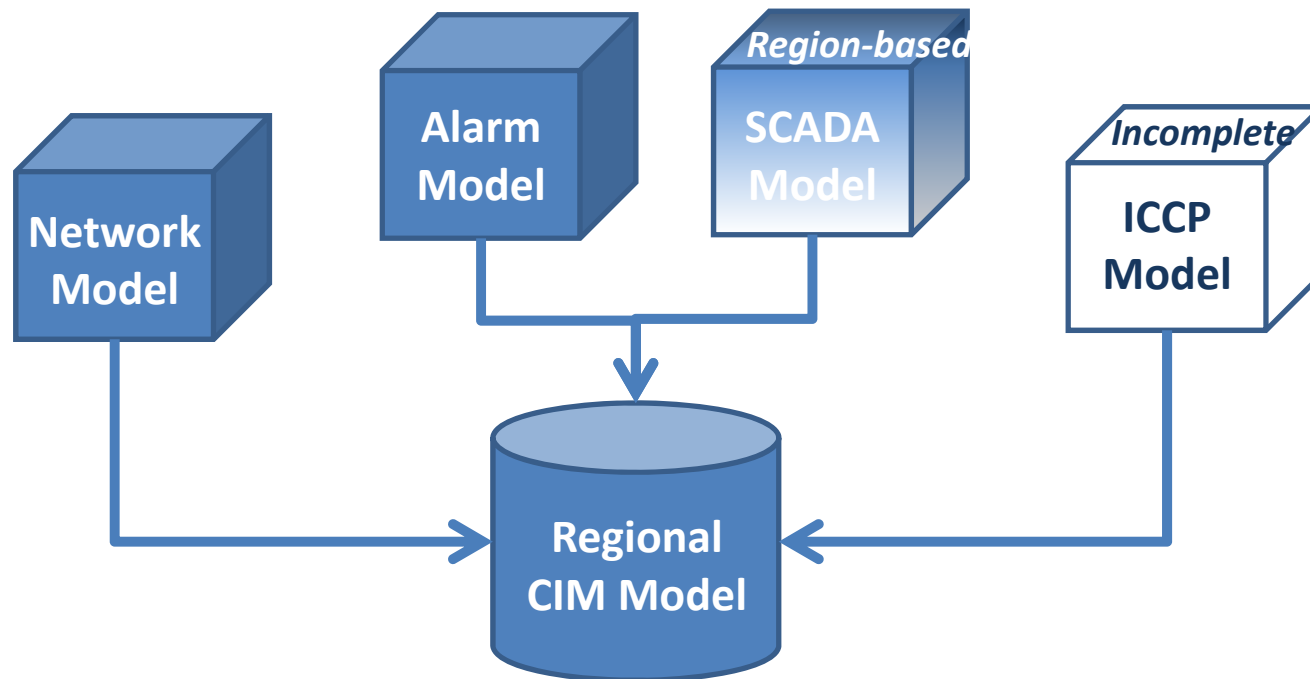
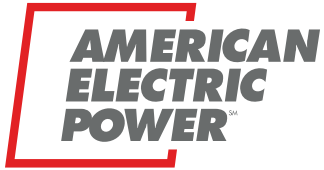


Fig. 3 Information archived in Regional CIM model



BOUNDLESS ENERGY™

AEP External Grid Modeling- Procedure

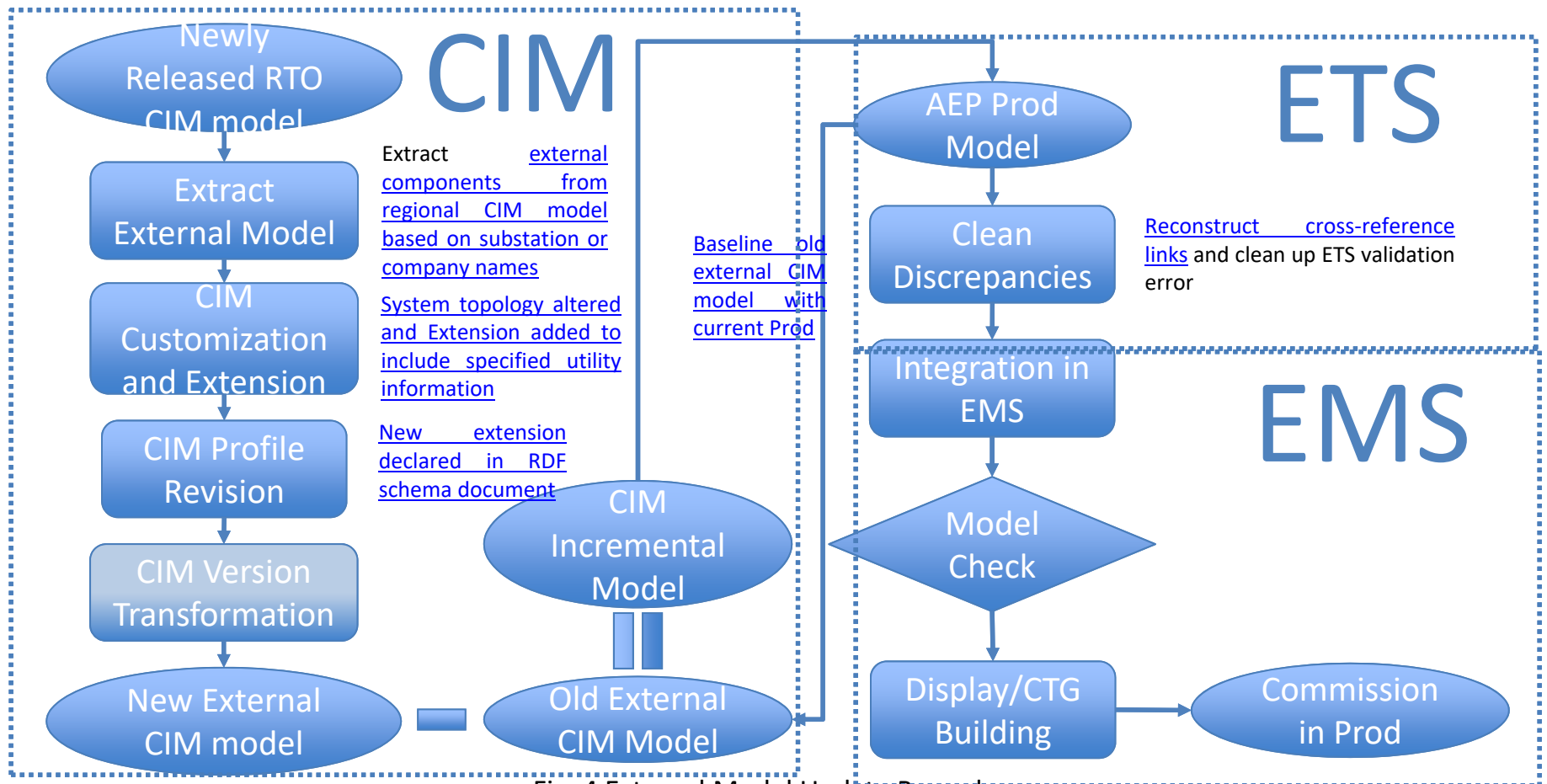


Fig. 4 External Model Update Procedure

AEP External Grid Modeling— Extraction

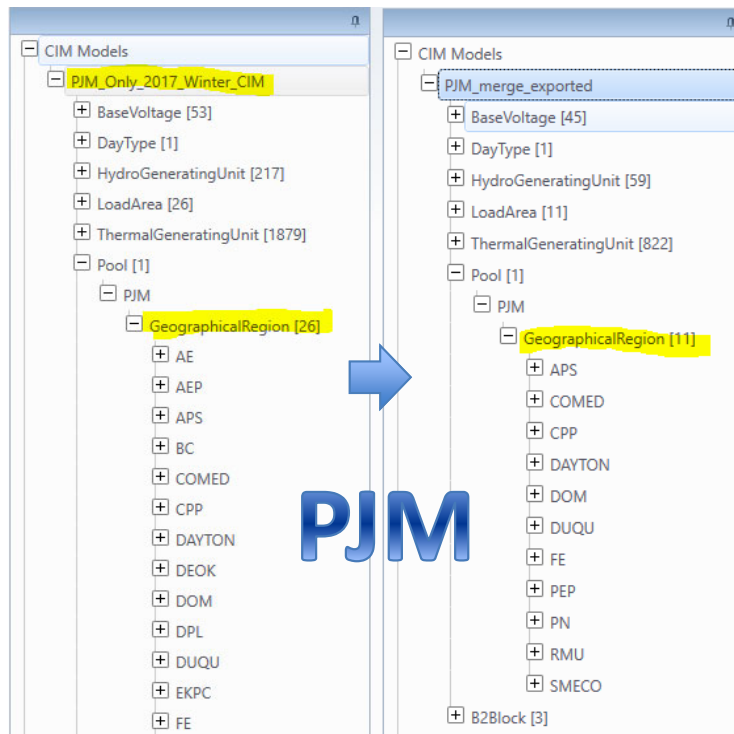


Fig. 5 Extraction of External Model from
PJM

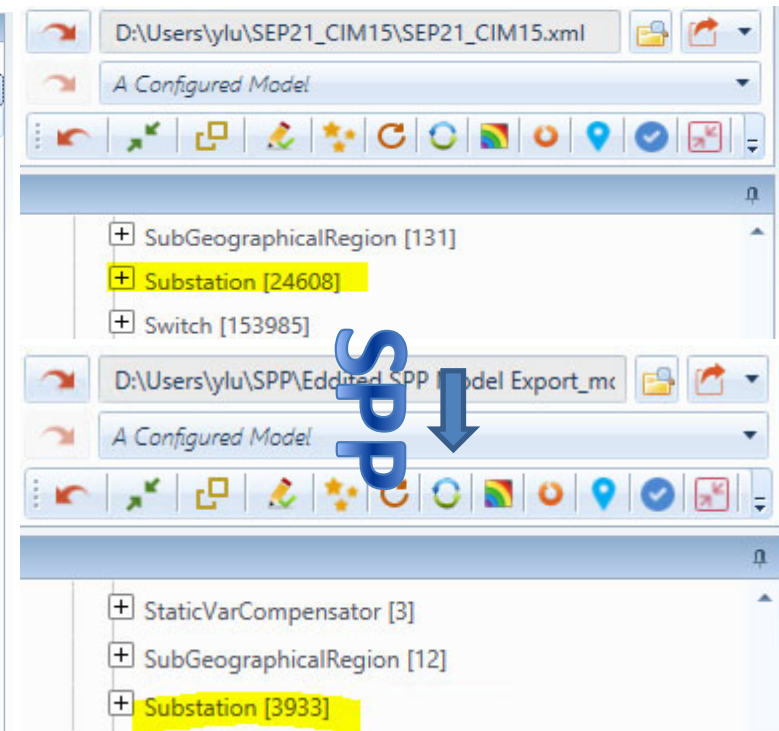


Fig. 6 Extraction of External Model from ERCOT

AEP External Grid Modeling— Boundary Delineation

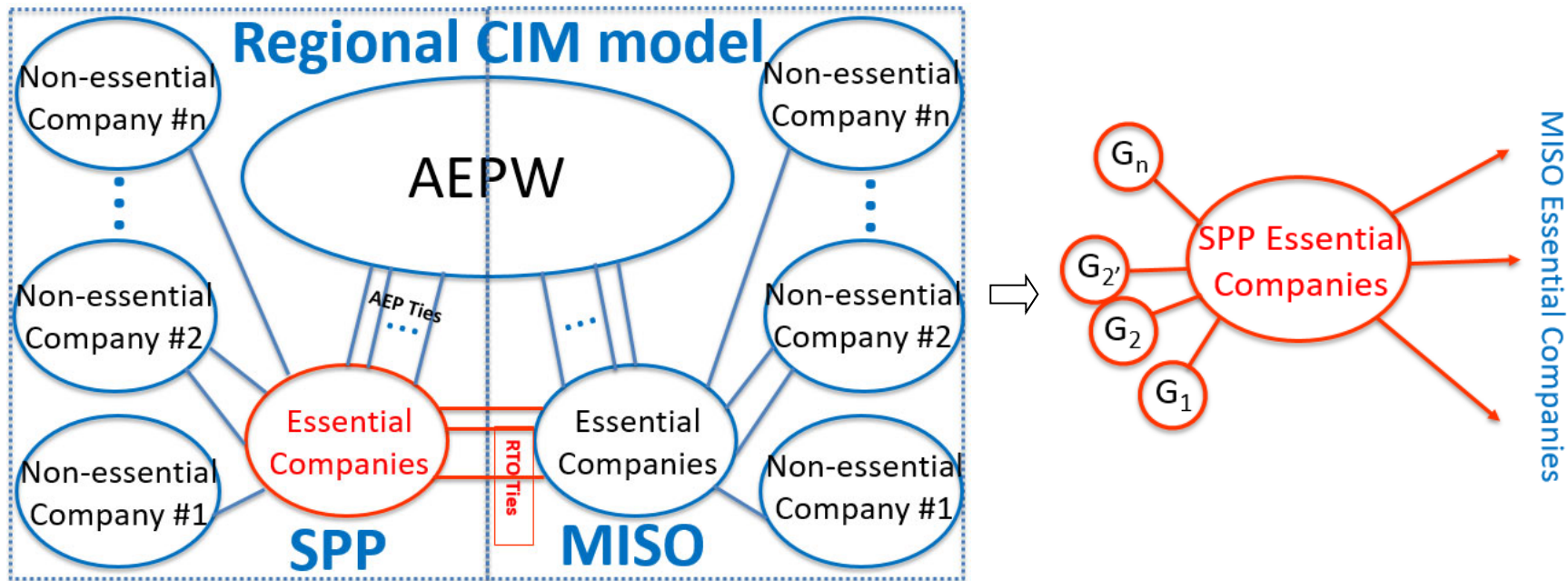


Fig. 7 Boundary Delineation in SPP CIM Model

1. Only 11 SPP companies are extracted
2. SPP side of tie-lines are extracted
3. Non-essential companies are equalized to pseudo unitsSM

AEP External Grid Modeling— Aggregation

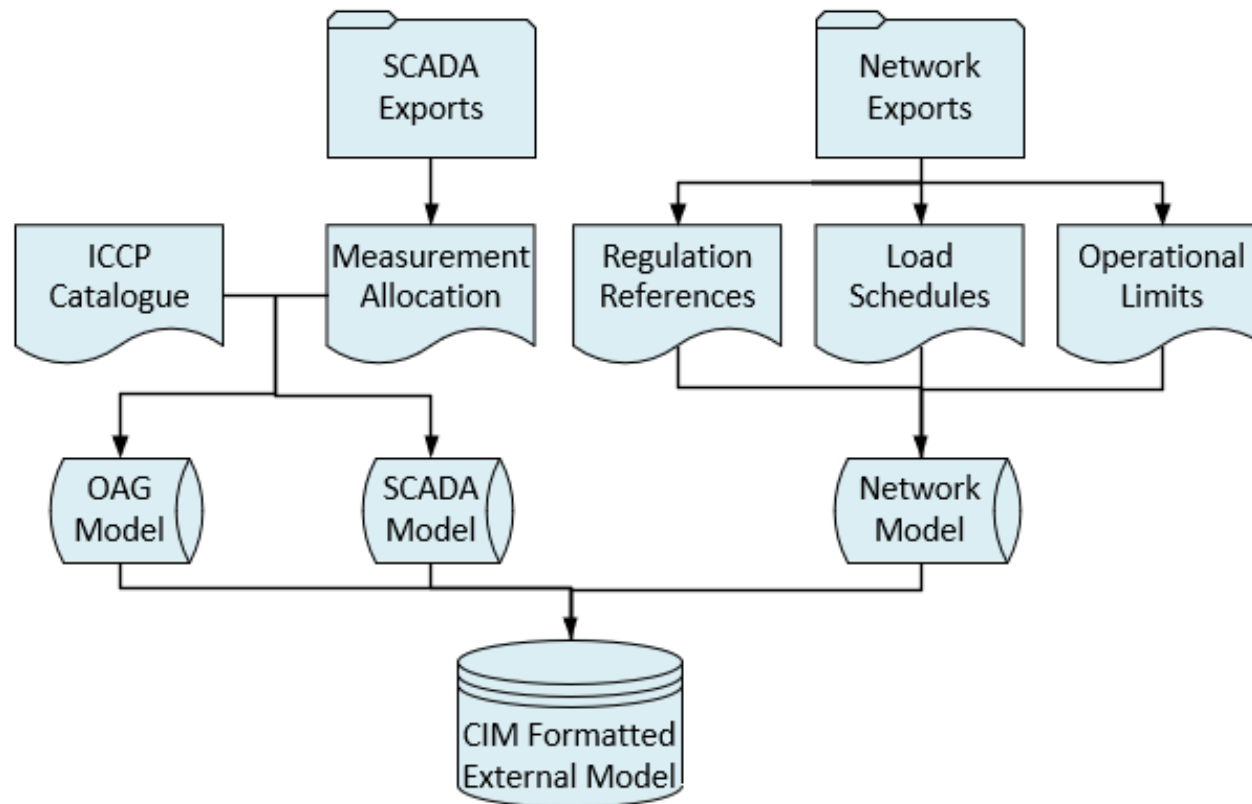


Fig. 8 Information Aggregation

AEP External Grid Modeling— Extension

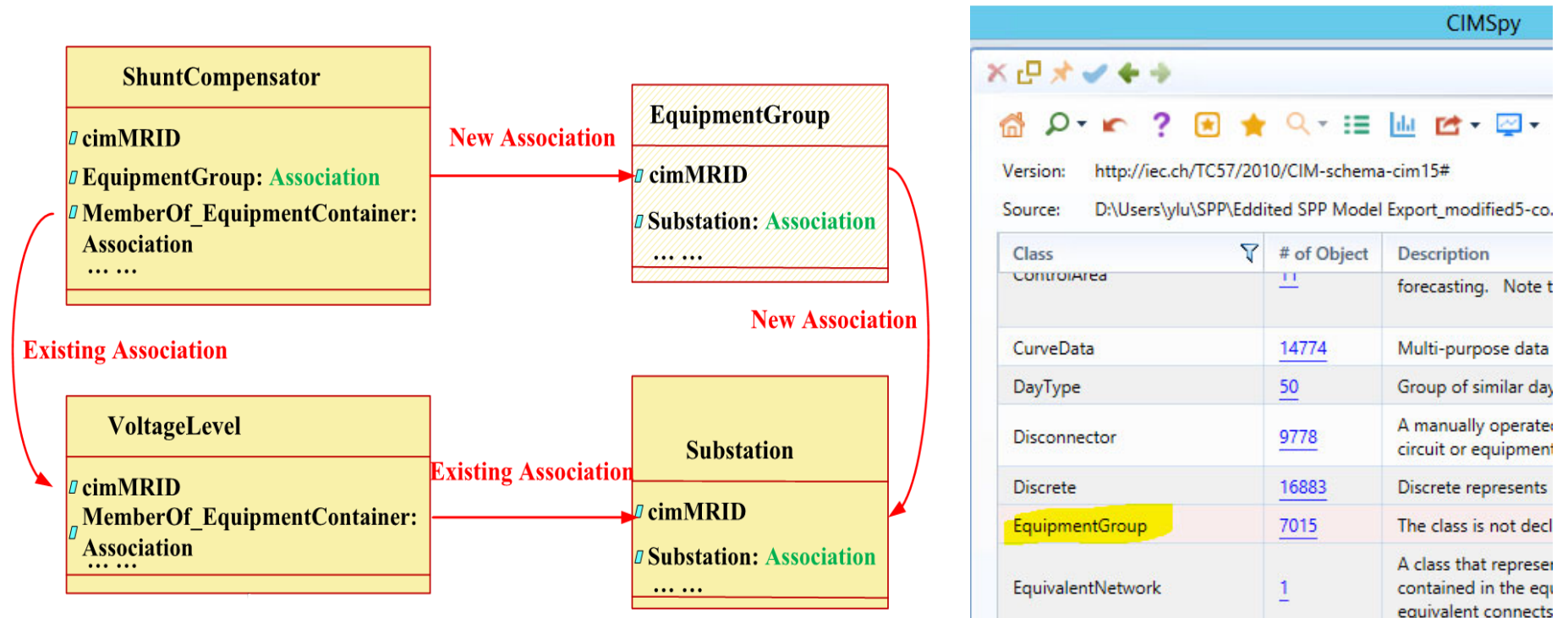


Fig. 9 CIM extension of EquipmentGroup

RTO model is loosely defined, extension adapts the model to utility format

AEP External Grid Modeling— Profile Revision

```

<rdf:Description rdf:about="http://iec.ch/TC57/2007/CIM-schema-cim12#ShuntCompensator.EquipmentGroup">
  <cims:inverseRoleName rdf:resource="http://iec.ch/TC57/2007/CIM-schema-cim12#EquipmentGroup.ShuntCompensator" />
  <cims:multiplicity rdf:resource="http://iec.ch/TC57/1999/rdf-schema-extensions-19990926#M:0..1" />
  <rdfs:comment>EquipmentGroup</rdfs:comment>
  <rdf:type rdf:resource="http://www.w3.org/1999/02/22-rdf-syntax-ns#Property" />
  <rdfs:label>EquipmentGroup</rdfs:label>
  <rdfs:range rdf:resource="http://iec.ch/TC57/2007/CIM-schema-cim12#EquipmentGroup" />
  <rdfs:domain rdf:resource="http://iec.ch/TC57/2007/CIM-schema-cim12#ShuntCompensator" />
</rdf:Description>

<rdf:Description rdf:about="http://iec.ch/TC57/2007/CIM-schema-cim12#EquipmentGroup.Substation">
  <cims:inverseRoleName rdf:resource="http://iec.ch/TC57/2007/CIM-schema-cim12#Substation.ChildEquipmentGroup" />
  <cims:multiplicity rdf:resource="http://iec.ch/TC57/1999/rdf-schema-extensions-19990926#M:0..1" />
  <rdfs:comment>
    Substation
  </rdfs:comment>
  <rdf:type rdf:resource="http://www.w3.org/1999/02/22-rdf-syntax-ns#Property" />
  <rdfs:label>Substation</rdfs:label>
  <rdfs:range rdf:resource="http://iec.ch/TC57/2007/CIM-schema-cim12#Substation" />
  <rdfs:domain rdf:resource="http://iec.ch/TC57/2007/CIM-schema-cim12#EquipmentGroup" />
</rdf:Description>

```

Newly Defined Associations of EquipmentGroup

Fig. 10 Declaration of EquipmentGroup in CIM Profile

Declare newly extended classes and associations in CIM Resource Description Framework Schema (RDFS) document for them to be correctly imported to e-terrasource

AEP External Grid Modeling— Transformation

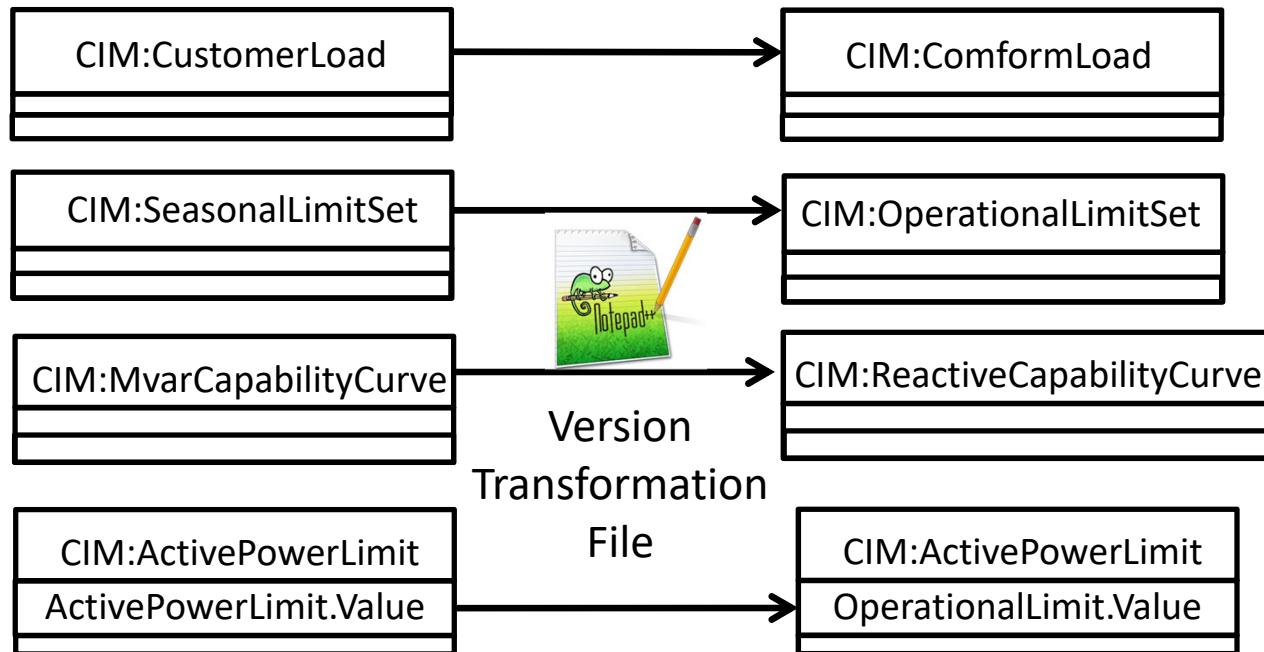


Fig. 11 CIM Version Transformation

AEP External Grid Modeling— Baseline

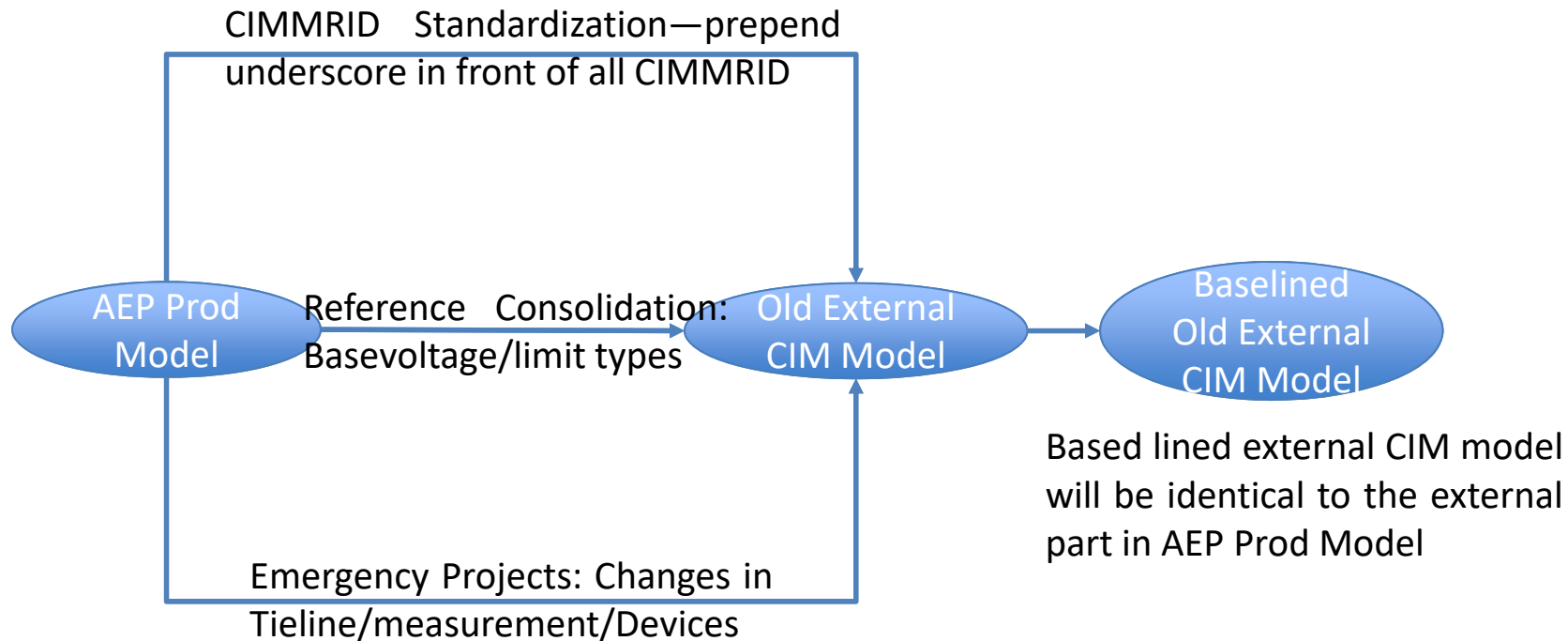
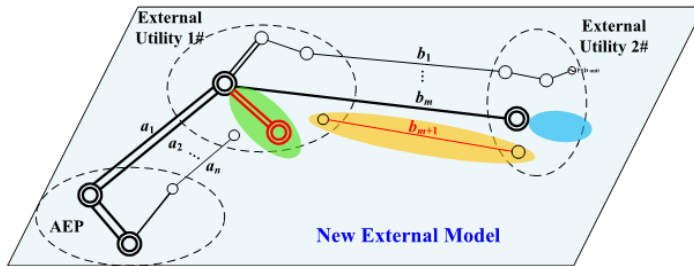


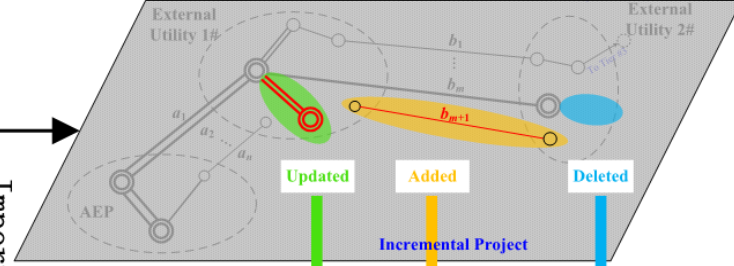
Fig. 12 Model Baselining

AEP External Grid Modeling— Compare and Merge

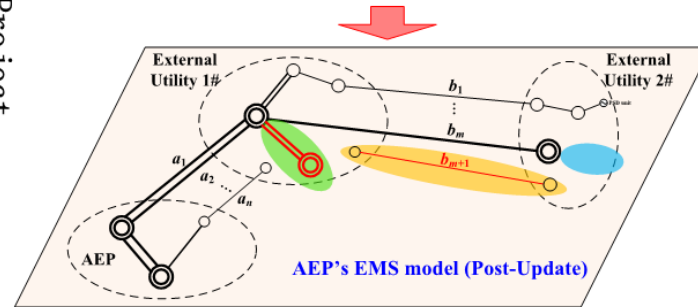
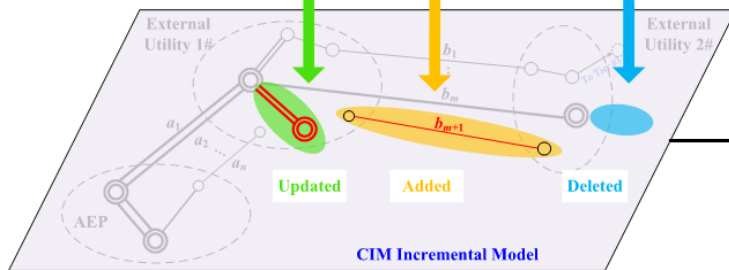
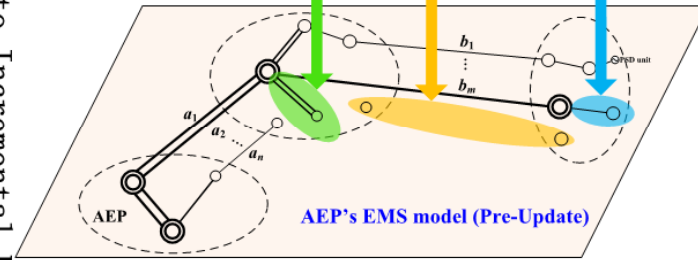
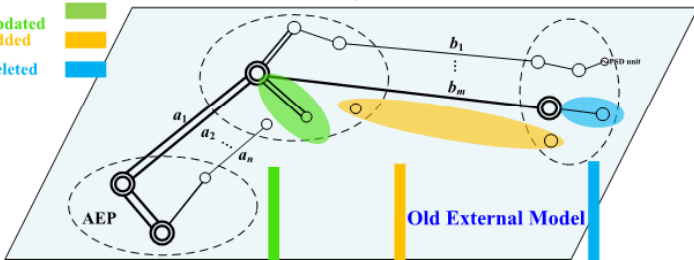
Inc. CIM model = New external model- Old external model



New EMS model = Current EMS model + Incrementals Project



- 1. Updated
- 2. Added
- 3. Deleted



Import to Incremental Project

Fig. 13 Load Incremental Changes to AEP Prod Model

AEP External Grid Modeling— Clean up

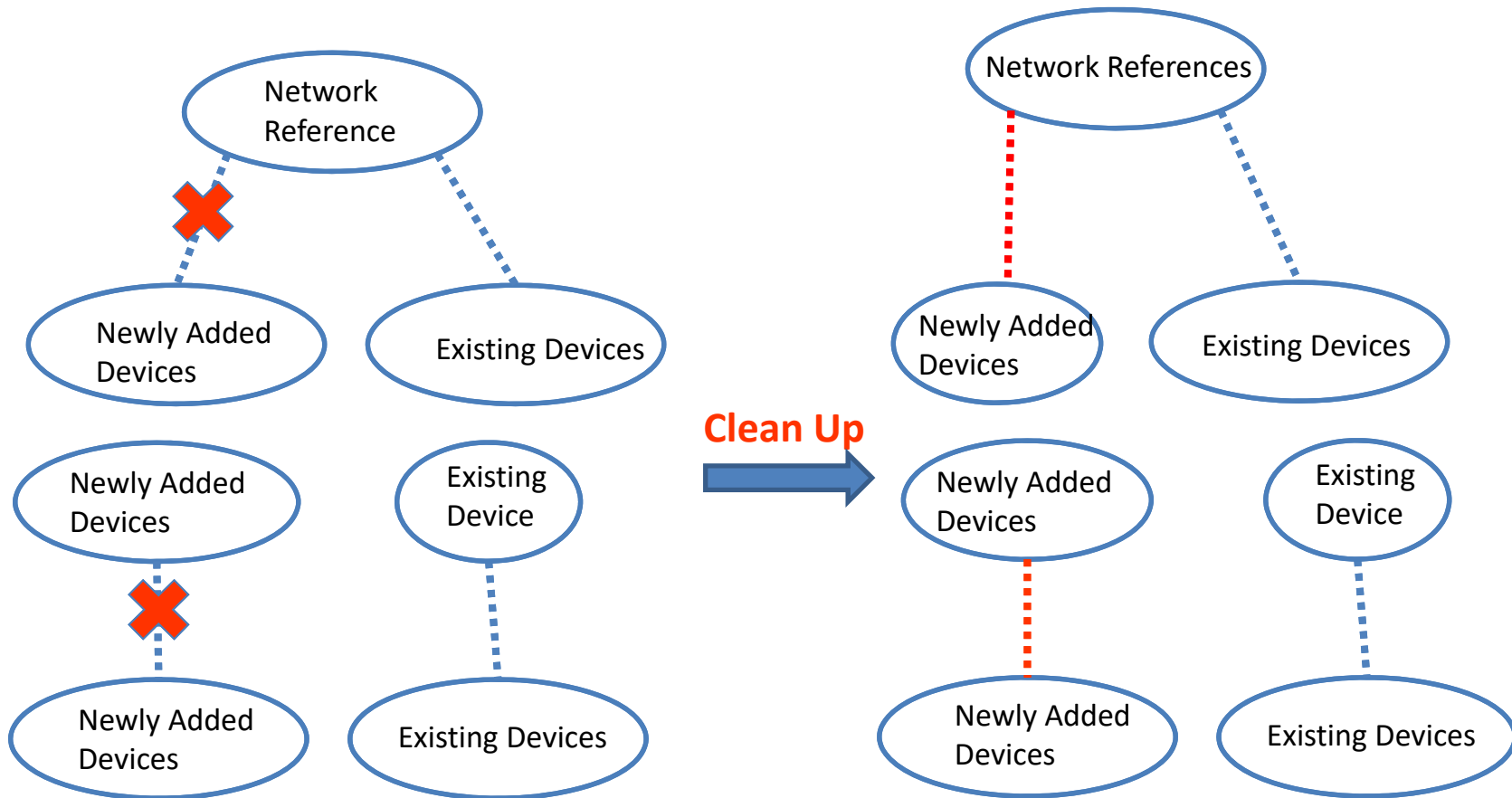


Fig. 14 Building Associations to bring in Newly Added Devices

AEP External Grid Modeling— Testing

Sequence

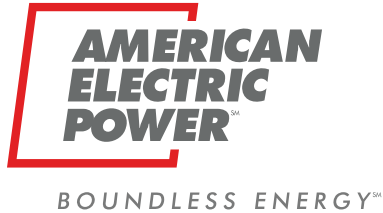
Save Next SE Result

Application / Task	Enable		Program Status	Last Completion	Periodicity
▾ RNET					
ESTIMATE	<input checked="" type="checkbox"/>	<u>VALID SOLUTION</u>	Sleeping	16-Jun-2021 14:05:23	60
▾ PLRTNET					
PLESTIM	<input type="checkbox"/>	PLRTNET IS READY		28-May-2021 09:14:16	60
▾ RTCA					
CA	<input checked="" type="checkbox"/>	<u>RTCA COMPLETED</u>	Sleeping	16-Jun-2021 14:04:41	120
▾ RTSENH					
CD	<input type="checkbox"/>	RTSENH IS DOWN		23-Apr-2019 17:20:03	60
CP	<input type="checkbox"/>	RTSENH IS DOWN		24-Apr-2019 14:06:45	120
PA	<input type="checkbox"/>	RTSENH IS DOWN		24-Apr-2019 14:06:47	120
▾ RTVSA					
VSA	<input type="checkbox"/>	RTVSA IS READY		24-Apr-2019 14:05:48	300
▾ RTLODF					
RTLODF	<input checked="" type="checkbox"/>	<u>RTLODF SOLUTION COMPLETED</u>	Sleeping	16-Jun-2021 14:04:23	120
▾ RMTNET					
RMTNET	<input type="checkbox"/>	RMTNET IS DOWN		24-Apr-2019 14:06:47	300



AEP External Grid Modeling— Current Status

- This CIM based external model update process has been successfully implemented for multiple times in all three of AEP's footprints
- The incremental methodology has facilitated multiple XMUs in both PJM and SPP footprint
- We are moving the CIM based model merge procedure to OSI environment



AEP External Grid Modeling— Summary

- The proposed CIM based methodology has been validated to be effective.
- The proposed methodology answers to the challenge of utility big data management and provides references to other entities
- The proposed methodology promotes power system interoperability and fulfils NIST recommendation.

*BOUNDLESS ENERGY*SM



BOUNDLESS ENERGY™

Tools

-
- e-terrasource (www.ge.com)
 - CIMSpy
(<http://www.powerinfo.us/CIMSpyEE.html>)

BOUNDLESS ENERGYSM

AEP CONFIDENTIAL

**AMERICAN
ELECTRIC
POWER™**

BOUNDLESS ENERGY™

QUESTIONS??



Contact Information:

ylu@aep.com

BOUNDLESS ENERGY™

AEP External Grid Modeling- CIM Bulk

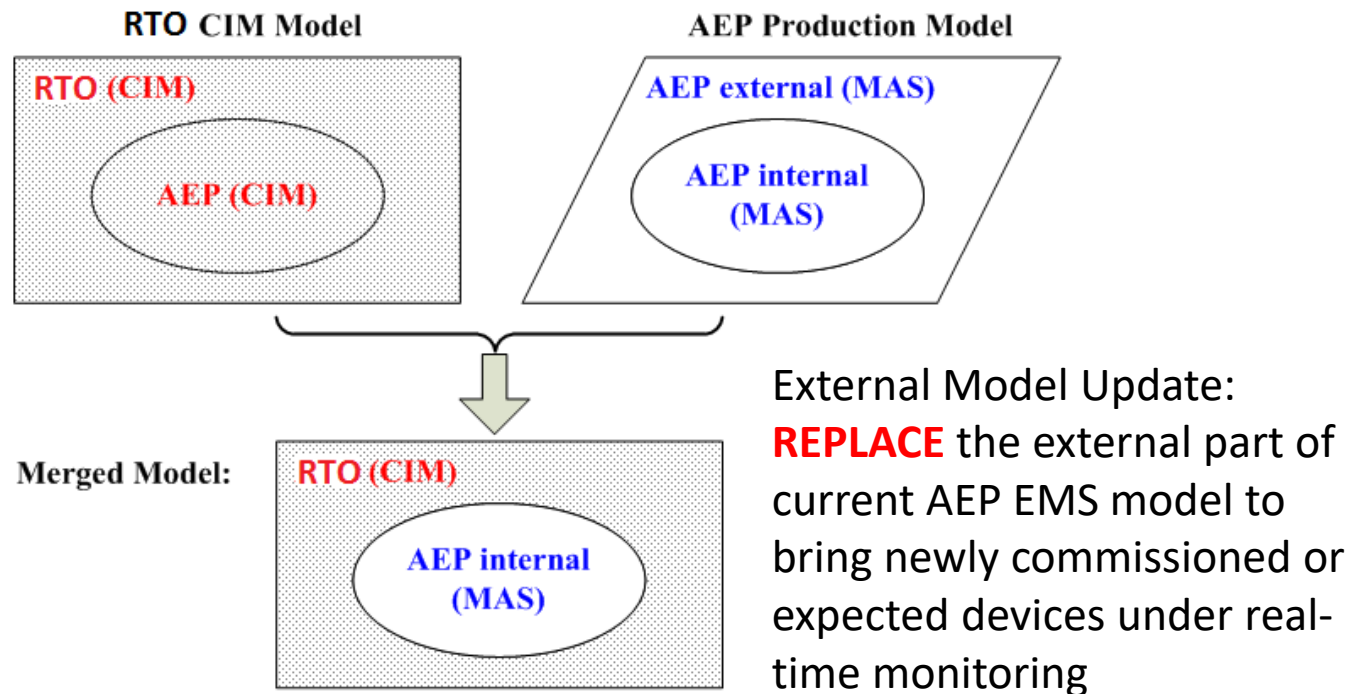


Fig. 2. AEP External Grid Modeling-CIM Bulk Method

AEP External Grid Modeling- CIM Incremental VS. CIM Bulk

- Avoid creating new internal MAS, which significantly increases database size.
- Introduce less changes to AEP Prod System, which dramatically reduces display building time.
- Avoid splitting and stitching, which requires intensive SQL coding to re-attach references with internal devices.
- Enhanced Compatibility with a wider range of vendor provided software

AEP External Grid Modeling- Architecture

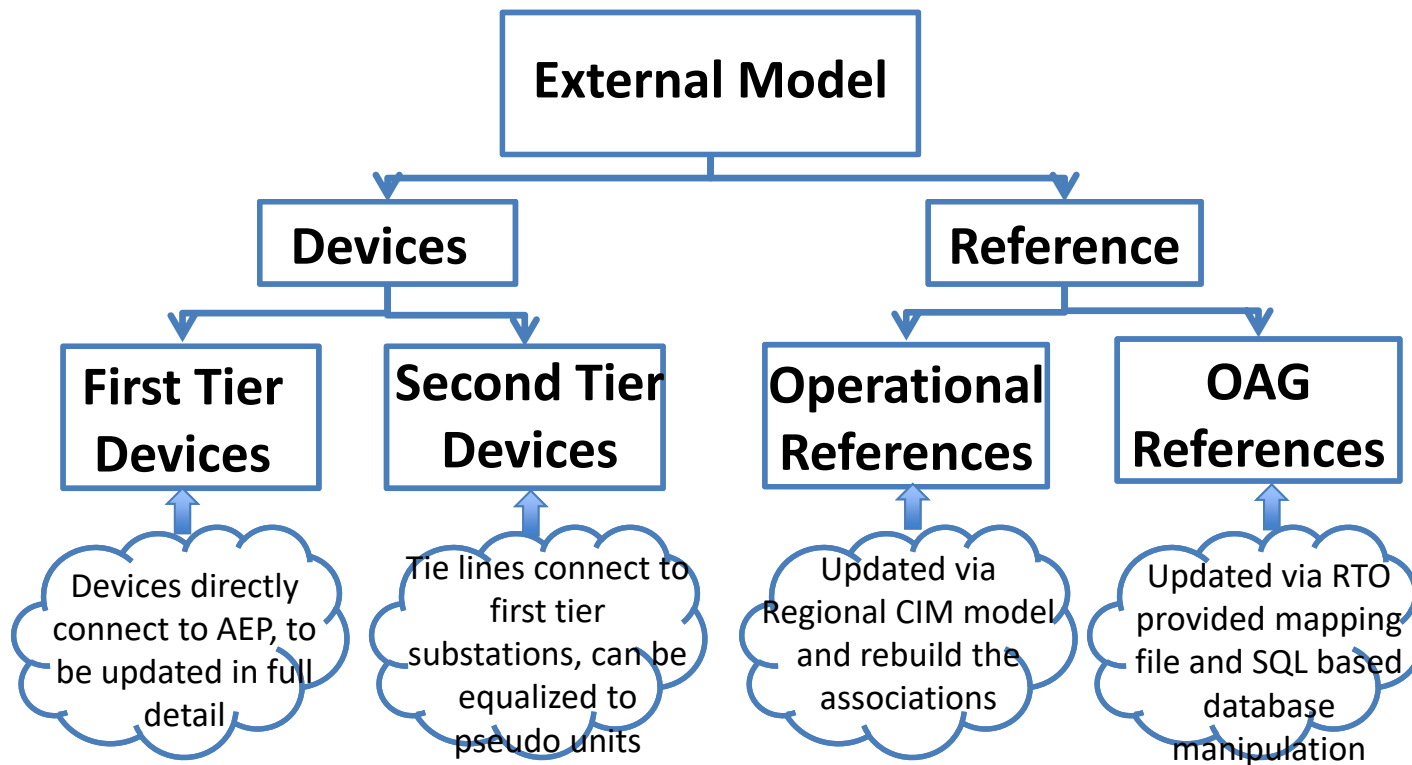


Fig. 5 External Model Architecture

AEP External Grid Modeling— Boundary Delineation

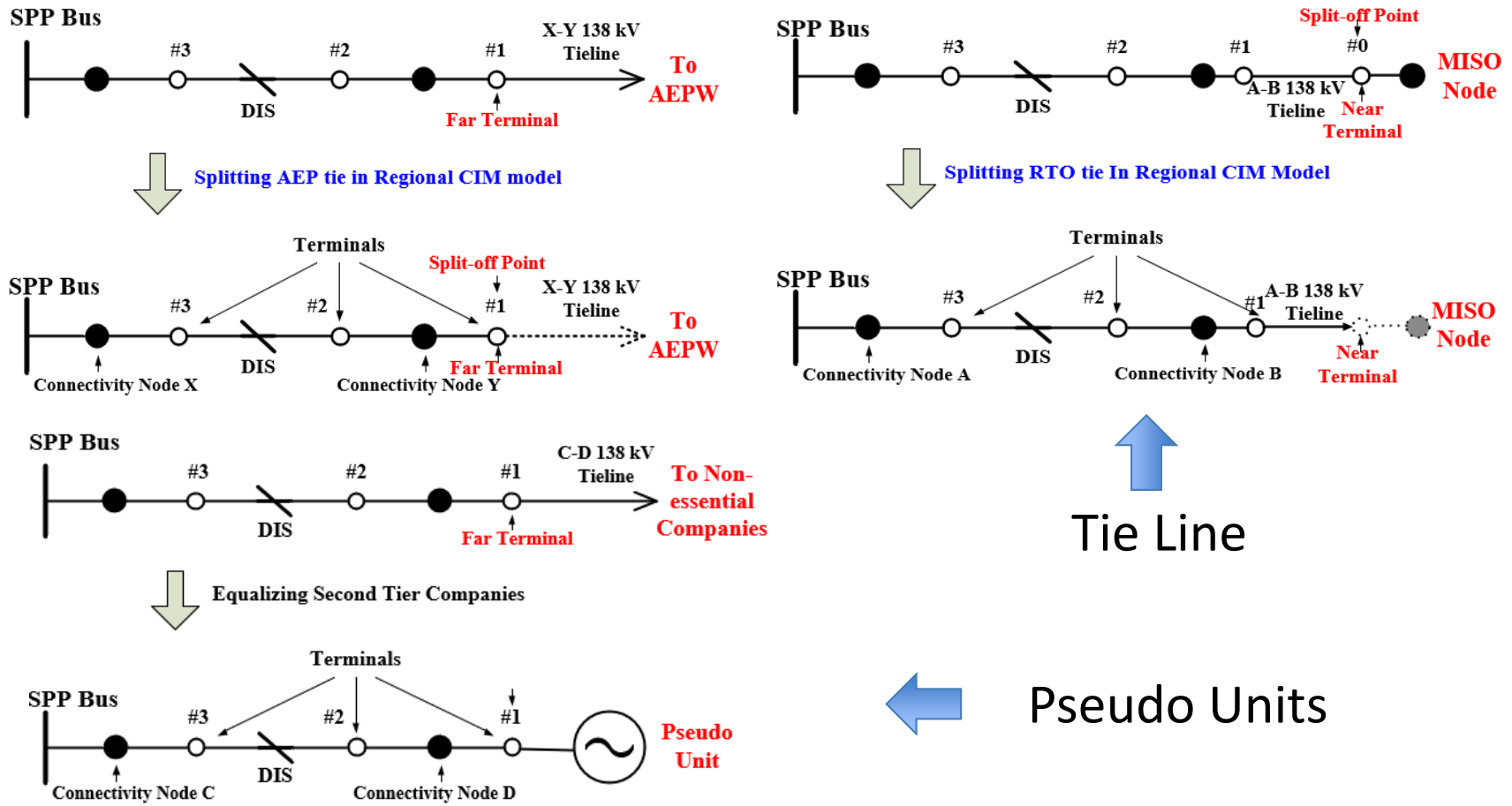


Fig. 10 Splitting Tie-line and Pseudo Units

AEP External Grid Modeling— Aggregation

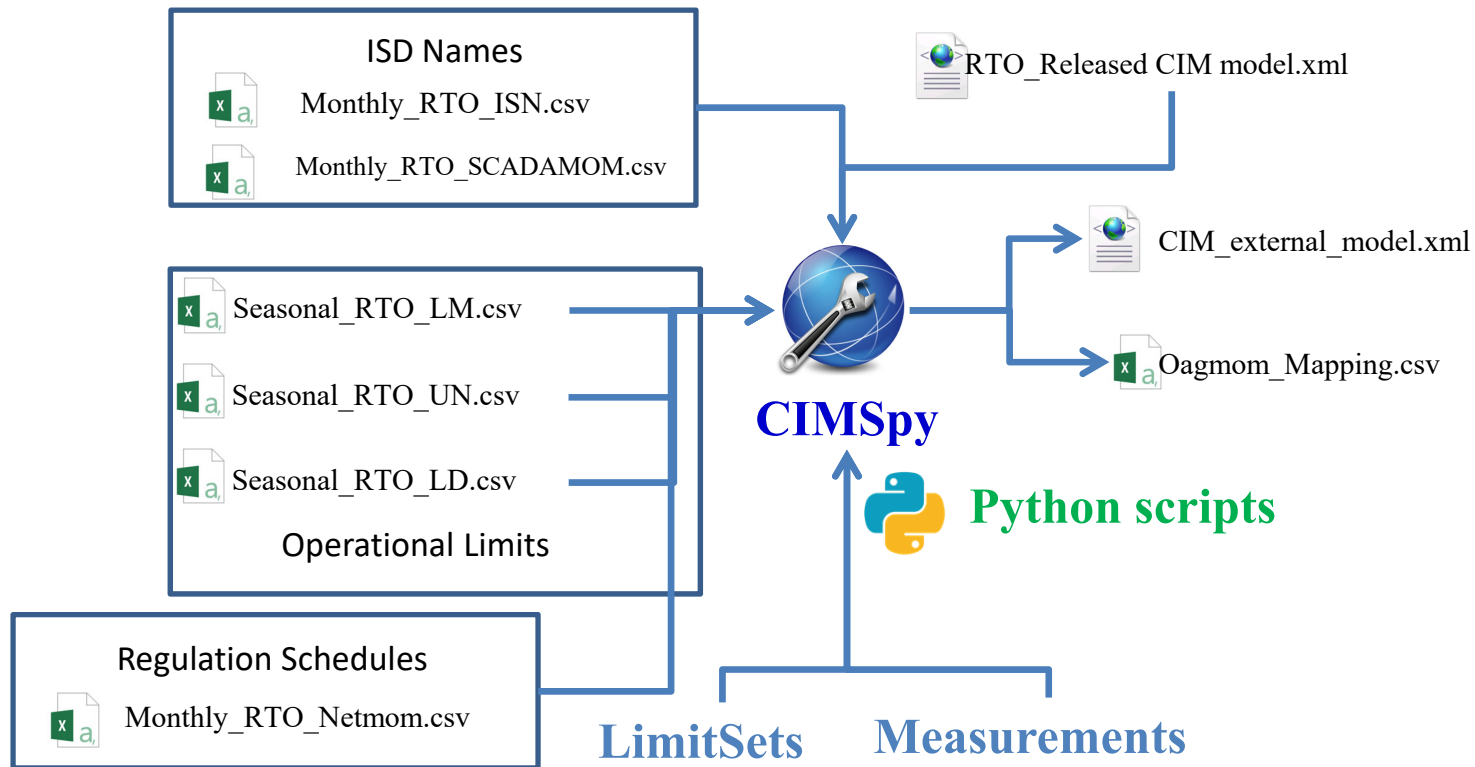
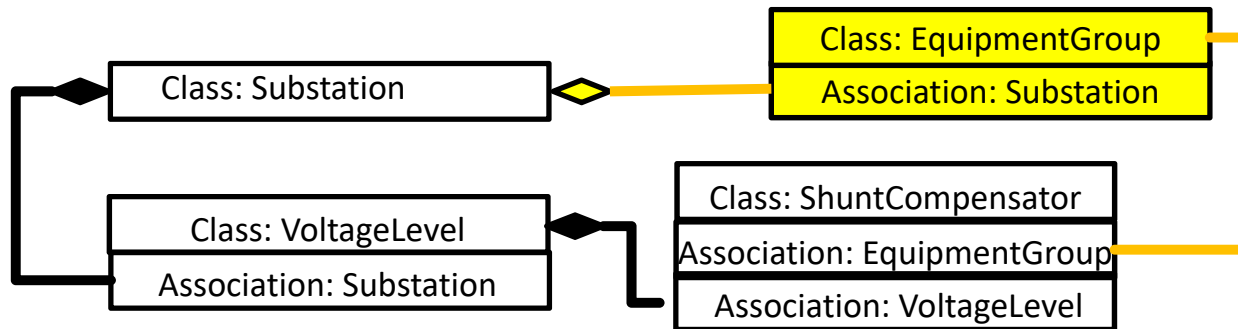


Fig. 12 Information Aggregation using API

AEP External Grid Modeling— Extension



Class	# of Object	Description
Discrete	18877	Discrete represents a discrete Measurement, i.e. a Measurem
EquipmentGroup	7697	The class is not declared in CIM or any extensions.
GeographicalRegion	11	A geographical region of a power system network model.

Fig. 15 CIM extension of EquipmentGroup

RTO model is loosely defined, extension adapts the model to utility format

AEP External Grid Modeling— Profile Revision

```

<rdf:Description rdf:about="http://iec.ch/TC57/2007/CIM-schema-cim12#ShuntCompensator.EquipmentGroup">
  <cims:inverseRoleName rdf:resource="http://iec.ch/TC57/2007/CIM-schema-cim12#EquipmentGroup.ShuntCompensator" />
  <cims:multiplicity rdf:resource="http://iec.ch/TC57/1999/rdf-schema-extensions-19990926#M:0..1" />
  <rdfs:comment>EquipmentGroup</rdfs:comment>
  <rdf:type rdf:resource="http://www.w3.org/1999/02/22-rdf-syntax-ns#Property" />
  <rdfs:label>EquipmentGroup</rdfs:label>
  <rdfs:range rdf:resource="http://iec.ch/TC57/2007/CIM-schema-cim12#EquipmentGroup" />
  <rdfs:domain rdf:resource="http://iec.ch/TC57/2007/CIM-schema-cim12#ShuntCompensator" />
</rdf:Description>

<rdf:Description rdf:about="http://iec.ch/TC57/2007/CIM-schema-cim12#EquipmentGroup.Substation">
  <cims:inverseRoleName rdf:resource="http://iec.ch/TC57/2007/CIM-schema-cim12#Substation.ChildEquipmentGroup" />
  <cims:multiplicity rdf:resource="http://iec.ch/TC57/1999/rdf-schema-extensions-19990926#M:0..1" />
  <rdfs:comment>
    Substation
  </rdfs:comment>
  <rdf:type rdf:resource="http://www.w3.org/1999/02/22-rdf-syntax-ns#Property" />
  <rdfs:label>Substation</rdfs:label>
  <rdfs:range rdf:resource="http://iec.ch/TC57/2007/CIM-schema-cim12#Substation" />
  <rdfs:domain rdf:resource="http://iec.ch/TC57/2007/CIM-schema-cim12#EquipmentGroup" />
</rdf:Description>

```

Newly Defined Associations of EquipmentGroup

Fig. 16 Declaration of EquipmentGroup in CIM Profile

Declare newly extended classes and associations in CIM Resource Description Framework Schema (RDFS) document for them to be correctly imported to e-terrasource

AEP External Model Update— Reconfiguration

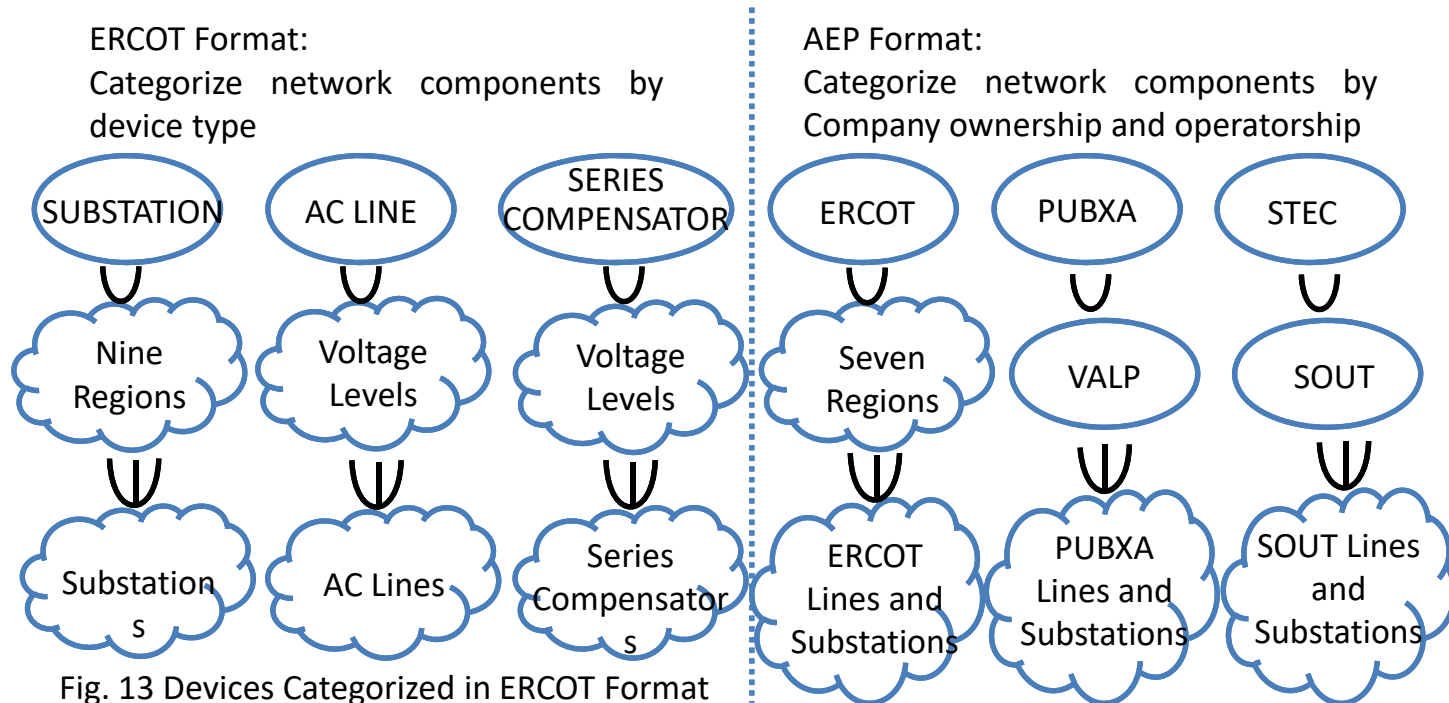


Fig. 13 Devices Categorized in ERCOT Format

Fig. 14 Devices Categorized in AEP Format

AEP External Grid Modeling— Clean up

EquipmentGroup

CIM path name	Substation	EquipmentGroupType
	KCPL KCPL BRKRIDGE	
BRKRIDGE BUS	KCPL KCPL BRKRIDGE	BUS
BRKRIDGE CB	KCPL KCPL BRKRIDGE	
BRKRIDGE DSC	KCPL KCPL BRKRIDGE	DSC
BRKRIDGE GEN	KCPL KCPL BRKRIDGE	
BRKRIDGE LD	KCPL KCPL BRKRIDGE	

Add Group Type

CIM path name	Substation	EquipmentGroupType
	KCPL KCPL BRKRIDGE	
BRKRIDGE BUS	KCPL KCPL BRKRIDGE	BUS
BRKRIDGE CB	KCPL KCPL BRKRIDGE	CB
BRKRIDGE DSC	KCPL KCPL BRKRIDGE	DSC
BRKRIDGE GEN	KCPL KCPL BRKRIDGE	GEN
BRKRIDGE LD	KCPL KCPL BRKRIDGE	LD



SQL Queries

Three Winding Transformer

Path name	Middle connectivity node	S
OKGE OKGE SUNNYSDE BK2		
OKGE OKGE SUNNYSDE BK3		

Add Middle Node

Path name	Middle connectivity node
OKGE OKGE SUNNYSDE BK2	OKGE OKGE SUNNYSDE EQX BK2
OKGE OKGE SUNNYSDE BK3	OKGE OKGE SUNNYSDE EQX BK3

Fig. 22 Building Associations to Fill in Required Fields of
Transformer and EquipmentGroup

AEP External Grid Modeling— Compare

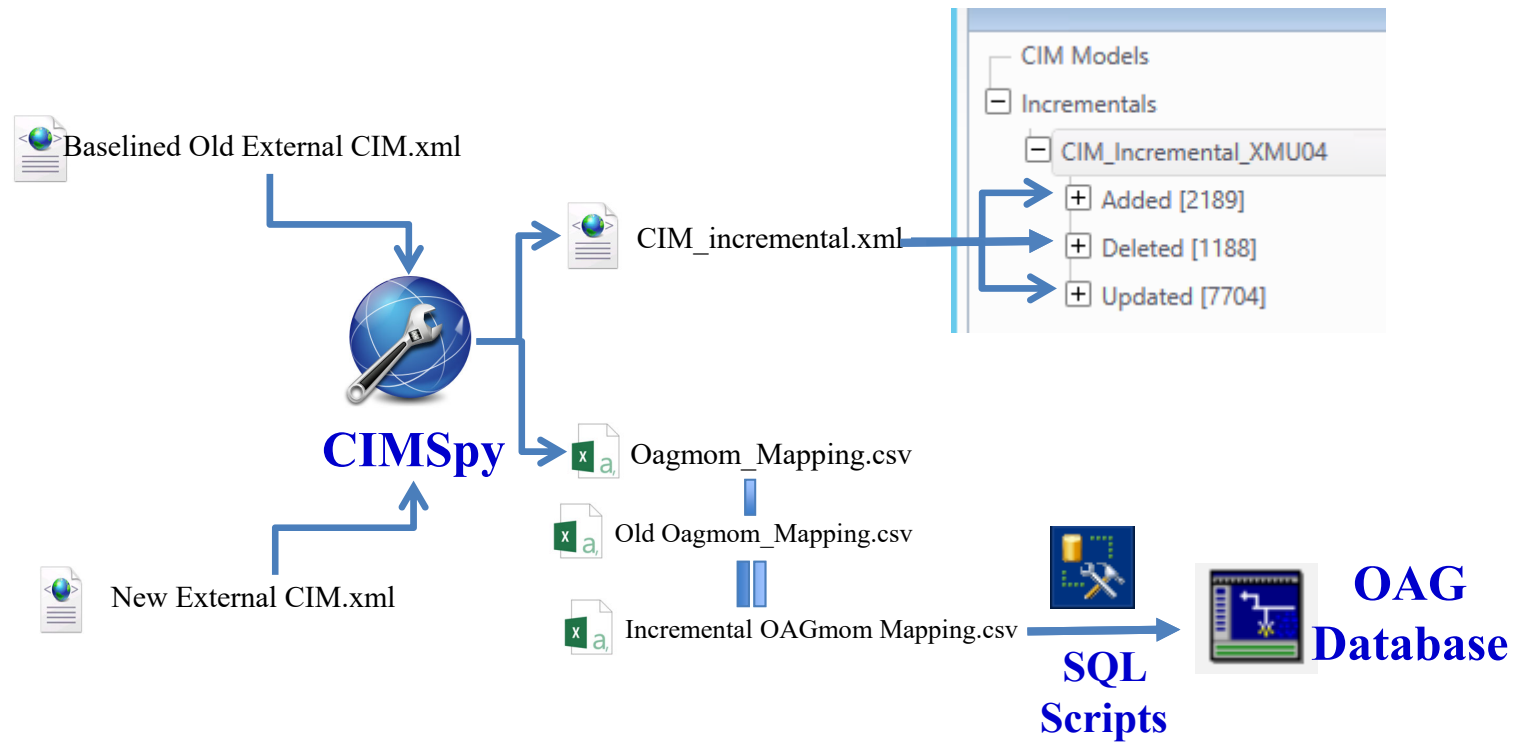
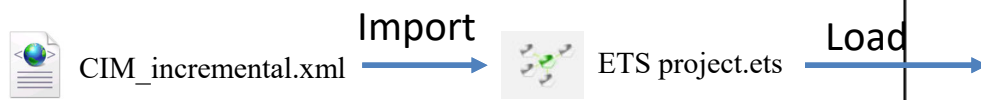


Fig. 19 Comparing new model against old model
to obtain incremental

AEP External Grid Modeling— Compare and Merge



1. Import incremental CIM model to ETS project
2. Load ETS project on AEP Prod Model.
3. Build ETS specified associations to newly added objects

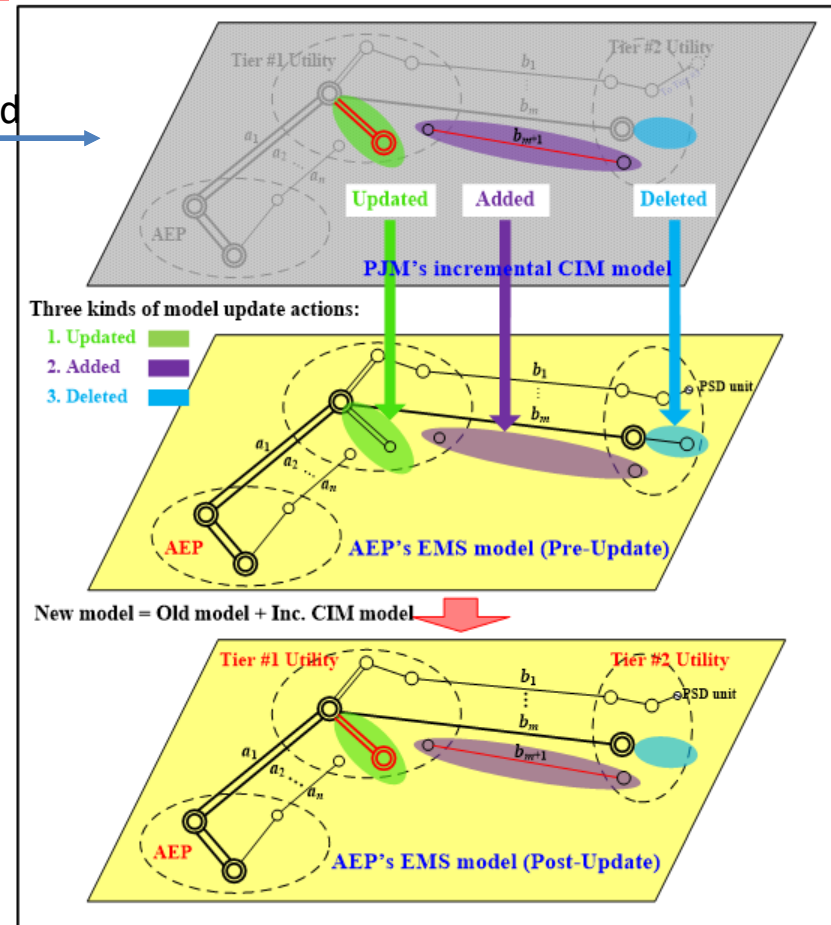


Fig. 20 Load Incremental Changes to AEP Prod Model



AEP External Grid Modeling— Testing

Real Time SE | Last: 16-Jun-2021 14:04:31 | Next: 16-Jun-2021 14:05:22 | **Sleeping** | **VALID SOLUTION** | Runs every 60 s | Run Sequence | i

Voltage Convergence:

Error Processing:

Quality Check:

Loss Calculation:

SYSTEM			
#	MW Gen	MW Load	Solution Converged?
1	67944.6	66356.5	Yes

- RELATED DISPLAYS
- SE
 - Parameters
 - Quality
 - Solution Iterations
 - Topology Errors
 - Network Cost Summary
 - Network Telemetered Data
 - Network Components
 - Network Data

BASECASE VIOLATIONS

Category	Alarm	Violation
Island	[Redacted]	[Redacted]
Branch	[Redacted]	[Redacted]

Main | Scada Vs Estimates | Company Solution Quality | Options

FILTER Internal | External | All | Company: [Dropdown] | ALL

Bus Mismatch More

STATION	KV	BUS	MW RESIDUAL	STATION	KV	BUS	MVAR RESIDUAL
GOODWN	115	3471	26.0	BVSE4	138	6292	23.4
KNOLL1	13.8	5218	24.7	MINGORD	138	6046	22.9
JONSBR	69	3422	15.8	WODSTK	13.8	8155	21.5
KNOLL1	13.8	5219	15.3	LONGWHT	12.5	6655	21.0
CIMARRON	345	4169	14.6	TULSAPWR	13.2	6305	19.0
QUITMAN2	69	7025	13.6	TEXARK_2	69	6884	14.1
UNIONAV	138	6110	12.0	POYNTER2	69	6759	13.4
CHAPEL_H	138	6511	11.5	BVCOMMC4	13.2	5940	13.2
SCOFFEYV	138	6233	11.0	WHITEHU	138	6906	13.2
NBENTON	12	6714	8.1	WESTERN	34	6860	13.1
EFAYETTE	69	9572	7.4	SEFAYETT	161	6780	12.5
BENTN279	161	6388	7.3	RICHMND2	69	6766	11.6
HSL1	10	4030	5.9	ECENTERT	69	6545	11.4
HONEYCRK	138	3656	5.1	EFAYETTE	69	9572	11.0
ORU	13.2	9532	4.8	WOODFORD	138	6314	10.2

Solution Quality

Total Unit Error
MW: 5448.4
MVAR: 6101.7

Total Tie Line Error
MW: 7511.4
MVAR: 5627.7

Bus Injection Deviation
MW: 711.1
MVAR: 291.4

Solution Cost Index: *****

Data Availability % **92.1**

Measurement Mismatch: Bus | Branch More

STATION	KV	BUS	MW RESIDUAL	STATION	KV	BUS	MVAR RESIDUAL
LAKOVR	500.0	9166	132.5	CIMARRON	138.0	4174	-214.7
LAKOVR	230.0	9165	-129.3	MICHOD	230.0	9127	183.8
MAYFLR	115.0	2948	107.8	FREPT5	230.0	9162	-162.8

Global Quality Check

Max MW Mismatch: [Redacted]

Max MVAR Mismatch: [Redacted]