Impact of IEEE 1547 Reactive Power Support Functions on Voltage Regulation of a Synthetic Residential Distribution Network

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Introduction

- Conventionally, distributed energy resources (DERs) had to operate at unity power factor (PF).
- Recent standards, e.g., IEEE 1547 and CSA C22.3 No. 9, have allowed reactive power support functions.
- Reactive power support functions will potentially allow higher penetrations of DERs.
- This work investigates the effect of the volt-var function on voltage regulation of a low-voltage (LV) residential distribution network.

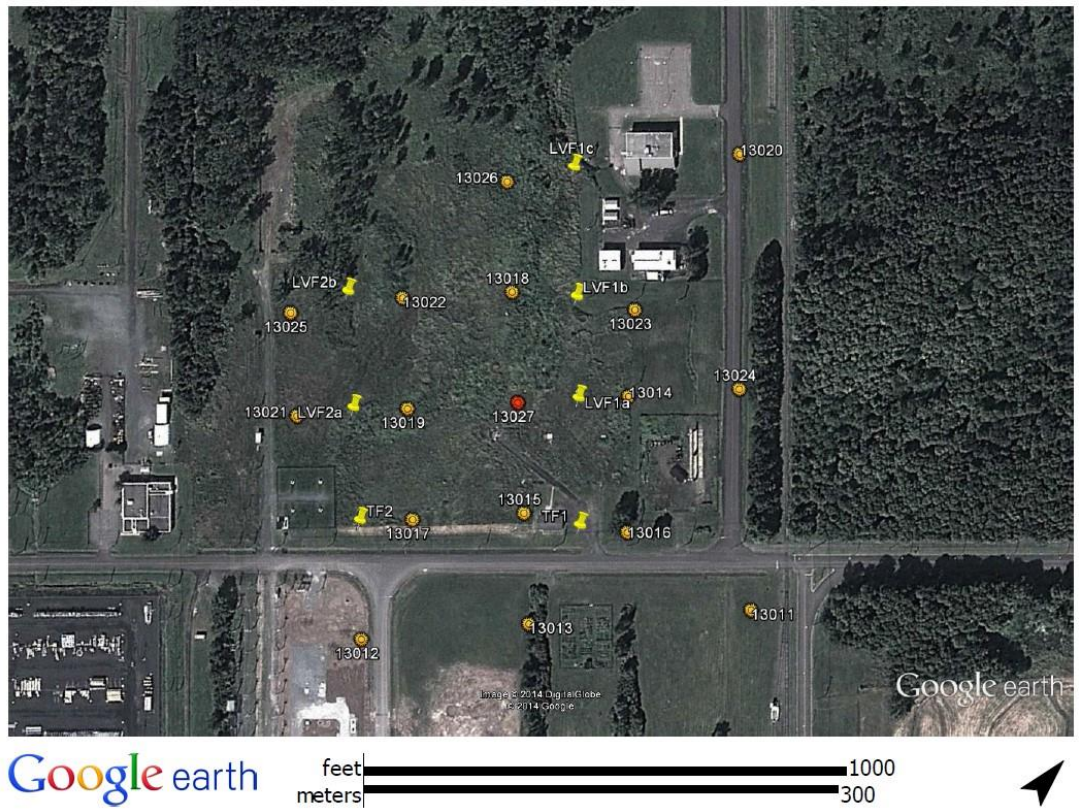
Objectives

- Test the Smart Inverter Control Toolbox developed in collaboration with OPAL-RT technologies.
- Investigate the impact of reactive power support functions on residential grids
- Test the system performance under high solar irradiance variability to detect any potential issues

System Under Study – Description

- Synthetic residential distribution network:
  - High-resolution solar irradiance data collected by sensors at the Institut de recherche en électricité du Québec (IREQ) in the city of Varennes, QC.
  - A house with a 5.5-kW solar photovoltaic (PV) array and a 5.0-kW inverter assumed at each sensor location.
  - Spatio-temporal interpolation to calculate the average solar irradiance at each house.
  - Time-domain model in Matlab/Simulink

System Under Study - Layout



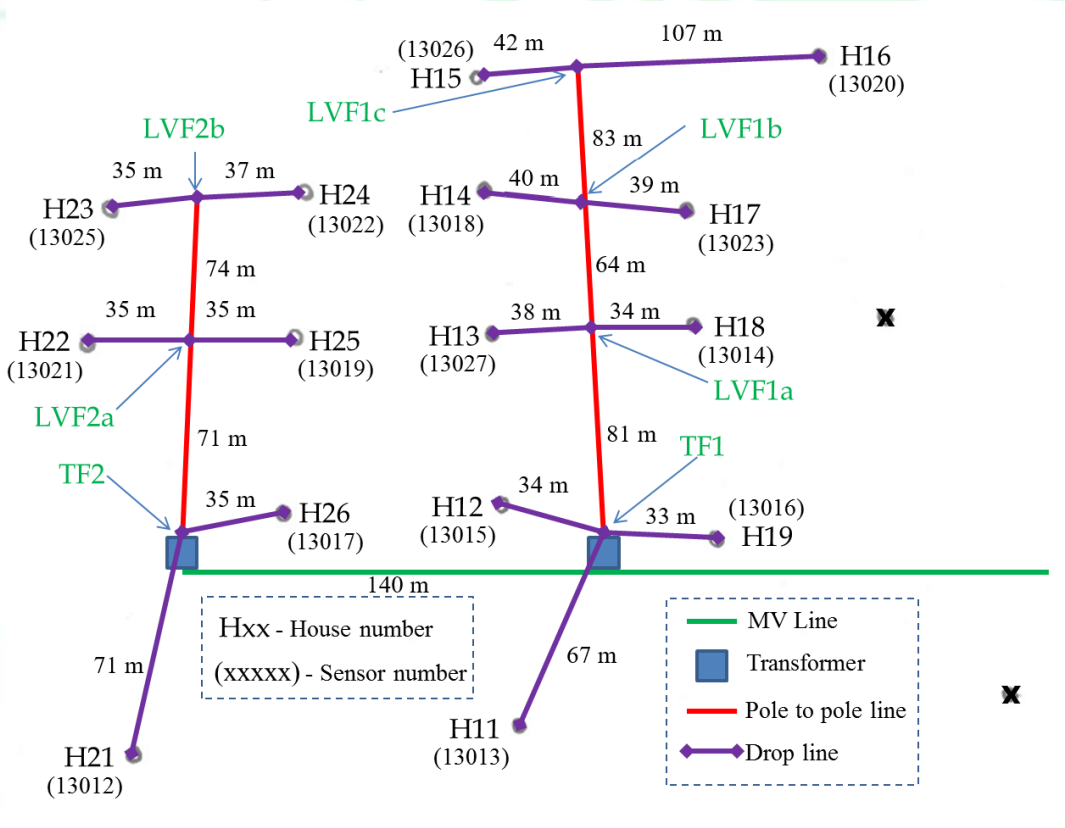


Fig. 1 Layout of the residential neighbourhood. (Left: sensor locations, Right: Electrical layout)

System Under Study – Solar Irradiance Profile

- 10 minutes of interpolated solar irradiance data at time resolution of 10 ms.

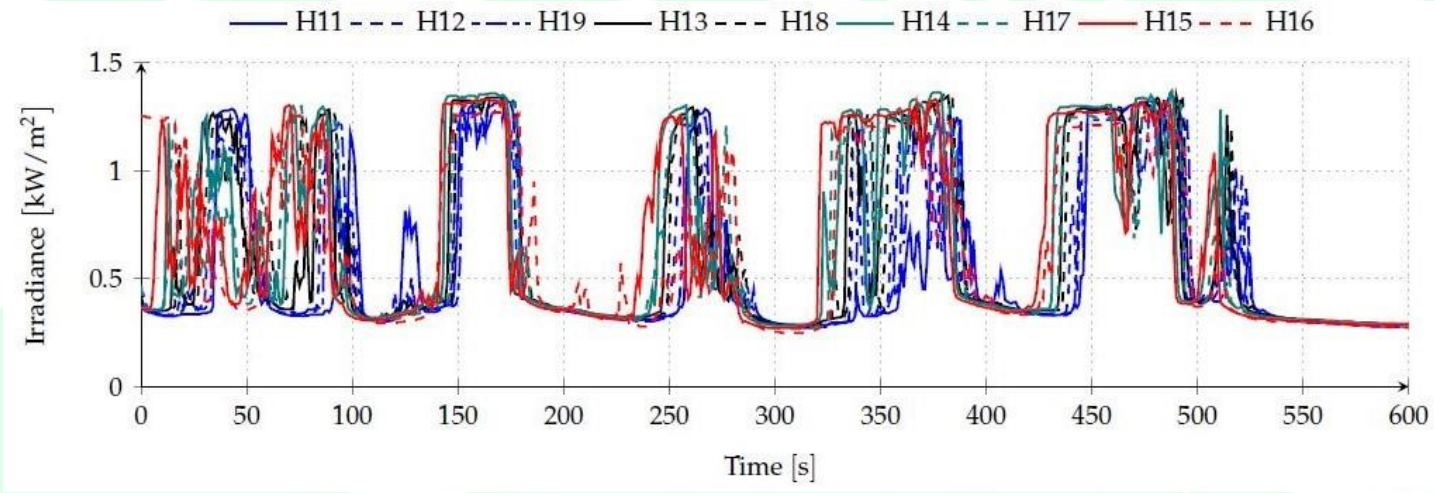


Fig. 2 Interpolated solar irradiance data at each house

Case Studies: Base Case – Unity PF

According to CSA CAN3-C235:

- NR: Normal Range limit
- OV: Overvoltage limit

Observations:

- Poor voltage regulation, as house voltages exceed the NR limit during high irradiance periods
- Houses farther from the transformer exhibit worse voltage regulations

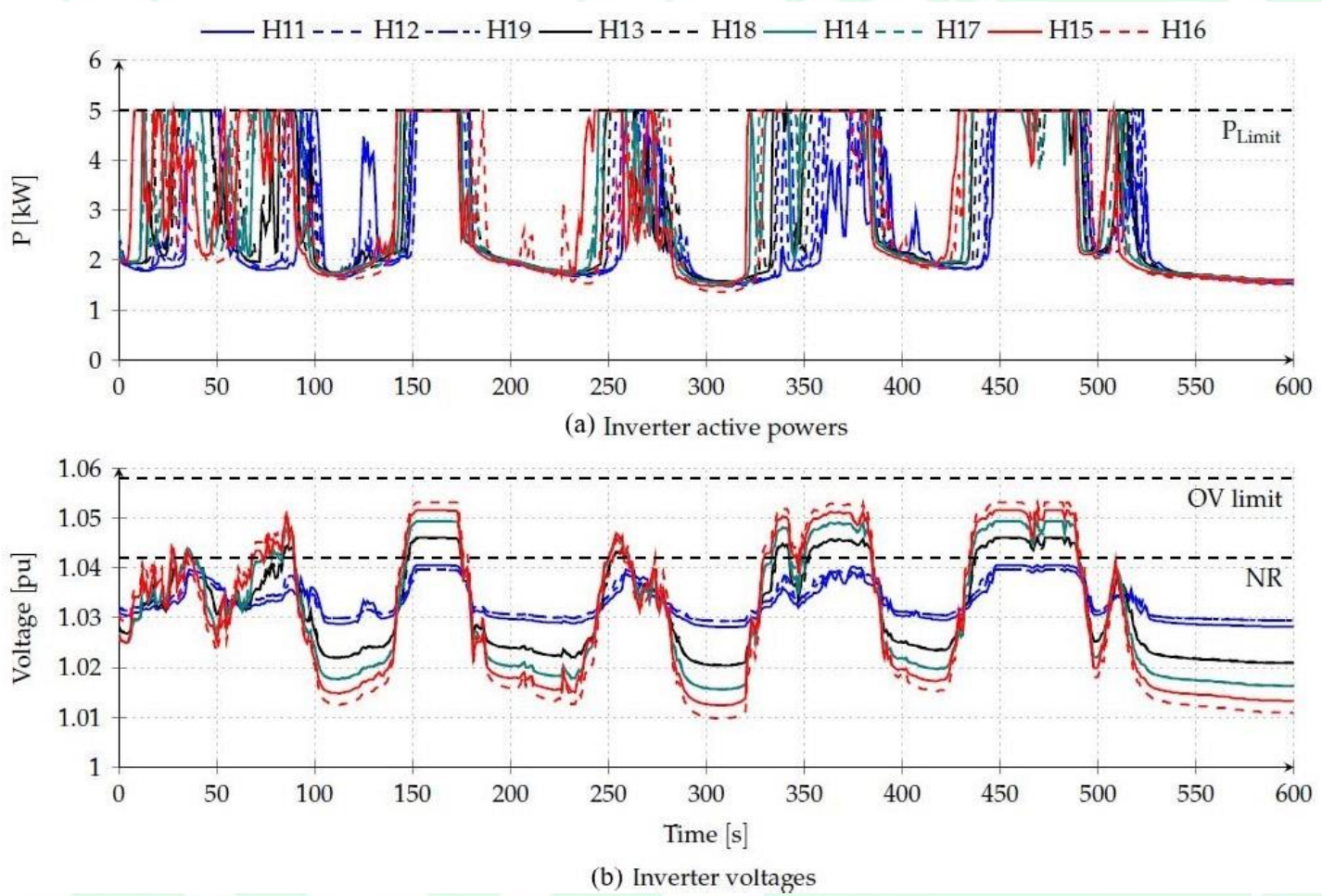


Fig. 3 Simulation results at unity PF

Case Studies: Volt-var curve settings

Default Settings:

- Dead-band (V = 0.98 to 1.02 pu)
- Time constant = 5 sec
- Qmax at 0.08 pu voltage deviation

Aggressive Settings:

- No dead-band
- Time constant = 1 sec
- Qmax at 0.02 pu voltage deviation

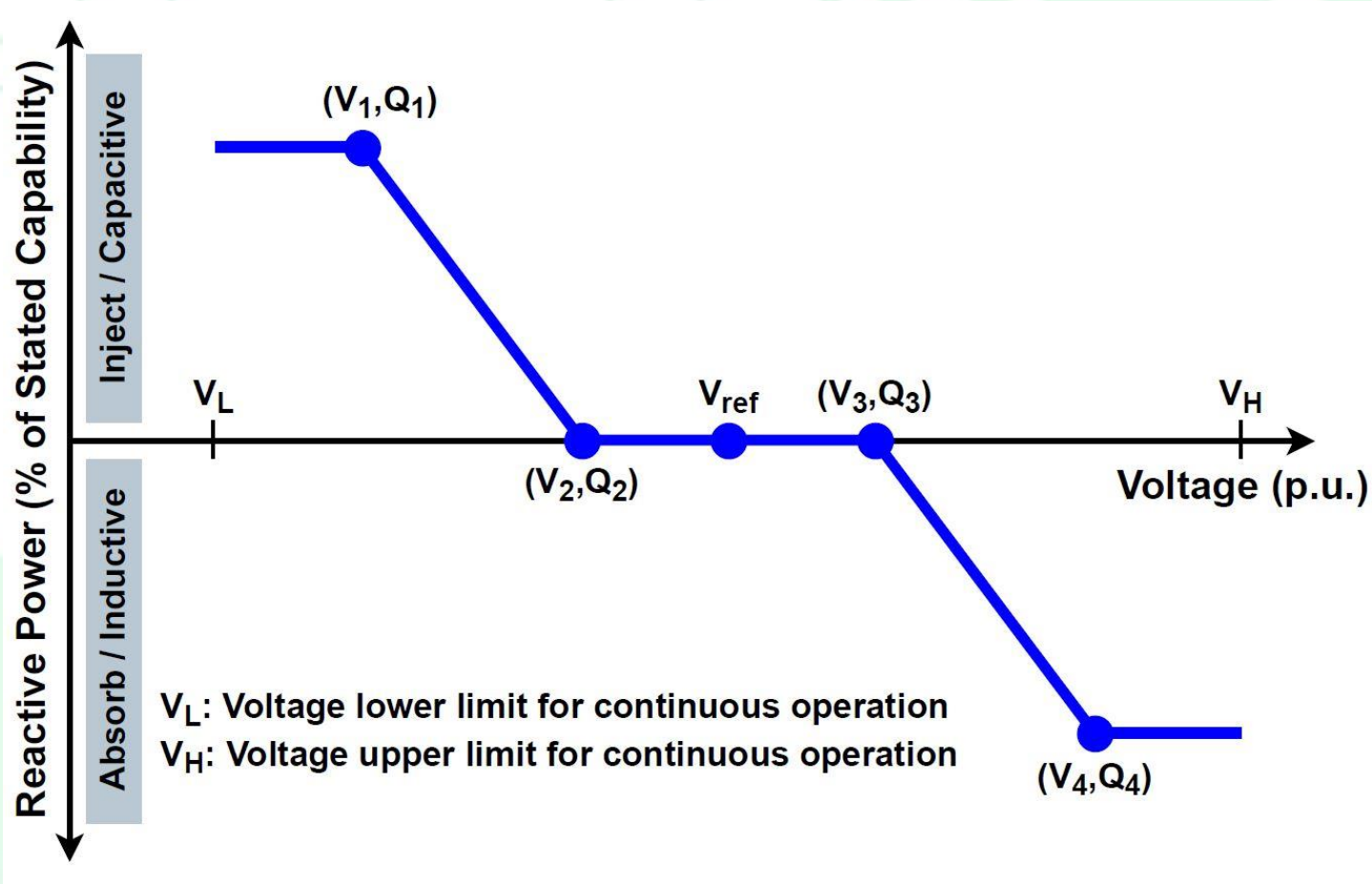


Fig. 4 Generic volt-var settings

Case Studies: Volt-var with Default Settings - 1

Observations:

- Reactive power varies vs voltage (volt-var)
- No reactive power for dead-band (V = 0.98 to 1.02 pu)
- Improved voltage profile

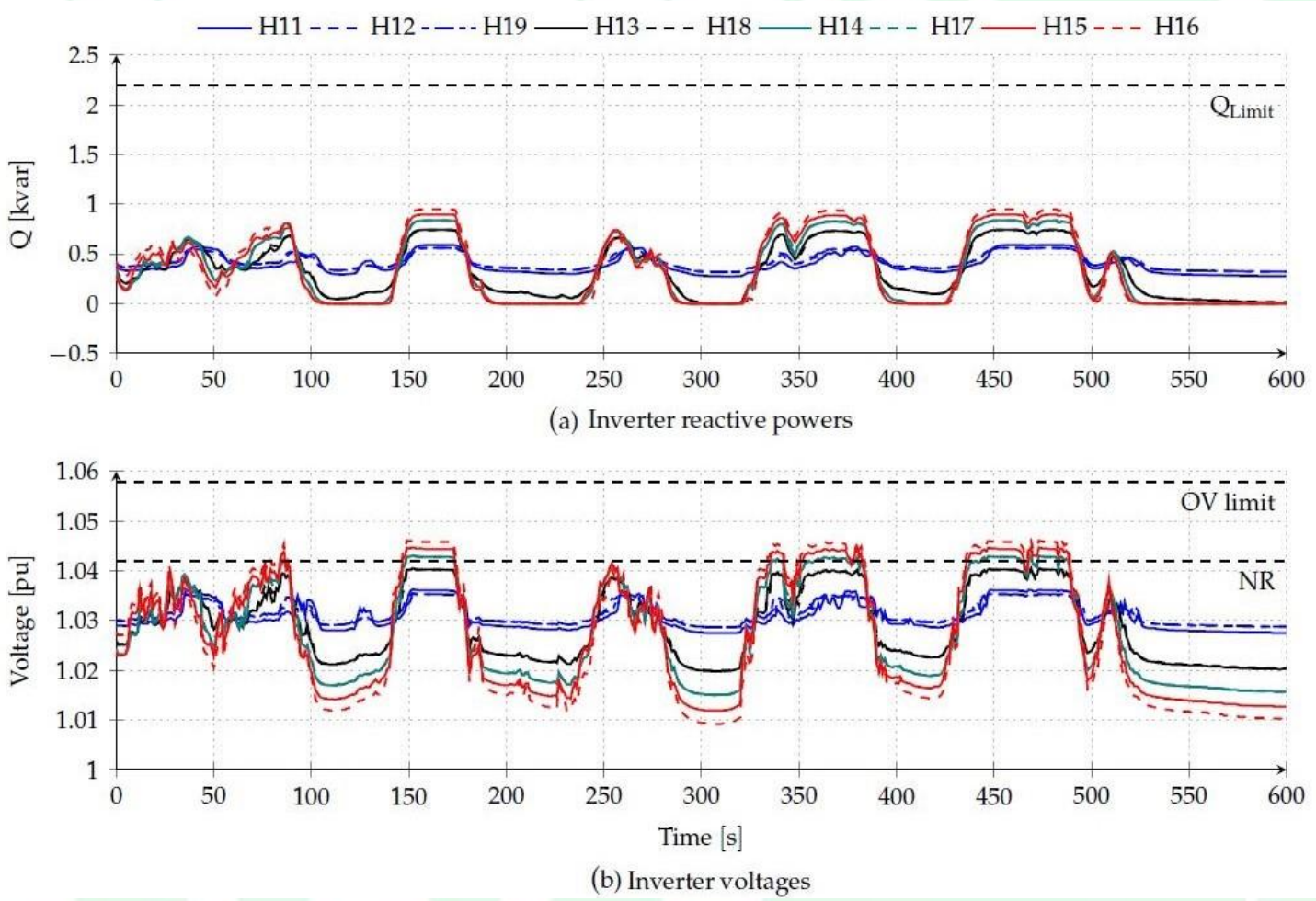


Fig. 5 Simulation results of inverters with volt-var function and default settings

Case Studies: Volt-var with Default Settings - 2

Observations:

- Slight active power curtailment
- Voltage regulation improved because of:
  - Reactive power
  - Curtailed active power

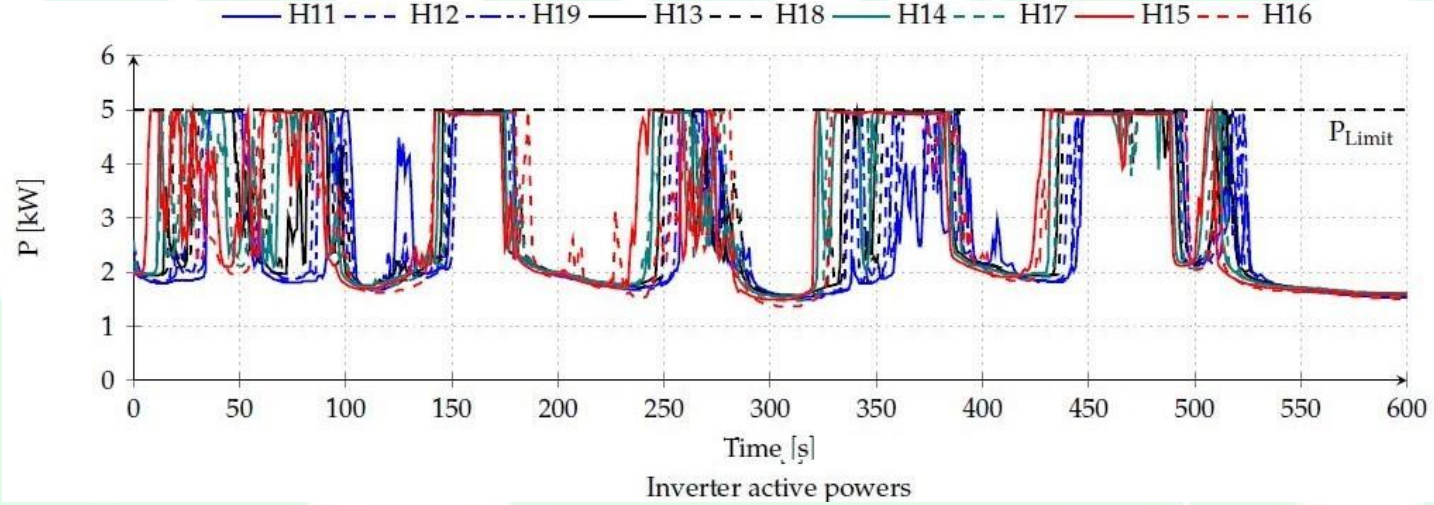


Fig. 6 Active powers of inverters with volt-var function and default settings

Case Studies: Volt-var with Aggressive Settings - 1

Observations:

- Increased reactive power, which reaches maximum value at times.
- Continuous change of reactive power vs voltage (no dead-band)
- Much improved voltage profile (V within NR)

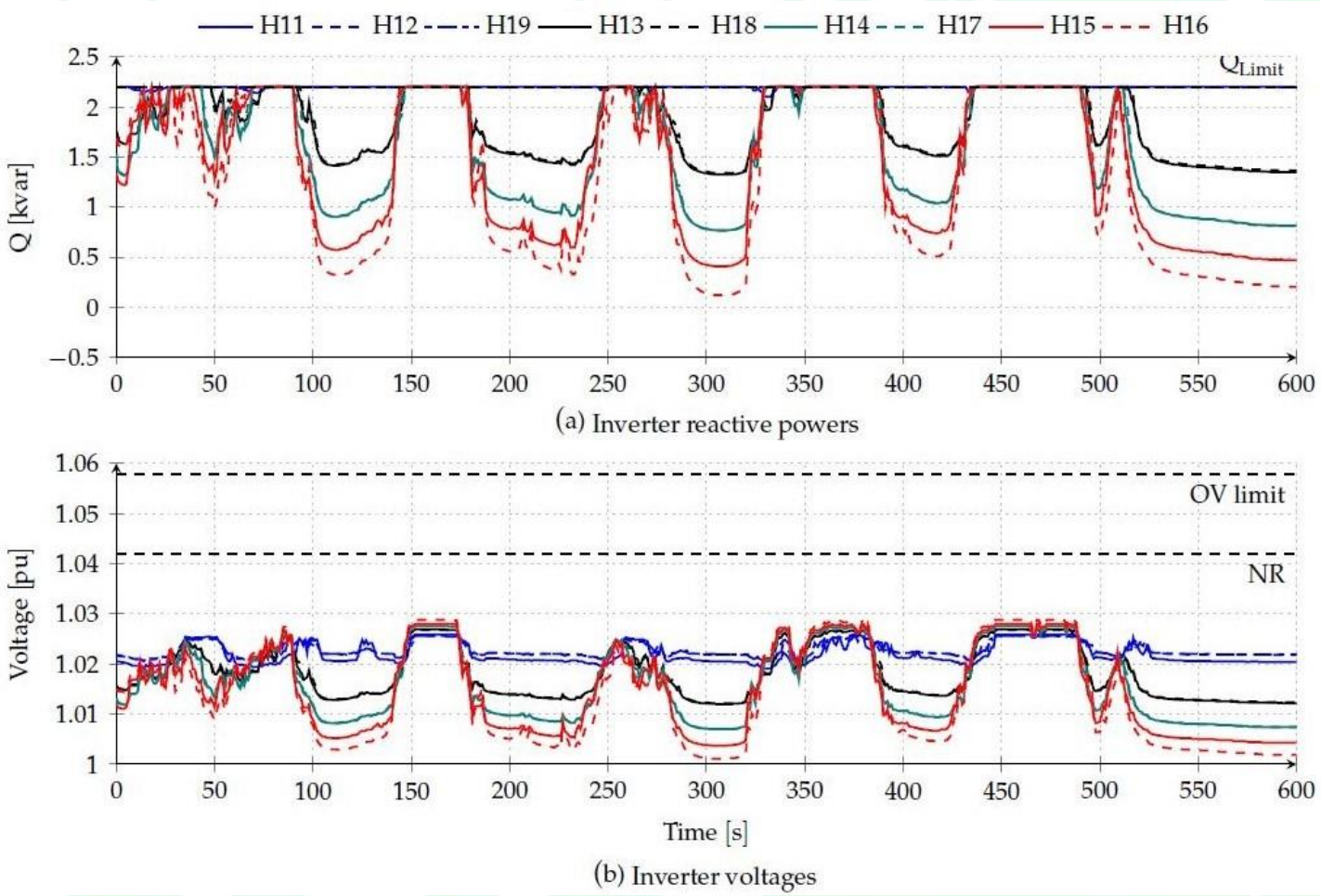


Fig. 7 Simulation results of inverters with volt-var function and aggressive settings

Case Studies: Volt-var with Aggressive Settings - 2

Observations:

- High curtailment of active power due to increased reactive power.

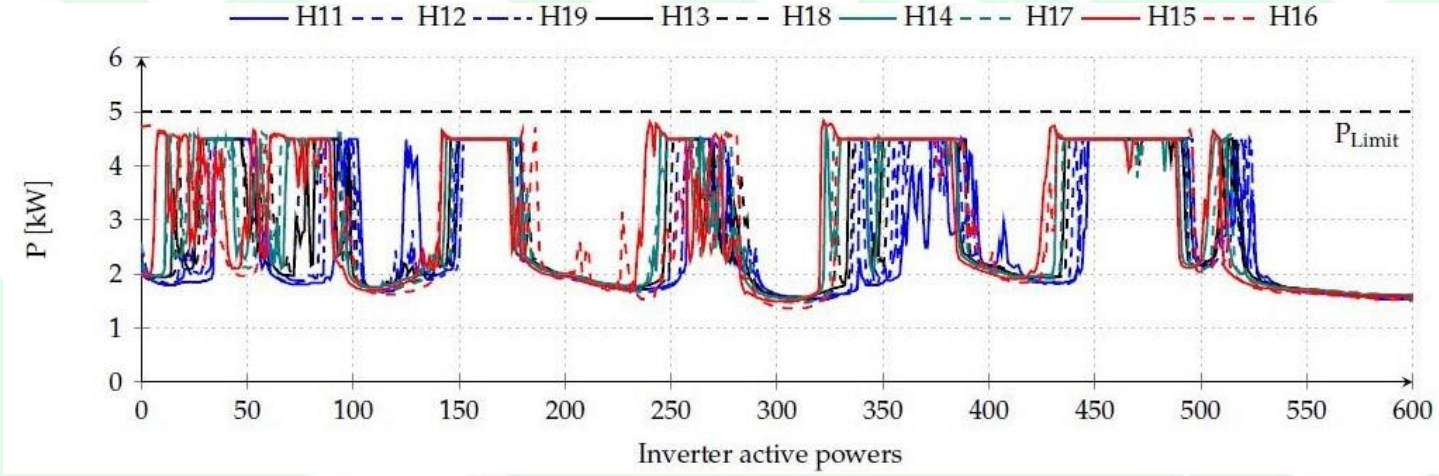


Fig. 8 Active powers of inverters with volt-var function and aggressive settings

Conclusions and Future Directions

- A platform is established to assess reactive power support functions.
- Reactive power support functions can improve voltage regulation.
- Voltage regulation might come at the expense of power curtailment.
- No notable issues related to high solar irradiance variability.
- Other aspects (e.g., transformer loading) to be considered
- Different types of networks and larger scale studies to be considered to develop a guideline for employing reactive power support functions.