# Automated Tool to Create Chronological AC Power Flow Cases for Large Interconnected Systems

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WECC PCDS - Production Cost Data Subcommittee meeting, May 4, 2020

# Outline

- Why do we need chronological AC power flow cases?
- AC Power flow convergence process
- Automation capability
- Dynamic model preparation
- Benefits

# Why do we need AC Chronological AC Power Flow (CPF)?

- Need to consider operational constraints in planning studies
- A few snap shots for the system (base power flow cases) are not sufficient to understand the operational impact of
  - High penetration of wind and solar
  - Moving into sub-hourly transactions between Balancing Authorities

# AC Power flow convergence process

Stage 1
- Prepare DC power flow cases using PCM results

Stage 2
- DC to AC convergence process

Stage 3
- Reactive power planning for voltage improvement

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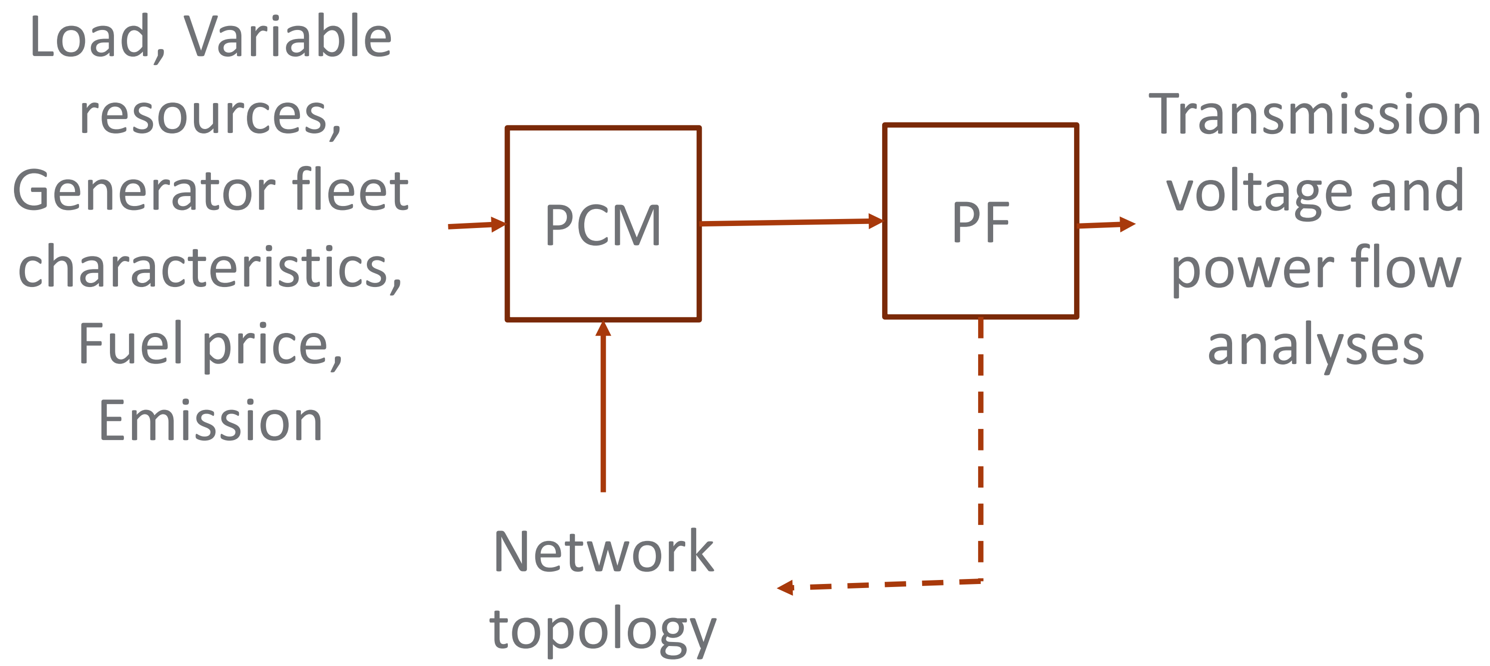
# Use of PCM simulation data

- The data needed to perform AC CPF:
  - Generation and load values at bus levels for different sequential time intervals
  - Power flows in the tie lines that surround the geographical area of interest
- State estimation (SE) data could be used to perform AC CPF analysis, but there are several hurdles:
  - The proprietary nature of such data
  - If obtained, the mapping of the SE (node-breaker) data to the planning model (bus-branch) data is a difficult task
  - SE data can not be used to analyze future scenarios
- Chronological PCM simulation data could be a good alternative.
  - Need model and validation before using simulation results in AC CPF analysis

# Planning study using PCM and PF

- A complete planning study includes 2 steps:
  - PCM provides a chronological hourly dispatch
  - Chronological AC PF
    - ✓ Provides information to improve the PCM model



# Challenges in using PCM simulation data to perform AC CPF

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- System topology consistency between PCM and PF
  - Not one-to-one match between PCM and PF
- System model difference between the two
  - PCM: DC model and linear solver. Does not consider loss and reactive power
  - PF: Full AC model and nonlinear solver. Includes loss and reactive power in the model
- Load distribution
  - PCM: Fixed load distribution for the entire simulation period
  - PF: Load distribution are quite different from time to time, especially from one season to another
- Voltage profile
  - PCM: fixed voltage
  - PF: voltages need to be defined in a quite complicated pattern at generator buses

# Results of the system topology matching

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| | PSLF (All) | PSLF (in service) | Exported GridView (All) | Exported GridView (In service) |
|---|---|---|---|---|
| Buses | 22509 | 22509 | 22509 | 22509 |
| Generators | 4417 | 4404 | 4414 | 4404 |
| Loads | 11126 | 9938 | 9938 | 9938 |
| Branches | 17666 | 16417 | 17667 | 16417 |
| Trans | 8911 | 8591 | 8911 | 8591 |
| Shunts | 2181 | 2181 | 2181 | 2181 |
| SVDs | 1472 | 1472 | 1472 | 1472 |

Completely matched

# AC Power flow convergence process

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| | |
|---|---|
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# Export PCM simulation results to power flow cases

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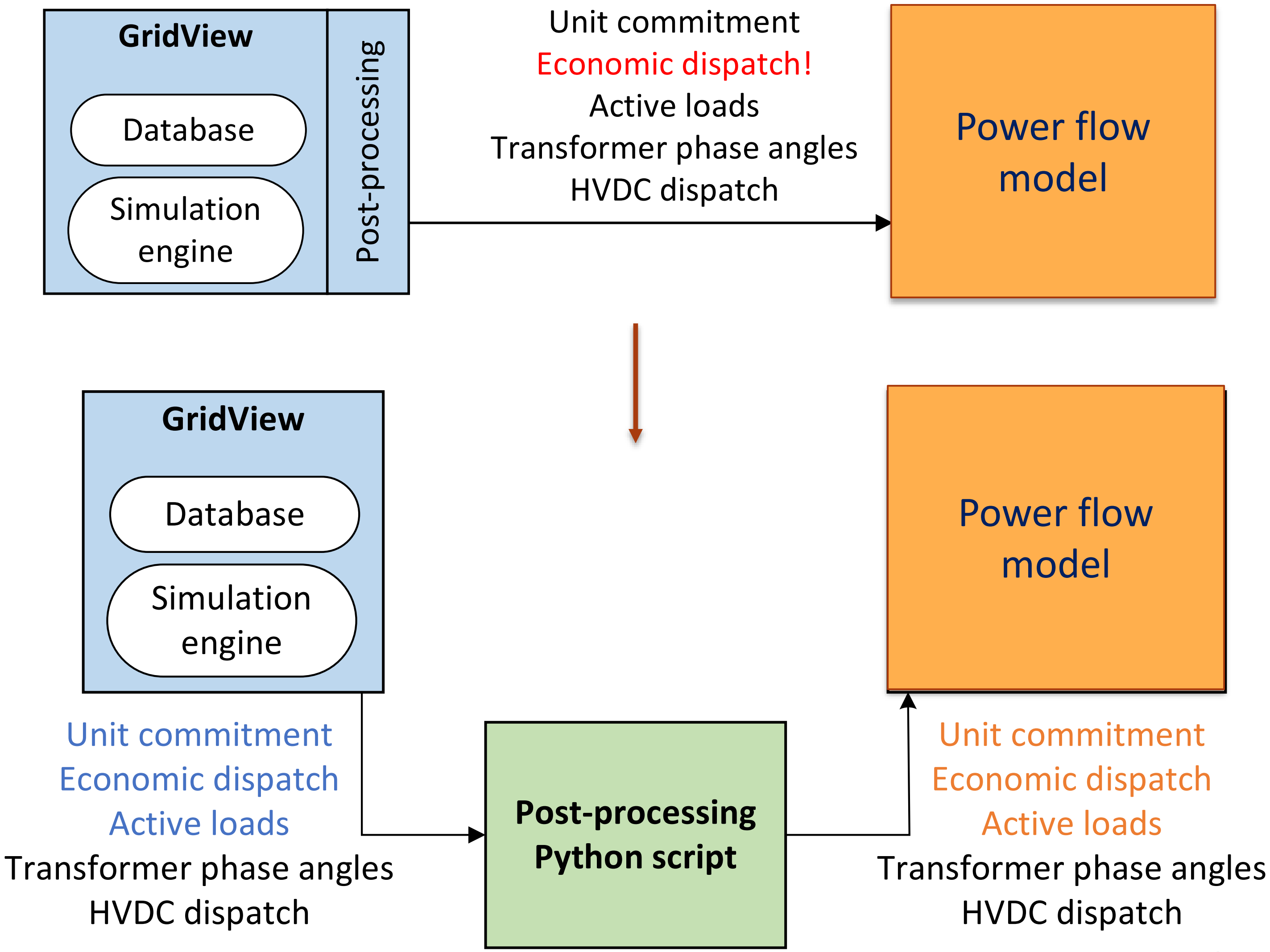
## Problem

- Several (> 10) units with incorrect updated dispatch (few hundreds MW difference)
- These units vary with hours → hard to automate the correction process

## Solution

- Develop a Python script to read and process PCM results in GridView to appropriate formats in PSSE/PSLF/PW power flow case



# Export PCM simulation results to power flow cases (contd.)

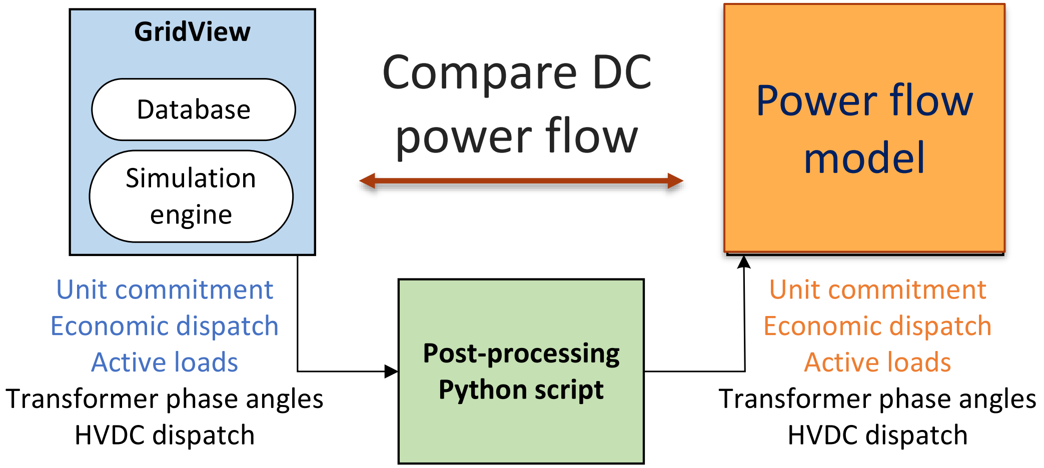
**Compare DC power flow in GridView simulation results and in the exported power flow case**

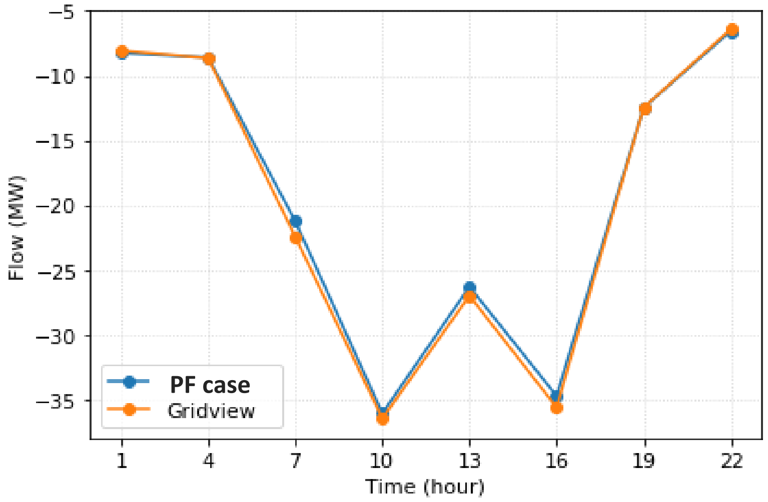
- Very good match of line flows at all lines and transformers

- For example, for one example hour (1 am, Mar 29, 2028):

- Total number of in-service lines and transformers: 26624
- All flow mismatches are less than 30 MW:
  - Between 20 MW and 30 MW: 3 lines/transformers
  - Between 10 MW and 20 MW: 7 lines/transformers
  - Less than 10 MW: the remaining 26614 lines/transformers

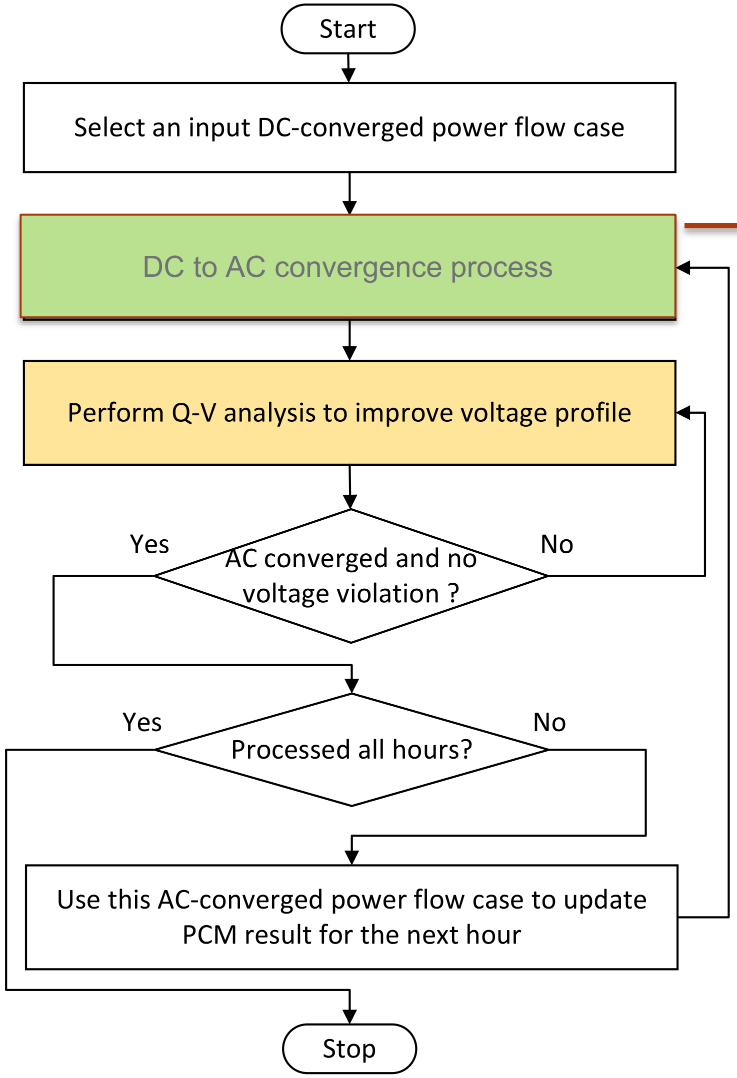
- The small mismatch can be attributed to the small dumped energy in GridView that is not reflected in the exported PSLF




*DC flow of line X1_X2 on July 24, 2028*

# DC to AC convergence process




- From input case (where total Pgen = total Pload), read and save Pslack from PCM result
- Keep gradually reducing load from PCM result by 0.1% from 100%:
  - Update the bus reactive power load to keep the power factor constant
  - Solve AC power flow with the reduced load
  - If AC power flow converges:

    Check if the generation at the slack bus is close to the saved Pslack from PCM result.

    If Yes, claim AC converges and stop. Otherwise, keep reducing the load.

# Flow comparison: AC vs. DC

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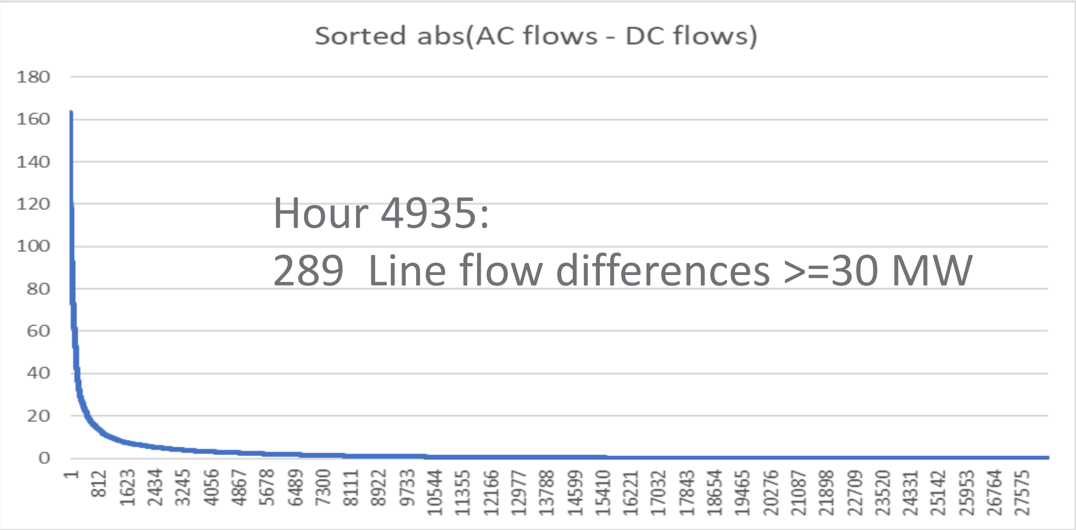
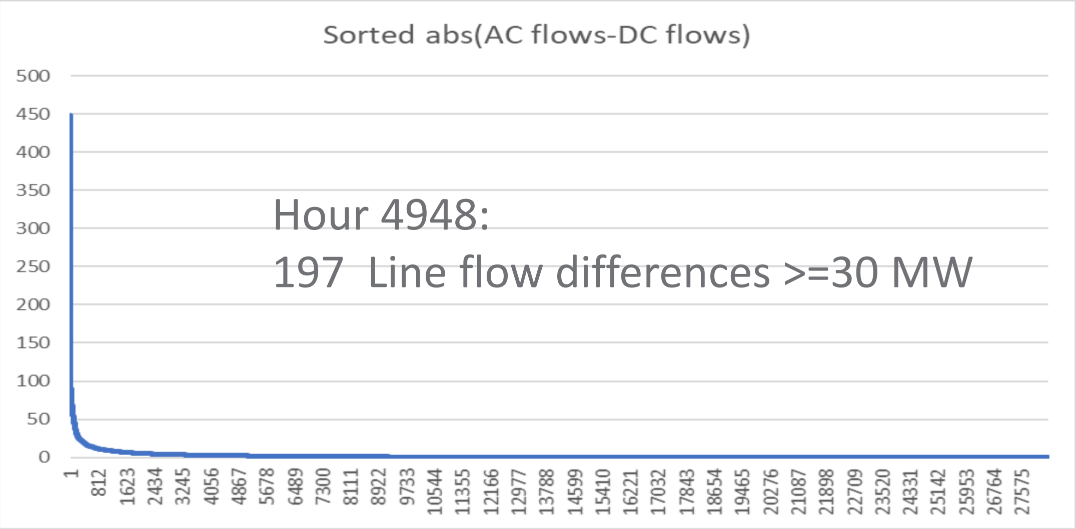
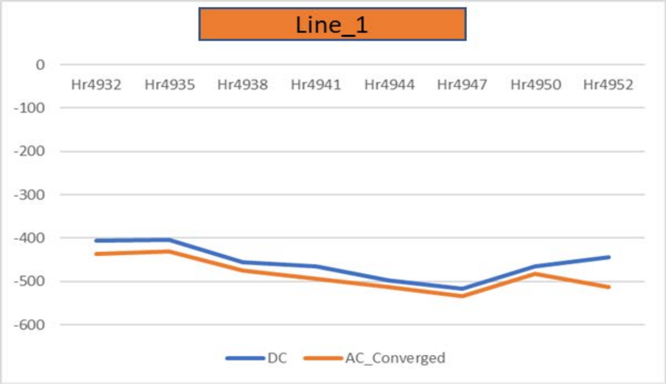
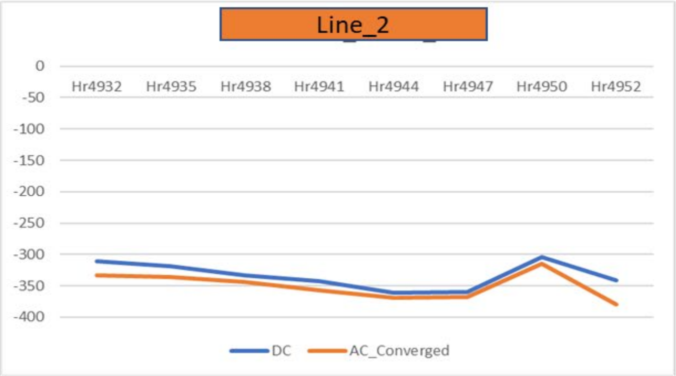



Total number of lines = 28352

## Comparing flow trend during the day





# AC Power flow convergence process

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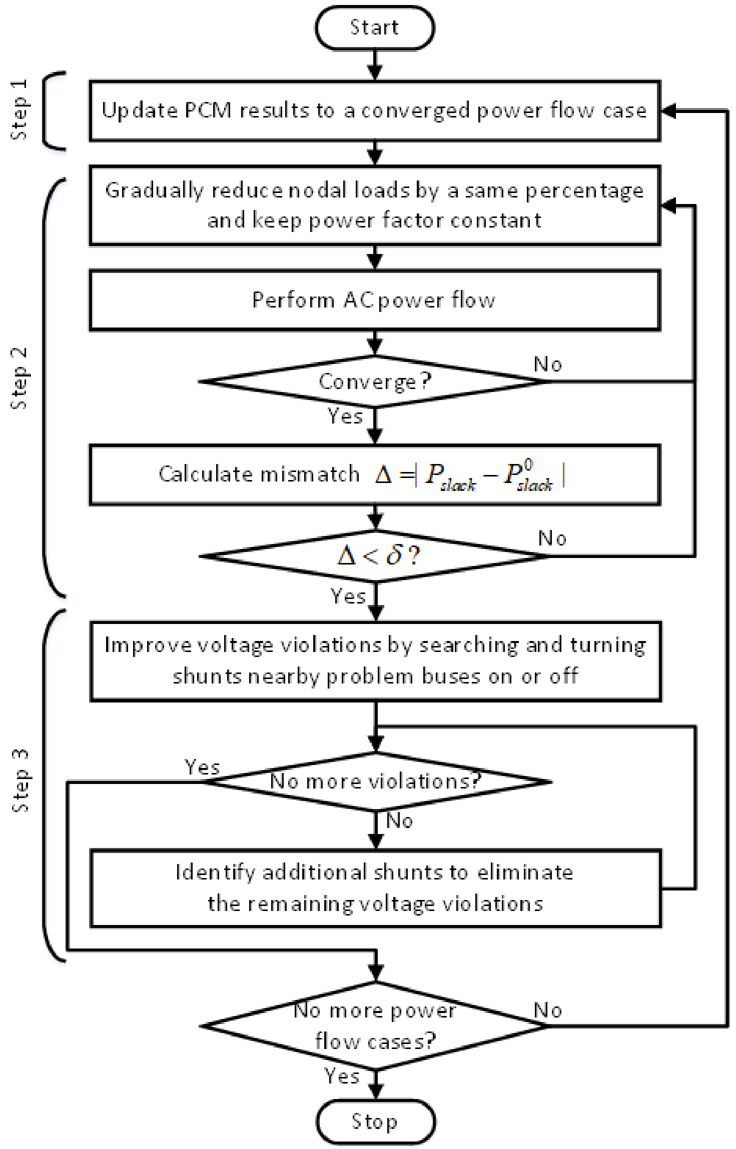
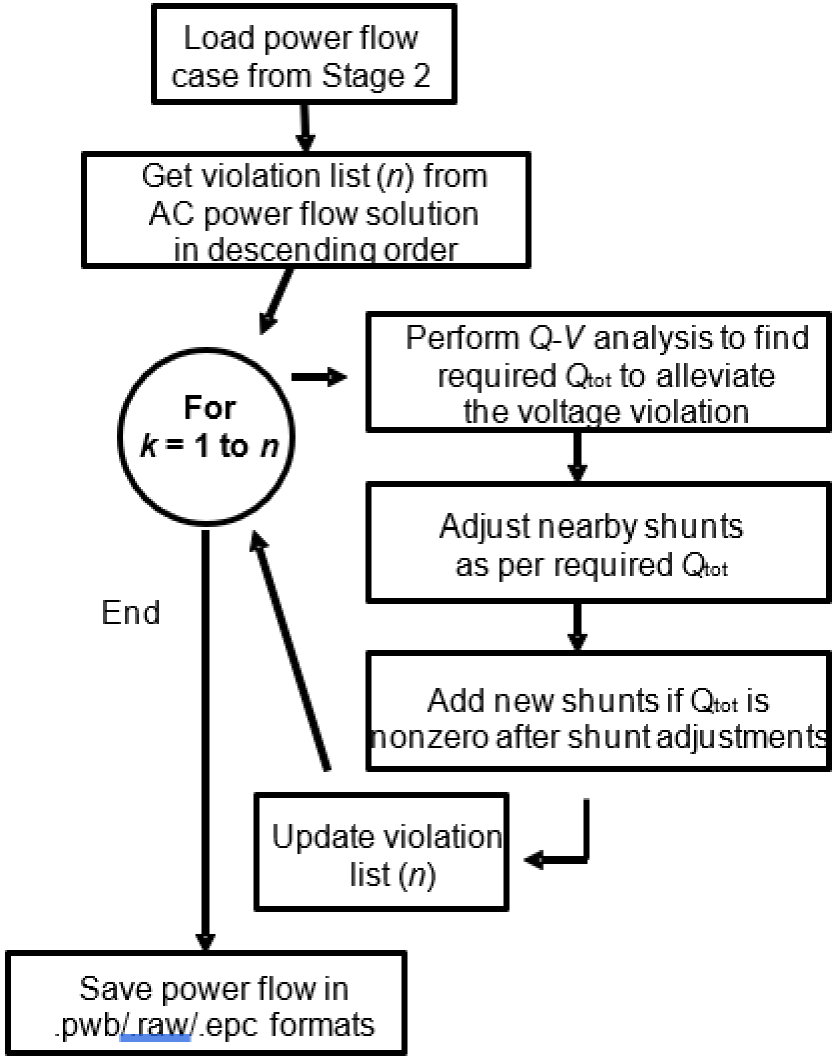
# Procedure to convert a DC-converged power flow case from PCM results to an AC-converged power flow case

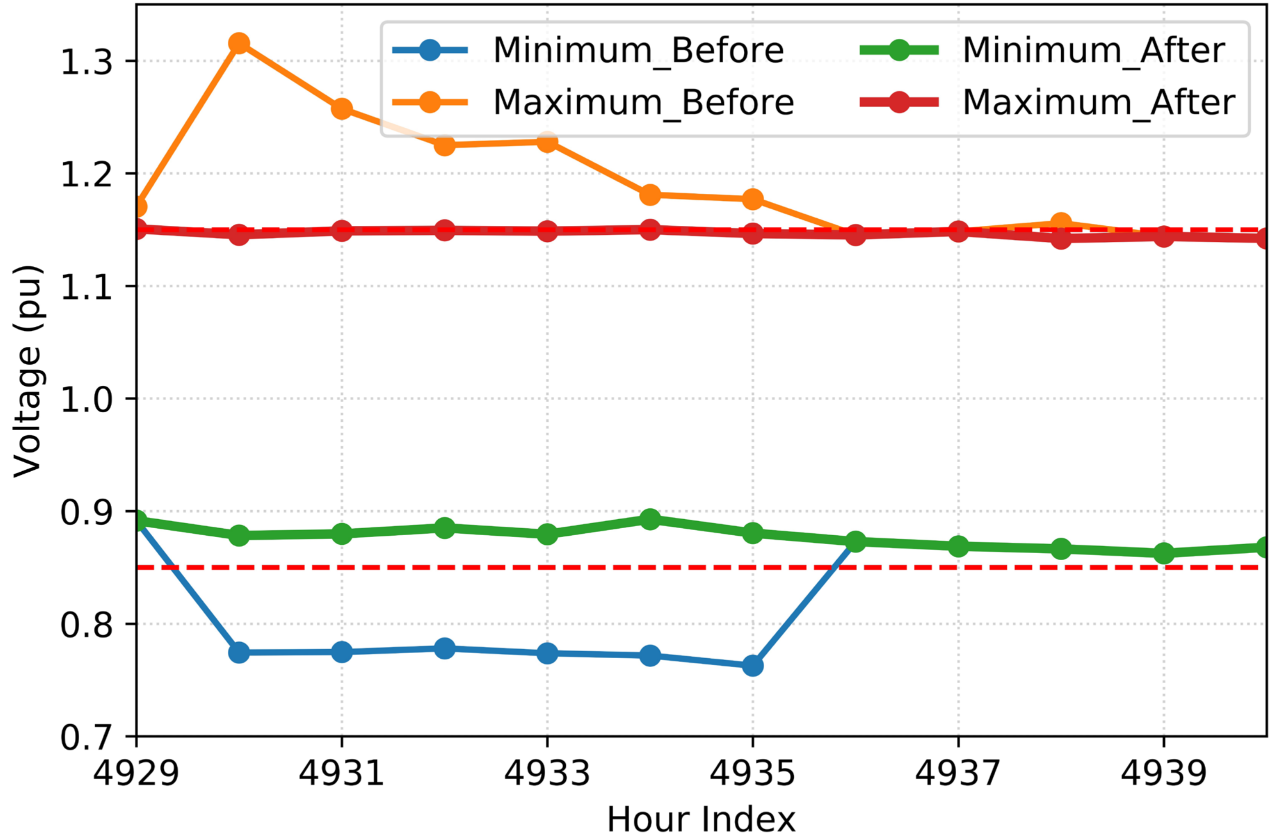


# Reactive power planning to improve voltage profile



# Case Study: Summary of the proposed method in all tested cases

Minimum and maximum load voltages for 12 hours simulation




Summary of the proposed method performance on tested cases

| Stage | Percentage |
|---|---|
| Percentage of cases converged without any adjustment | 51.9 % |
| Percentage of cases converged only by adjusting existing var resources | 31.0 % |
| Percentage of cases converged with additional var resources | 6.5 % |
| Percentage of cases that cannot get convergence | 10.6 % |

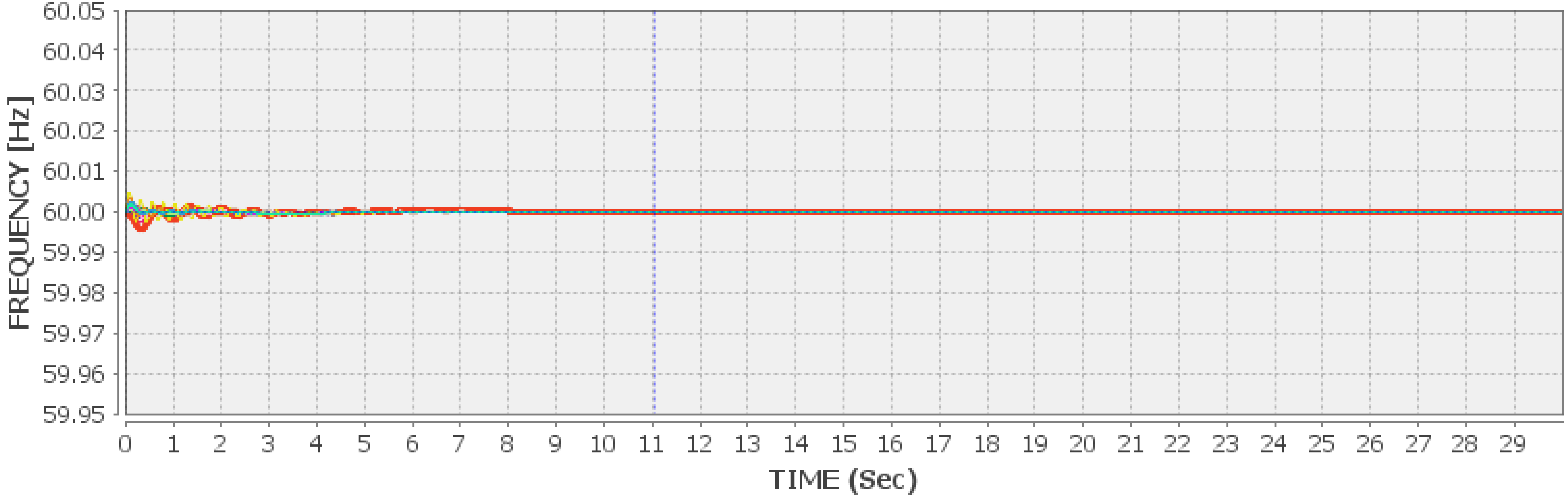
# Dynamic Model Preparation

## Current issues:

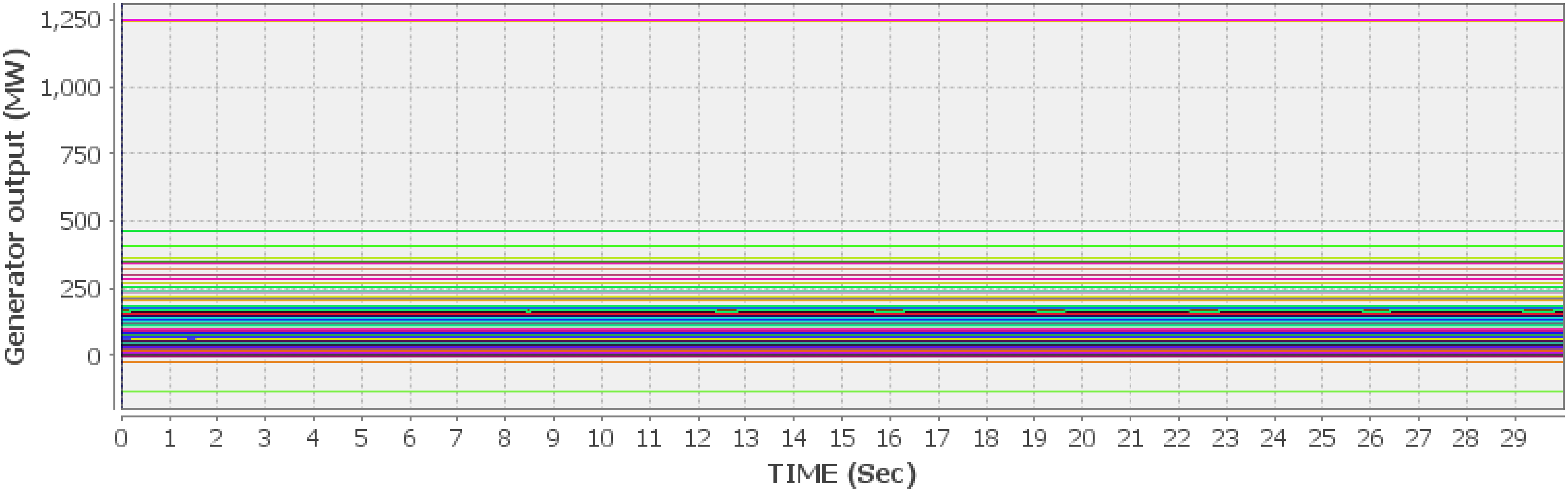
- Many generating units do not have dynamics data associated with the generator record in the base case
- Many generating units modeled in the power flow base case did not have a turbine type identified.
- In some cases, the unit ID in the power flow base case did not match the unit ID in the dynamics data
- Multiple STATCOMs and other dynamic reactive resources are modeled as generators in the base case rather than using SVS17 models
- WECC MVWG approved the retirement of the REEC_B model in April 2019. So need convert REEC_B to REEC_A with momentary cessation/ convert REEC_B to REEC_D without momentary cessation
- To develop cases with different dispatches, need to check the generator governor response in each one

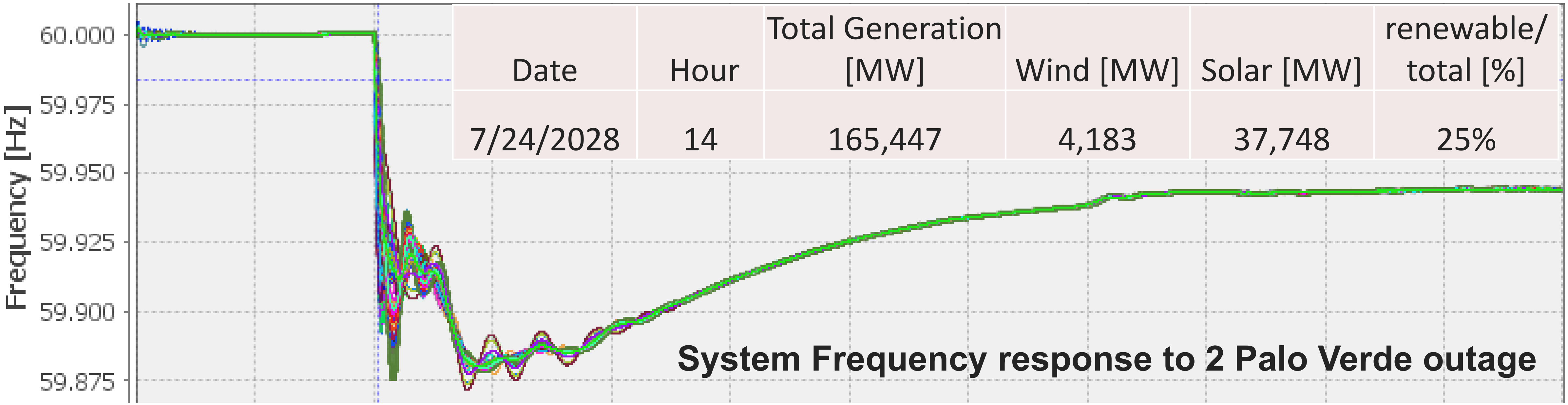
# Flat start simulation results: Frequency [Hz]

| Date | Hour | Total Generation [MW] | Wind [MW] | Solar [MW] | Wind+Solar [MW] | Wind/Total [%] | Solar/Total [%] | renewable/ total [%] |
|---|---|---|---|---|---|---|---|---|
| 7/24/2028 | 14 | 165447 | 4,183 | 37,748 | 41,932 | 3% | 22 % | 25 % |

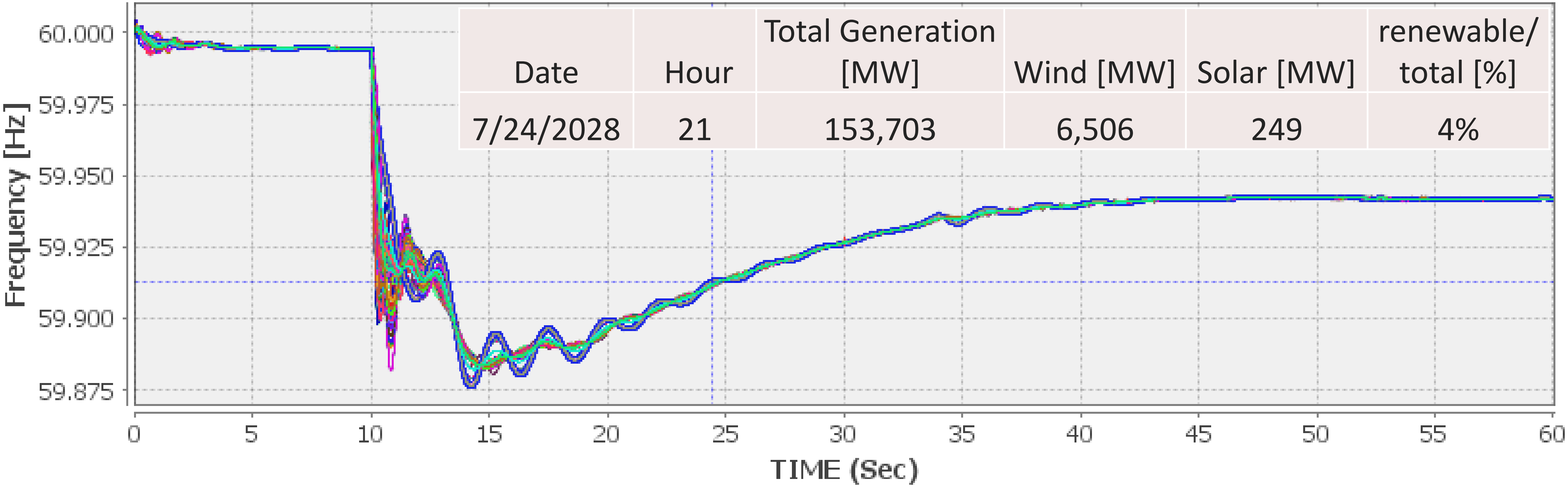


# Flat start simulation results: Generator output [MW]






| Date | Hour | Total Generation [MW] | Wind [MW] | Solar [MW] | renewable/ total [%] |
|---|---|---|---|---|---|
| 7/24/2028 | 14 | 165,447 | 4,183 | 37,748 | 25% |




| Date | Hour | Total Generation [MW] | Wind [MW] | Solar [MW] | renewable/ total [%] |
|---|---|---|---|---|---|
| 7/24/2028 | 21 | 153,703 | 6,506 | 249 | 4% |

# Benefits

- This tool automates the process of converting DC power flow from PCM results to an AC-converged power flow cases.
- The tool can create a power flow case in 5-10 min.
- Tool saves the power flow case with the better voltage profile in formats such as .pwb of PowerWorld, .raw of PSS/E, and .epc of PSLF.
- Developed AC power flow cases can be used for dynamic simulations to show frequency response at different generation mixes for different contingencies.
- This capability is helpful for transmission planning studies at various system operating conditions.
- The developed tool and procedures are applicable to any large, interconnected systems such as WECC, the Eastern Interconnection, and the Electric Reliability Council of Texas.
- This work also facilitates interconnection of new renewable generation, helps achieve national renewable targets, and improves system reliability.

# Acknowledgements

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The work is supported by Department of Energy's (DOE's) Office of Electricity (OE) Advanced Grid Modeling (AGM) program. The project team especially thanks Dr. Ali Ghassemian from DOE-OE for his continuing support, help, and guidance. Special thanks to WECC staff , Nick Hatton and Kent Bolton for their technical support.

B. Vyakaranam, Q. H. Nguyen, T. B. Nguyen, N. A. Samaan and R. Huang, "Automated Tool to Create Chronological AC Power Flow Cases for Large Interconnected Systems," in ***IEEE Open Access Journal of Power and Energy***, doi: 10.1109/OAJPE.2021.3075659

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# Thank you!

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