UVLS Study Using WECC Composite Load Model and PowerWorld Time Step Simulation Tool

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January 2013
Overview

- Introduction to Composite Load Model
- Introduction to Time Step Simulation
- Modeling UVLS Relays in PowerWorld
- Running a Time Step Simulation
- Plotting Results
- Identifying UVLS Relay Actions
Under Voltage Load Shedding

- Northwest Area utilities have been completing an evaluation of the existing under voltage load shedding program using TSS.
- PowerWorld was utilized for the ability to use the WECC composite load model in powerflow studies.
  - The WECC Composite Load Model (CMPLDW) was used to more accurately capture voltage sensitive load behavior post-contingency.
- Is UVLS Program still necessary and are relays properly coordinated?
WECC Composite Load Model

- Powerflow cases typically model loads as constant power
  - Distribution transformer and feeder impedance are included with the load.
WECC Composite Load Model

- Composite Load Model explicitly models distribution transformer and feeder characteristics, as well as the characteristics of individual load components.
WECC Composite Load Model

- **Motor A load (MA):** three-phase motor with constant torque representative of compressor motors found in commercial air-conditioners and refrigerators
- **Motor B load (MB):** high inertia motors with speed-dependent load representative of motors driving pumps
- **Motor C load (MC):** low inertia motors with speed-dependent load also representative of motors driving pumps
- **Motor D load (MD):** single-phase residential air-conditioners and heat pumps
- **Power electronic load (PE):** computers and loads with variable frequency drives
- **Static load (C1):** incandescent lights and resistive space and water heating.
WECC Composite Load Model

- Composite Load Model was originally designed for use in transient stability simulations
  - PowerWorld developed a feature to explore mid-term dynamics of the distribution voltage regulator data in the model
- Motor and electronic loads in the powerflow conversion are constant MVA
  - The user can optionally change these to voltage sensitive static load (ZIP) quantities, if data is available
Conversion to ZIP

- James Randall at Bonneville Power Administration (BPA) developed the coefficients for the various load types to convert loads to an equivalent ZIP Model
- Gordon Comegys at ColumbiaGrid automated many of the processes used in this study for converting loads and correctly modeling generation and reactive resources
Conversion to ZIP

- Converting loads to a ZIP model requires load types to be identified based on their composite load model parameters.
- Coefficients are then applied according to load type.
Conversion to ZIP

- The ZIP conversion process can be automated with an .aux file once custom strings are populated in the case
Conversion to ZIP

- Composite Load Model with ZIP Equivalent
  - Constant Current and Constant Impedance load components are now populated
Time Step Simulation Tool - Overview

- Time Step Simulation Tool is located under the Tools tab in Simulator.
- Allows the user to specify operating conditions and obtain power flow solutions for a set of points in time.
Time Step Simulation Tool - Overview

- Pre-powerflow and post-powerflow actions are specified in the form of Script Commands
- These Script Commands can consist of individual actions
  - Example: Using the SetData command
    ```
    SetData(BRANCH,[BusNum,BusName,BusNum:1,BusName:1,LineCircuit,LineStatus])
    ```
  - SetData can be used to change the status of any power system element as well as to set Simulator Solution Options
- Groups of actions can be scripted in an .aux file and loaded using the LoadAux command
  - ```LoadAux(“FileLocation.aux”,”Yes”)```
Time Step Simulation Tool - Overview

- The input tab allows data to be input on a time point basis.
Time Step Simulation Tool - Overview

- Values to monitor during the simulation are specified in the Results tab.
Time Step Simulation Tool - Overview

- Elements are selected by choosing View/Modify and setting the Time Selected field to “Yes”.
- Add/Remove Fields allows the values to monitor for each element to be selected.
Modeling UVLS Relays

- Relay voltage set-points are modeled as Model Conditions
Modeling UVLS Relays

- Relay trip times and loads to trip are modeled as Time Step Actions in the TSS Tool.
Additional Considerations

- Typical powerflow studies model voltage regulation on the transmission system transformers and allow automatic operation of capacitor banks
  - This option is disabled as part of post-transient methodology
- With CMPLDW, transmission transformers and switched shunts are modeled as fixed and distribution transformers are modeled as load tap changing
- 500 kV switched shunts which operate automatically on a known time delay are modeled to reflect automatic operation
### Additional Considerations

- Distribution transformers are modeled as LTCs with a 30 second delay in LTC action following voltage excursion outside of dead band and resulting tap changes every 2 seconds.

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<th>From Name</th>
<th>To Number</th>
<th>To Name</th>
<th>Circuit</th>
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Additional Considerations
Additional Considerations

- Generator line drop and reactive current compensation is activated
  - This option disables generator AVR control as modeled
  - More realistic method of generator voltage control - generator will regulate its terminal voltage
    - Post-transient study methodology includes this action
  - Available in Contingency Analysis Dialog
Running the Time Step Simulation

- Additional setting are chosen from the ‘Options’ menu (i.e. pause simulation if the solution diverges, results storage, etc.)
- The Time Step Simulation is run by choosing ‘Do Run’ from the TSS menu
Plotting the Results

- Results can be plotted by right clicking on the column to plot and choosing Set/Toggle/Columns > Plot Column(s)
Plotting the Results

- To plot multiple values, either choose multiple columns from the Results window or change the value in the Plot? Column to “Yes”.

![Bus Timepoint Custom Results Column Plot](image)
Study Results

- Voltage sensitive load characteristics can be seen when plotting BES bus voltage
Study Results

- When loads are tripped, this action may be apparent by plotting bus voltage
Study Results

- Some scenarios resulted in extremely low voltages across the Puget Sound Area
Study Results

- Plot of MW flow through distribution transformers can also be used to determine whether load is tripped
Challenges

- Tripping a fraction of a load is currently not possible with the Composite Load Model.
  - Load was broken up into corresponding blocks prior to implementing composite load model
- Considerable manual work is involved in plotting results and investigating whether load shedding occurred
Conclusion

- The PowerWorld Time Step Simulation Tool was a valuable tool for performing this study
  - Ability to model distribution LTC transformers
  - Voltage sensitive load characteristics demonstrated with composite load model
Questions???