Development and Implementation of Dynamic Load Models

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In the beginning…

Electric power Industry started using digital simulations back in late 1960s

The first 30+ years of simulations were focused on modeling power generators

Load representation was very simplistic,
reflecting limitations of the computing technology of the time

The need for dynamic load modeling was recognized by the electric power industry since 1980s – GE, PTI, IEEE and EPRI Loadsyn efforts

Need for Dynamic Load Modeling

Dynamic load modeling came to forefront of the discussion following several system events 1990s
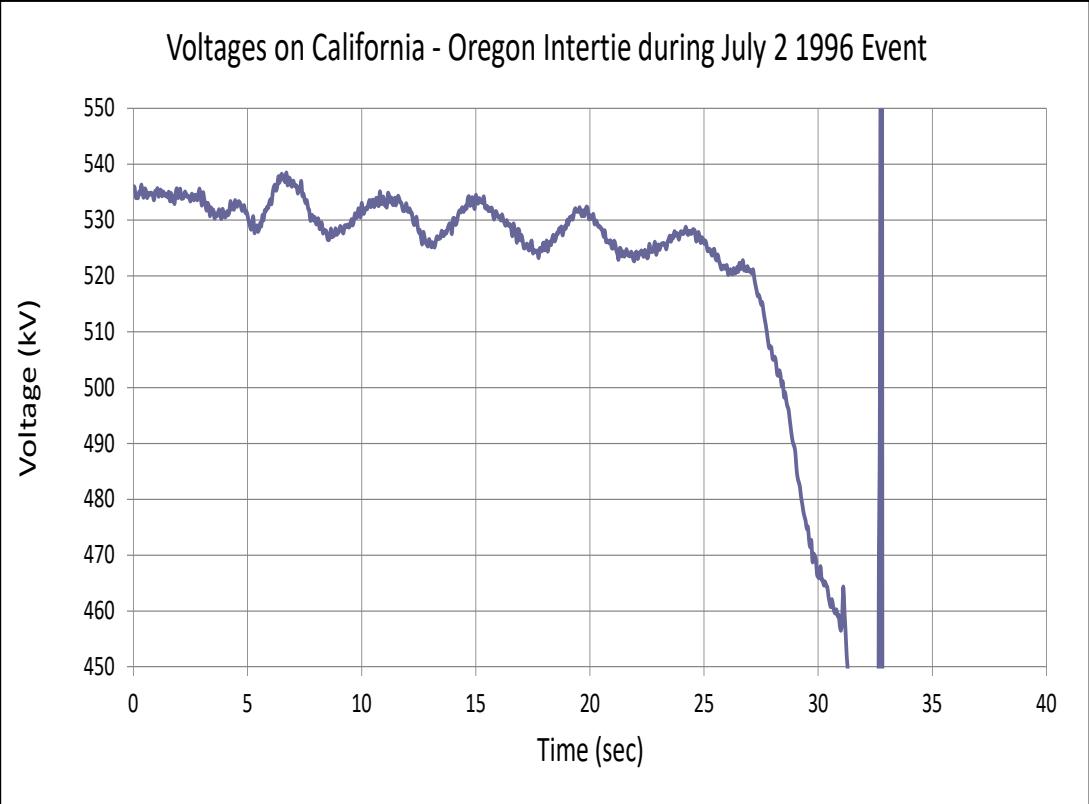
Large scale events of delayed voltage recovery in Florida, Georgia, and Southern California

Inter-area power oscillations in the Western Interconnection, including 1996 power outages
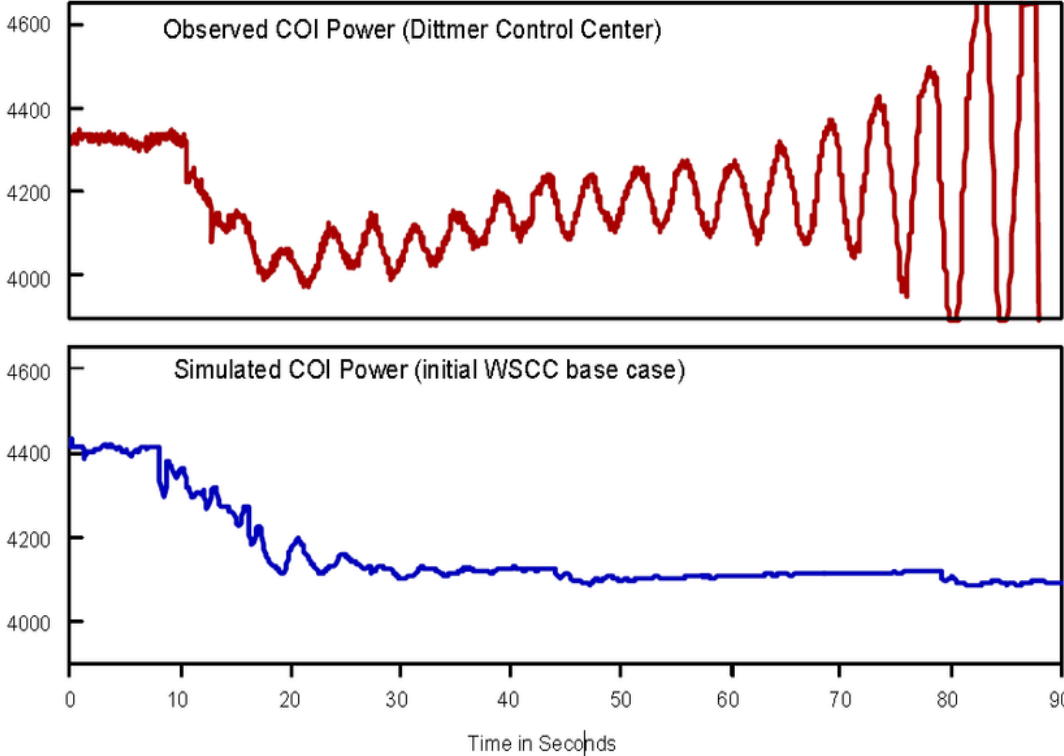
System Events in the West

July 2 1996
Voltage collapse in Boise, Idaho, propagated into California-Oregon Intertie, and caused uncontrolled separation
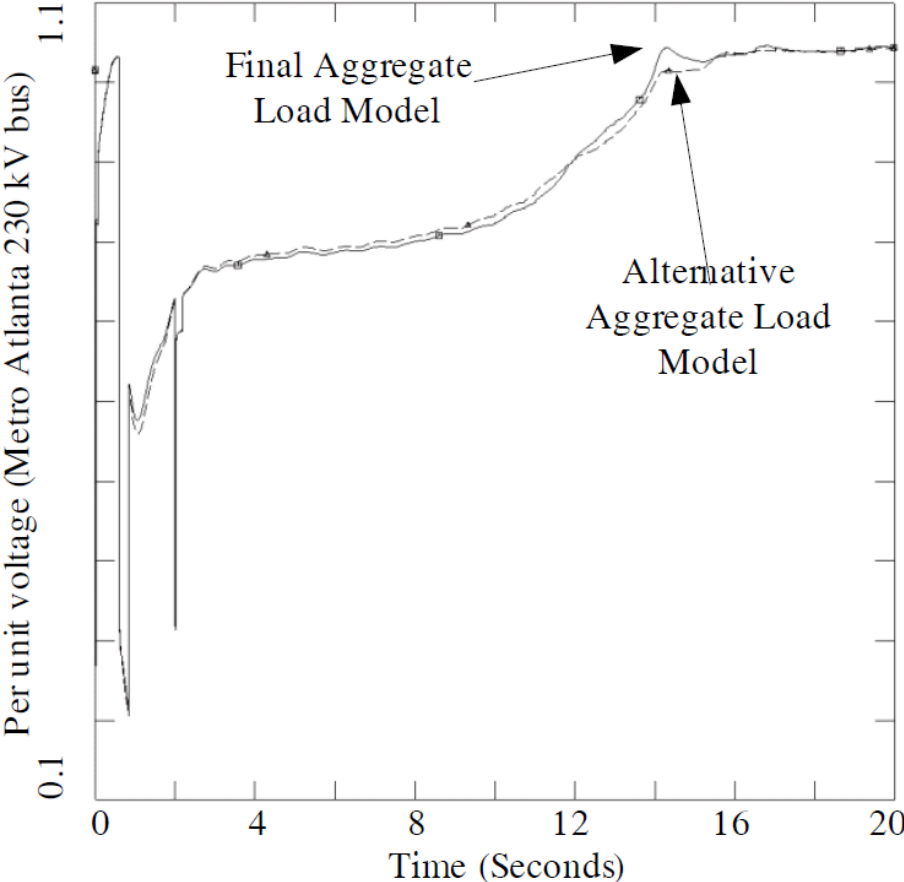

August 10 1996
Sequence of outages in Pacific Northwest caused instability and uncontrolled separation
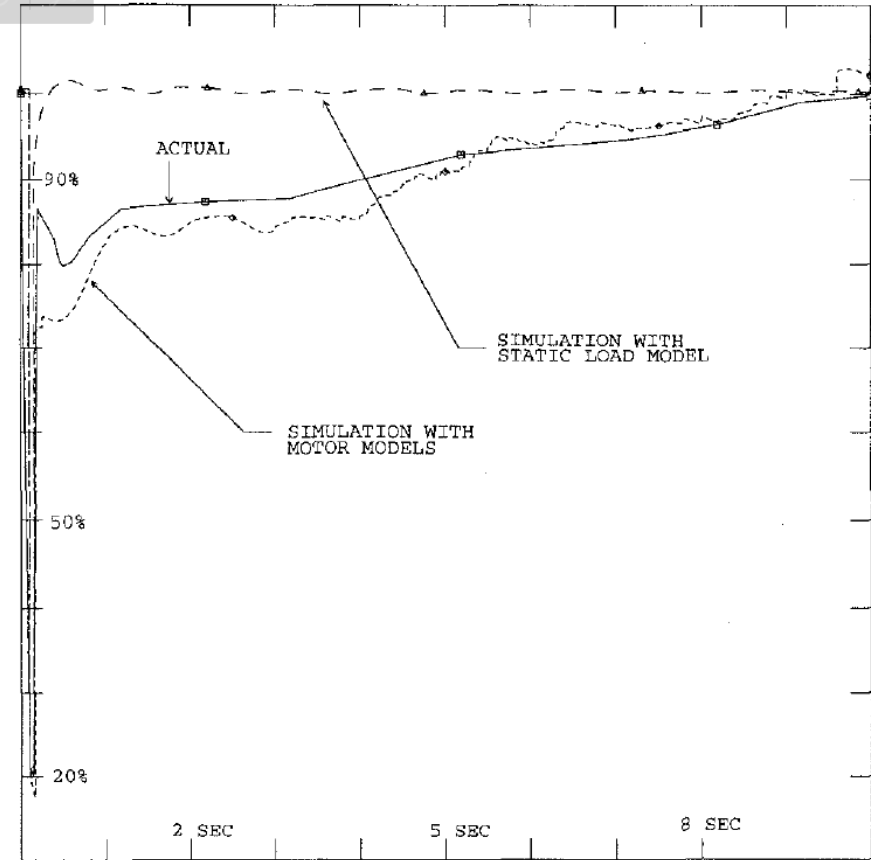25.5 GW generation tripped, 28.5 load tripped

System Events
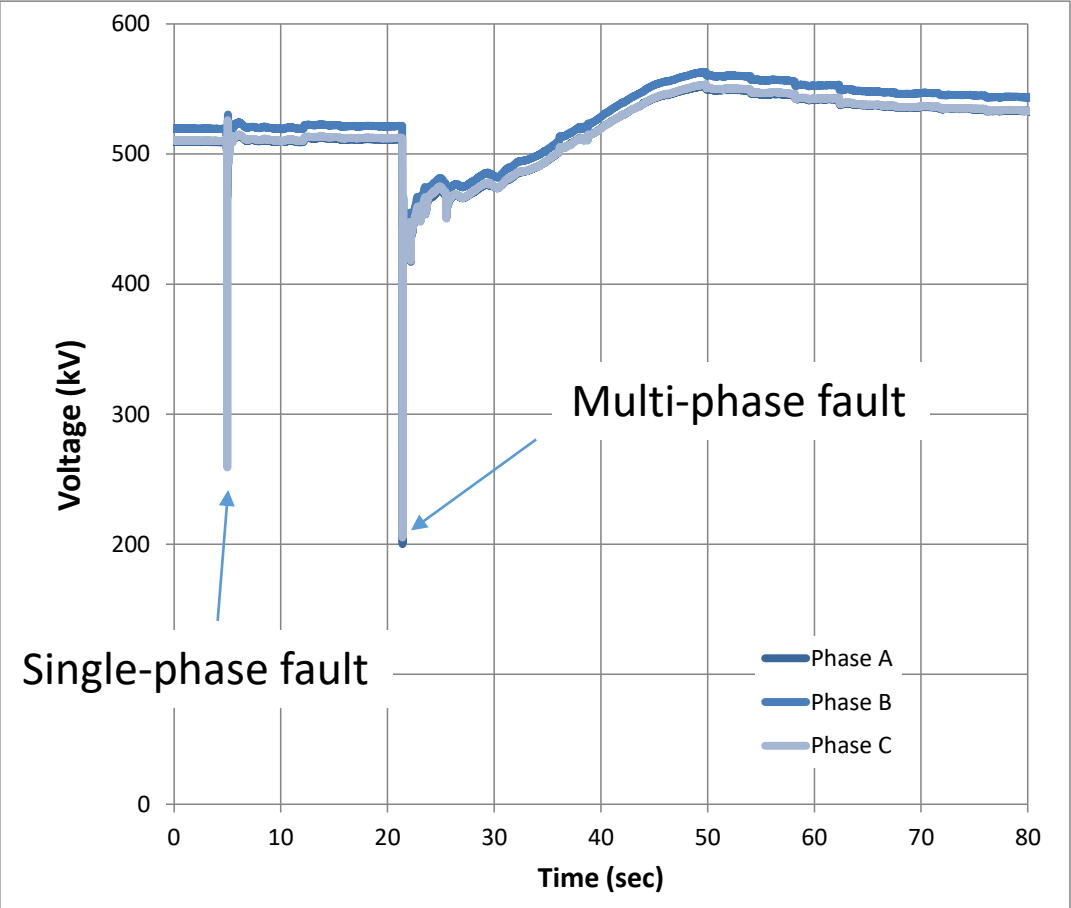

Southern Company
July 1999 - 1,900 MW load disconnected

Florida Power and Light
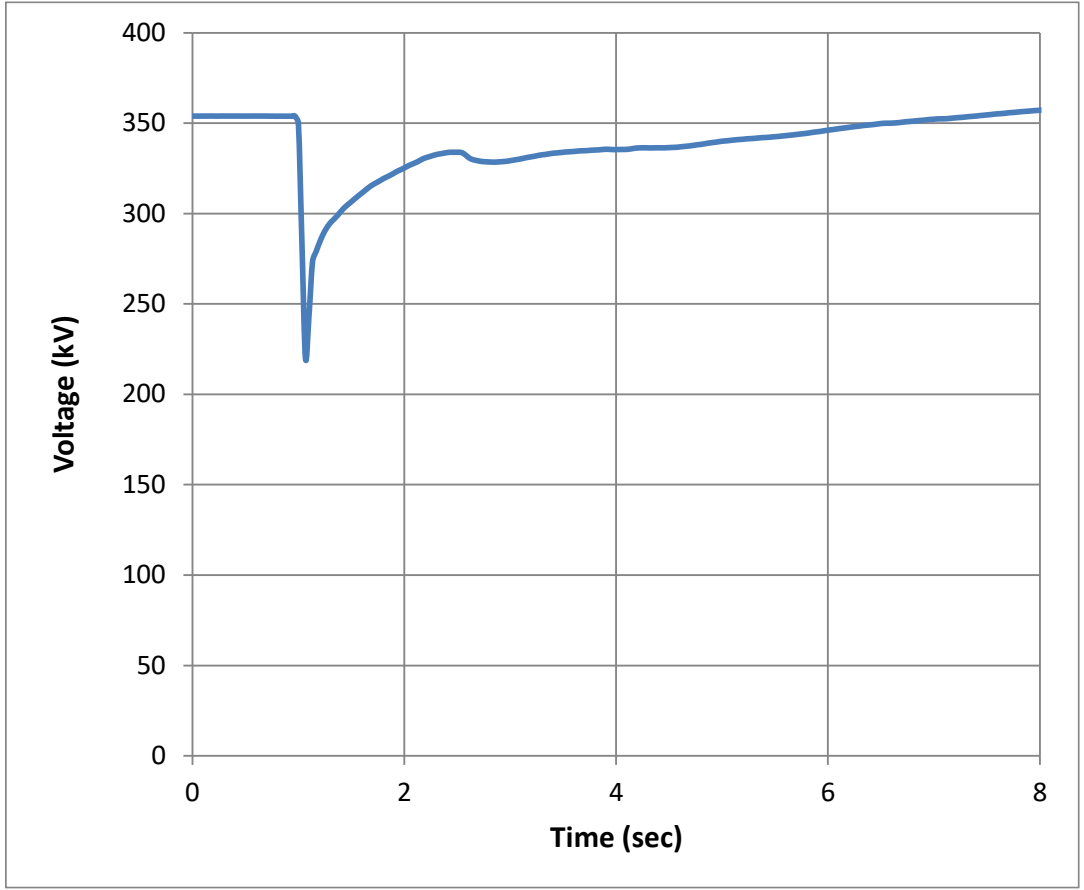August 1988 - 825 MW load disconnected

System Events

Southern California
August 1997 ~ 3,500 MW of load disconnected

Multi-phase fault

Single-phase fault

Phase A
Phase B
Phase C

Voltage (kV)

Time (sec)

Arizona
July 2003 – estimated ~1,500 MW of load disconnected (in addition ~2,700 MW of generation tripped)

Voltage (kV)

Time (sec)

NERC Transmission Issues Subcommittee prepared a technical reference on Fault-Induced Delayed Voltage Recovery in 2009

https://www.nerc.com/docs/pc/tis/fidvr_tech_ref%20v1-2_pc_approved.pdf

DOE-NERC Workshops

- DOE and NERC held three workshops on dynamic load modeling and fault-induced delayed voltage recovery:
    - 2008 - https://certs.lbl.gov/publications/2008-us-doe-workshop-role-residential
    - 2009 - https://certs.lbl.gov/publications/2009-doe-nerc-workshop-fault-induced
    - 2015 - https://certs.lbl.gov/publications/2015-workshop-fault-induced-delayed

- DOE engaged AC manufacturers in the discussion

- More technical documents can be found on CERTS website https://certs.lbl.gov/initiatives/fidvr

Dynamic Load Model Development

Western Interconnection launched a major effort to improve dynamic load models in mid 2000s

US DOE, CERTS Program, California Energy Commission and EPRI provided significant support during the early stages of the model development:

- Testing of electrical end uses, developing models
- Load composition analysis
- Load monitoring
- Cross-industry engagement – air-conditioner manufacturers, electric vehicle manufacturers
- National Labs – LNBL and PNNL

Dynamic Load Model Development

DOE funded critical work on

- Testing electrical end-uses and developing models (particularly air-conditioners)

- Surveys and testing of end-use protection and controls

Developed models were implemented in grid simulation packages used in North America, like GE PSLF, Siemens PTI PSS® and PowerWorld

Dynamic Load Model Development

DOE funded critical research on Load Composition Model

Developed Load Composition Model and Data management techniques are implemented in NERC Load Model Data Tool

 "Success of model deployment is dependent on model management tools"

Dynamic Load Model Implementation

Dynamic load models are required by NERC Transmission Planning Reliability Standard

Dynamic Load Model was implemented in grid simulation packages like GE PSLF, Siemens PTI PSS®E and PowerWorld

Distributed Energy Resource (DER) model was integrated in Dynamic Load Model
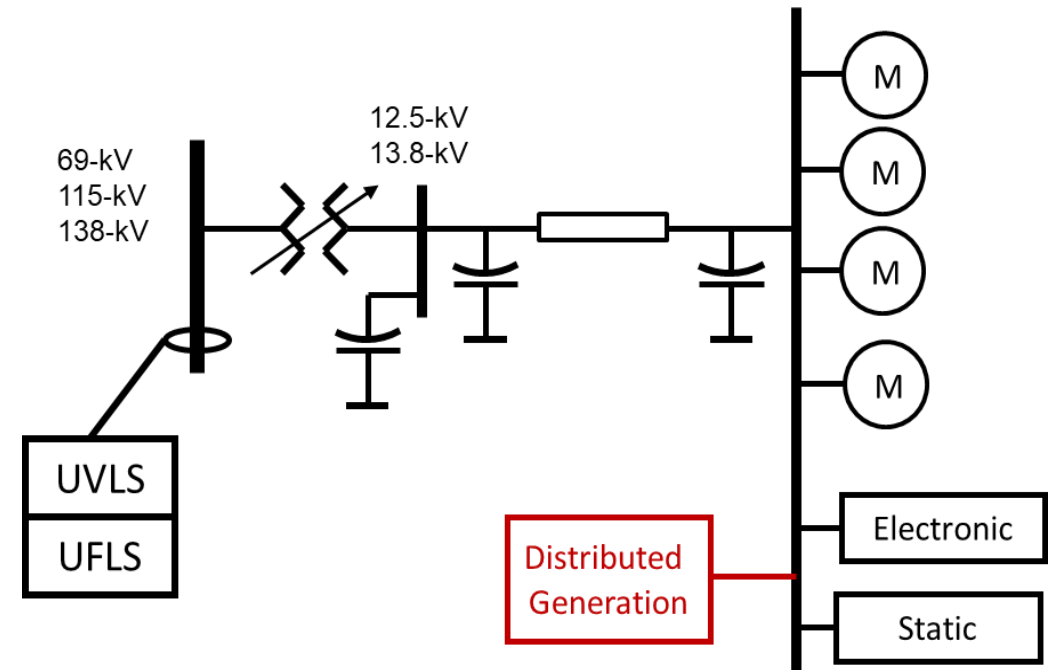
Moving Forward - Keeping Models Up to Date

Where we are now:

- Dynamic Load Model was approved for stability studies in Western Interconnection by WECC in 2011
- Many Transmission Planners in Eastern Interconnection and ERCOT are in various phases of Dynamic Load Model implementation

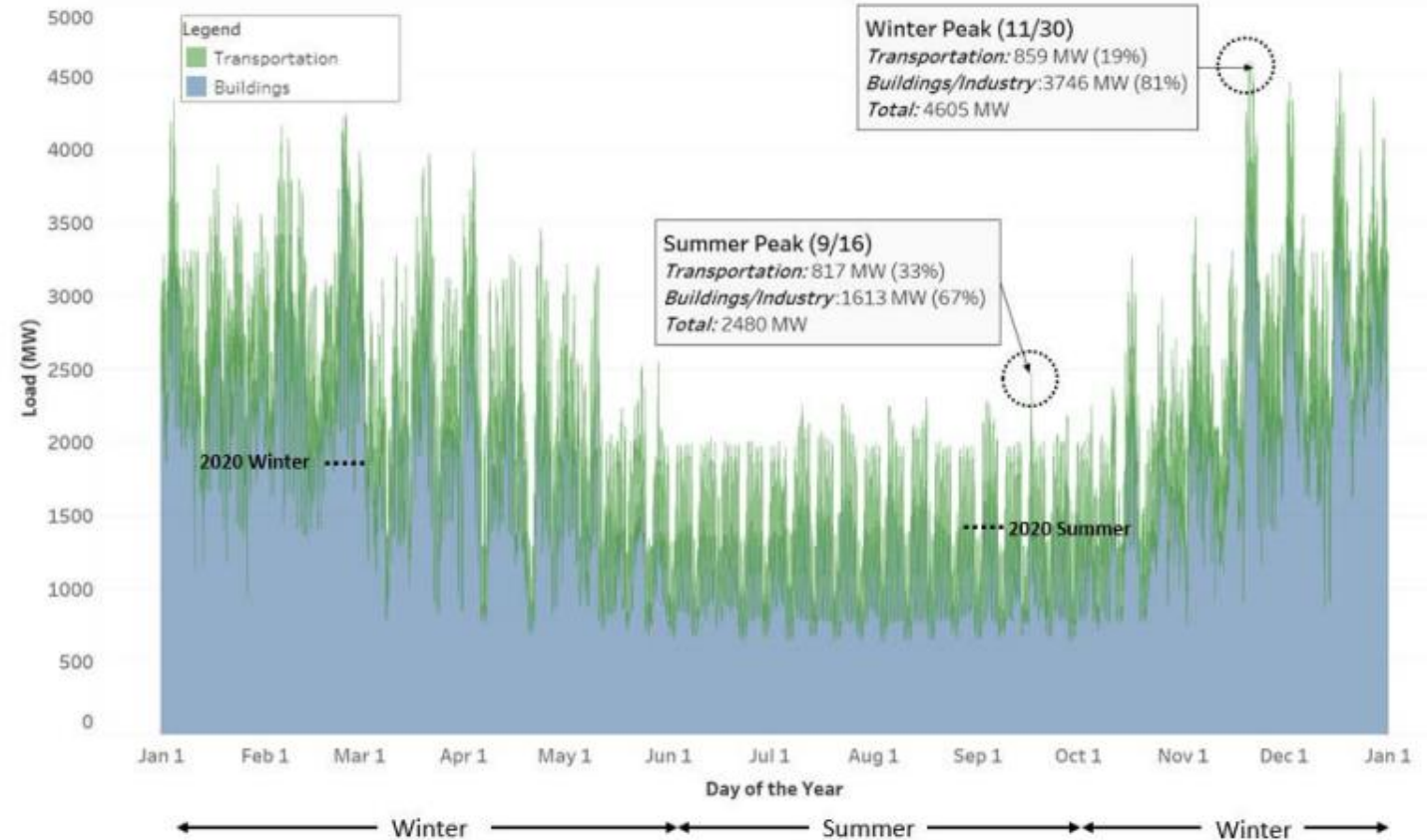On-going effort is needed to keep models up to date:

- Updates to protection and control models
- Changes in electrical end-uses – lighting, resistive heating to heat pumps, motors to electronic drives (LBNL survey)
- Updates to load composition models (LBNL, SLAC, BPA)
  - More customers want to have detailed load model data

New Challenges – Electrification

Transportation and building electrification are expected to increase total electric demand in the system

Credit: Electric Power Research Institute

https://powerlines.seattle.gov/wp-content/uploads/sites/17/2022/01/Seattle-City-Light-Electrification-Assessment.pdf

New Challenges – Electrification End-Uses

NERC is working towards modular Dynamic Load Model where one can "plug and play" load model components

There is a need to update load model components
- Electronic motor drives
- EV vehicle charges
- Heat pumps and air-conditioners
- DERs
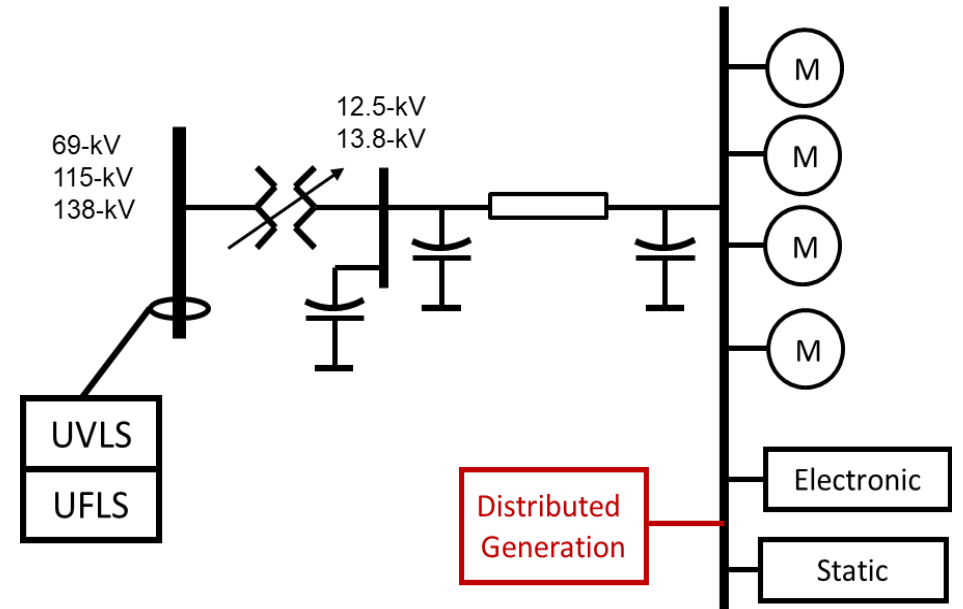
End-use testing is needed for model development

Thank You