Composite Load Model Studies for Portland Area

Presentation by
Dmitry Kosterev, BPA
NERC and WECC LMTF Meetings
May 2018
Presentation Outline

• Overview of the study area
• Part I – Modeling
• Path II – Initial Studies and Observations
• Part III – Sensitivity Studies
Portland Metro Area

• Population is about 2.45 million
  – Robust population growth at 1.2 to 1.5%

• Large Load Serving Entities (LSEs) in the area:
  – Portland General Electric (2/3 of the area load)
  – PacifiCorp
  – Clark County Public Utilities

• Summer peak load is about 5 GW
Portland Metro Area

- Manufacturing
- Semiconductor and Software
- Apparel:
  - NIKE, Columbia Sportswear, Adidas North America, ...
- Healthcare
- Banking and Finance
- Electric Power:
  - Portland General Electric, PacifiCorp, Clark County PUD, Avangrid Renewables, Vestas Wind Power Systems, Bonneville Power Administration, ...
PGE BA set all-time summer peak load records on August 3, 2017

PGE is the largest LSE in the area, 2/3 of the total area load
PGE BA net load also includes loads in Willamette Valley south of Portland
I: Modeling
Composite Load Model

69-kV
115-kV
138-kV

12.5-kV
13.8-kV

UVLS
UFLS

DG

AC

Electronic
Static

M
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Portland Temperatures in August 2017

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Load Model Data – Load Shapes

PGE Net Load

Hot Day – August 3, 2017 – 105F Day
Normal Day – August 8, 2017 – 92F Day
Cool Day – August 14, 2017 – 75F Day
Load Model Data – Load Composition

Percentage of Temperature-Sensitive Load

Hot Day – August 3, 2017 – 105F Day
Normal Day – August 8, 2017 – 92F Day
Industrial Load - Active Power

Industrial Load - Percentage of Temperature Sensitive Load

Industrial Load - Reactive Power
Portland, OR

WECC Load Model Composition spreadsheet is used for climate zone “NWV = North West Valley”

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End-Use Model Data

• Motor A – 3-phase compressor motors in air-conditioners and refrigerators
  – 20% trip / lock out for voltage sag below 65% for 0.1 sec
  – 75% trip at 50% voltage and restart at 65% voltage

• Motor B – fans
  – 30% trip at 55% voltage and restart at 65% voltage
  – 30% trip at 50% voltage and restart at 60% voltage

• Motor D – 1-phase compressor motors
  – Performance model
  – Vstall is 45%, Tstall is 0.03 seconds
  – 10% have under-voltage trip at 60% voltage
  – 20% of remaining motors re-start (or run backwards) when voltage recovers above 95% for 0.3 sec
Load Model Data Tool
Control Modeling

• Delayed voltage recovery can initiate switching of shunt reactors and capacitors as well as operation of under-voltage load shedding schemes

• Shunt capacitor controls (definite time under-voltage and over-voltage) are added to dynamic data and represented using “msc01” models

• Under-voltage load shedding relays are already modeled in the WECC dynamic data
II: Initial Studies
DISCLAIMER:
THIS STUDY IS AN EXPLORATORY STUDY OF A NEW DYNAMIC LOAD MODEL, NO CONCLUSION SHALL BE MADE ON COMPLIANCE WITH NERC RELIABILITY STANDARDS BASED ON THE STUDY RESULTS
Study Questions

MODELING:
• Evaluate the numeric performance of the dynamic load model with AC stalling feature enabled
• Identify future model developments

SYSTEM PERFORMANCE:
• Evaluate risk of FIDVR occurrence and spread through Portland area, and amount of load loss
• Evaluate risk of FIDVR cascading outside Portland area
• Evaluate impact of through transfers on voltage recovery and load loss during FIDVR events

CRITERIA:
• Inform development of a transient voltage criteria
Base Cases

• WECC staff developed model validation base cases for 2017 summer conditions:
  – Northwest peak load on August 3, 2017 at 16:44
  – Northwest peak export on September 1, 2017 at 19:44

• BPA staff performed additional tuning of the base cases to make it work with dynamic data
  – Deterioration of WECC dynamic data quality is evident, primarily wind and solar generation models

• Scenario cases were developed for both validation cases by dispatching generation to increase transmission system stress
Contingencies

- **P1** – Single element with normal clearing
  - 500-kV line fault 3-phase, no auto-reclosing
  - 500-kV line 1-phase fault with failed auto-reclosing
  - 230-kV line 3-phase fault with failed auto-reclosing

- **P2** – Bus fault with normal clearing
  - 230-kV bus 1-phase fault, no auto-reclosing
  - 230-kV bus 3-phase fault (beyond TPL Standards), no auto-reclosing

- **P4** – Line fault with a breaker failure to open
  - 500-kV line 1-phase fault, stuck breaker, ring bus clearing, no auto-reclosing
  - 230-kV line 1-phase fault, stuck breaker, bus section clearing, no auto-reclosing

- **P5** – Delayed clearing on lines with no redundant transfer trip
  - 230-kV bus 1-phase fault, Zone 2 clearing on remote end
Historic Events

Not many disturbance events are available for Portland area load model benchmarking.

No FIDVR events during transmission level faults in recent history – we would like to keep it this way.

Local utilities do not conduct maintenance during heavy summer loads, thereby reducing the risk of outages due to a human error.

We had a three-phase fault at 230-kV SVC back in fall 1997, cool day not much air-conditioning load.

BPA estimated about 500 MW load loss.
P1: 3-phase Line Fault

130 simulations plotted:
FIDVR with full voltage recovery in less than 12 seconds
Green = UVLS models removed
Blue = UVLS models active
P1: 3-phase Line Fault

130 simulations plotted:
FIDVR does not affect the entire metro area
Green = UVLS models removed
Blue = UVLS models active
P1: 3-phase Line Fault

130 simulations plotted:

FIDVR does not affect the entire metro area

Green = UVLS models removed
Blue = UVLS models active
P1: 3-phase Bus Fault

130 simulations plotted:

FIDVR is contained to parts of Portland

Green = UVLS models removed
Blue = UVLS models active
P1: 3-phase Bus Fault

130 simulations plotted:
- UVLS can be activated by delayed voltage recovery
- System is stable without UVLS
- Load tripping is from 500 to 1,200 MW

Green = UVLS models removed
Blue = UVLS models active
P2: 1-phase Bus Fault

80 simulations plotted:
**No FIDVR**, loss of 0 to 30 MW of voltage sensitive loads due to a fault
P2: 3-phase Bus Fault (beyond required)

80 simulations plotted:
FIDVR, recovery in less than 15 seconds
UVLS up to 550 MW, loss of up to 1,200 MW of voltage sensitive loads due to a fault
P4: 1-phase Line Fault, Breaker Failure

90 simulations plotted:
No FIDVR, no UVLS, loss of 0 to 700 MW of voltage sensitive loads due to a fault
P5: 1-phase Fault, Zone 2 Clearing

No FIDVR, no UVLS, up to 500 MW voltage sensitive load loss due to fault
Power System Performance Requirements

WECC Criterion TPL-001-WECC-CRT-3
- FIDVR – recover above 80% voltage within 20 seconds
- Power swing – shall not remain below 70% for more than 30 cycles and shall not remain below 80% for more than 2 seconds
Takeaways

Modeling:
- Dynamic load model with latest NERC/WECC “default” data set performed well and produced credible results

Performance:
• No additional system reinforcements are required based on the initial study
• Three-phase faults, as required for P1 contingencies, will cause air-conditioner stalling and delayed voltage recovery
  – Delayed voltage recovery is well within the WECC transient voltage criteria (80% in 20 sec)
  – End-use load tripping is in ball-park with expected
  – FIDVR events are localized and do not propagate into the BPS
  – UVLS may operate, UVLS operation is not required to meet WECC transient voltage criteria (more on this later)
• Single-phase to ground faults (including multiple contingencies) do not result in delayed voltage recovery, do not trigger UVLS operation
System Performance Discussion

- Existing TPL performance requirements (P1 – P7) are developed for studying classical angular stability of synchronous generators.
- The existing requirements do not account for stalling of residential air-conditioners during a fault.
- Simulations of NERC TPL P1 Category 3-phase faults result in delayed voltage recovery because of air-conditioner stalling during the fault.
- Voltage performance meets stability and transient WECC voltage criteria without requiring UVLS schemes.
- However, UVLS schemes can be activated because of the delayed voltage recovery caused by air-conditioner stalling during 3-phase faults, 3-phase faults are very rare.
- UVLS schemes are not activated by more common 1-phase faults (even for P2, P4 or P5 category contingencies).
Does UVLS operation represent “non-consequential” loss of load in the above scenario?

We think NO:

• the system meets stability and transient voltage performance for P1 3-phase faults without depending on UVLS
• while UVLS may be activated for 3-phase faults, they are extremely rare in the area, summer peak exposure is small, and the risk is further minimized by maintenance practices
• ULVS is not activated for more common 1-phase faults
III: Sensitivity Studies
(inspired by Rob O’Keefe from AEP)
Sensitivity Studies

• Air-conditioner stall voltage
  – Stall voltage 40% and 45%

• Three-phase motor tripping
  – NERC Default Data
  – NERC default voltage protection settings are lowered by 5%
  – No 3-phase motor tripping

• Load composition
  – WECC data
  – SCADA- derived heuristic data
## Sensitivity Studies – Load Composition

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1-phase AC and refrigeration

3-phase AC and refrigeration

Fans
Sensitivity Studies

WECC Load Composition, 40% vstall, Default Protection

- Portland Metro 230-kV Voltages
- Portland Metro 115-kV Voltages
- SVC Reactive Power

NW Load Tripped by Load Shedding Schemes

- NW Load Tripped by Equipment Protection and Control

120 MW

~1,000 MW
Sensitivity Studies

WECC Load Composition, 40% vstall, Default Protection reduced by 5%
Sensitivity Studies

WECC Load Composition, 40% vstall, **no 3phase motor tripping**

- **Portland Metro 230-kV Voltages**
- **Portland Metro 115-kV Voltages**
- **SVC Reactive Power**

- **NW Load Tripped by Load Shedding Schemes**
  - 850 MW

- **NW Load Tripped by Equipment Protection and Control**
  - ~600 MW
Sensitivity Studies

WECC Load Composition, 45% vstall, Default Protection

- Portland Metro 230-kV Voltages
- Portland Metro 115-kV Voltages
- SVC Reactive Power
- NW Load Tripped by Load Shedding Schemes
- NW Load Tripped by Equipment Protection and Control

320 MW
~1,250 MW
Sensitivity Studies

WECC Load Composition, 45% vstall, Default Protection reduced by 5%

Portland Metro 230-kV Voltages

NW Load Tripped by Load Shedding Schemes

340 MW

Portland Metro 115-kV Voltages

NW Load Tripped by Equipment Protection and Control

~1,300 MW

SVC Reactive Power
Sensitivity Studies

WECC Load Composition, 40% vstall, no 3phase motor tripping

~870 MW

~1,000 MW
Sensitivity Studies

SCADA Load Composition, 40% vstall, Default Protection

- Portland Metro 230-kV Voltages
- Portland Metro 115-kV Voltages
- SVC Reactive Power
- NW Load Tripped by Load Shedding Schemes
- NW Load Tripped by Equipment Protection and Control

~670 MW
~1,750 MW
Sensitivity Studies

SCADA Load Composition, 40% vstall, Default Protection reduced by 5%

~700 MW

~1,800 MW
Sensitivity Studies

SCADA Load Composition, 40% vstall, Default Protection reduced by 5%.  
No UVLS models

Portland Metro 230-kV Voltages

Portland Metro 115-kV Voltages

SVC Reactive Power

NW Load Tripped by Load Shedding Schemes

0 MW

NW Load Tripped by Equipment Protection and Control

~1,800 MW
Sensitivity Studies

SCADA Load Composition, 40% vstall, no 3-phase motor tripping

Portland Metro 230-kV Voltages

Portland Metro 115-kV Voltages

SVC Reactive Power

NW Load Tripped by Load Shedding Schemes

~850 MW

NW Load Tripped by Equipment Protection and Control

~1,250 MW
Sensitivity Studies

SCADA Load Composition, 45% vstall, Default Protection

~650 MW

~1,750 MW
Sensitivity Studies

SCADA Load Composition, 45% vstall, Default Protection reduced by 5%

- Portland Metro 230-kV Voltages
- Portland Metro 115-kV Voltages
- SVC Reactive Power
- NW Load Tripped by Load Shedding Schemes
- NW Load Tripped by Equipment Protection and Control

~700 MW
~1,900 MW
Sensitivity Studies

SCADA Load Composition, 45% vs stall, Default Protection reduced by 5%, no ULVS models
Sensitivity Studies

SCADA Load Composition, 45% vstall, no 3phase motor tripping

Portland Metro 230-kV Voltages

Portland Metro 115-kV Voltages

SVC Reactive Power

NW Load Tripped by Load Shedding Schemes

NW Load Tripped by Equipment Protection and Control

900 MW

~2,000 MW
## Sensitivity Study Results Summary

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<th>Impact*</th>
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<td>Changing air-conditioner Vstall voltage from 40 to 45%</td>
<td>1/10 = small</td>
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<td>Lowering voltage trip threshold for 3-phase motors</td>
<td>2/10 = small</td>
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<td>Removing motor tripping</td>
<td>9/10 = significant</td>
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<td>Load composition assumption</td>
<td>6/10 = important</td>
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*from decision-making standpoint
Next Steps

• Continue load composition analysis using SCADA data and recent NEEA data
  – develop load data analytics (Tony Faris, BPA)
  – develop substation-specific load composition estimates
• Continue load monitoring efforts with regional utilities
• Test 2nd generation composite load models with “mt1ph” model
• Continue sensitivity studies
  – high percentage of power electronic loads
  – unexpected generator or SVC control action / tripping
• Risk metrics
2018 IEEE PES Meeting is scheduled for August 5 to 9, 2018 in Portland, OR