Fast Frequency Support Provided by Grid-Connected Photovoltaic with Supercapacitor System

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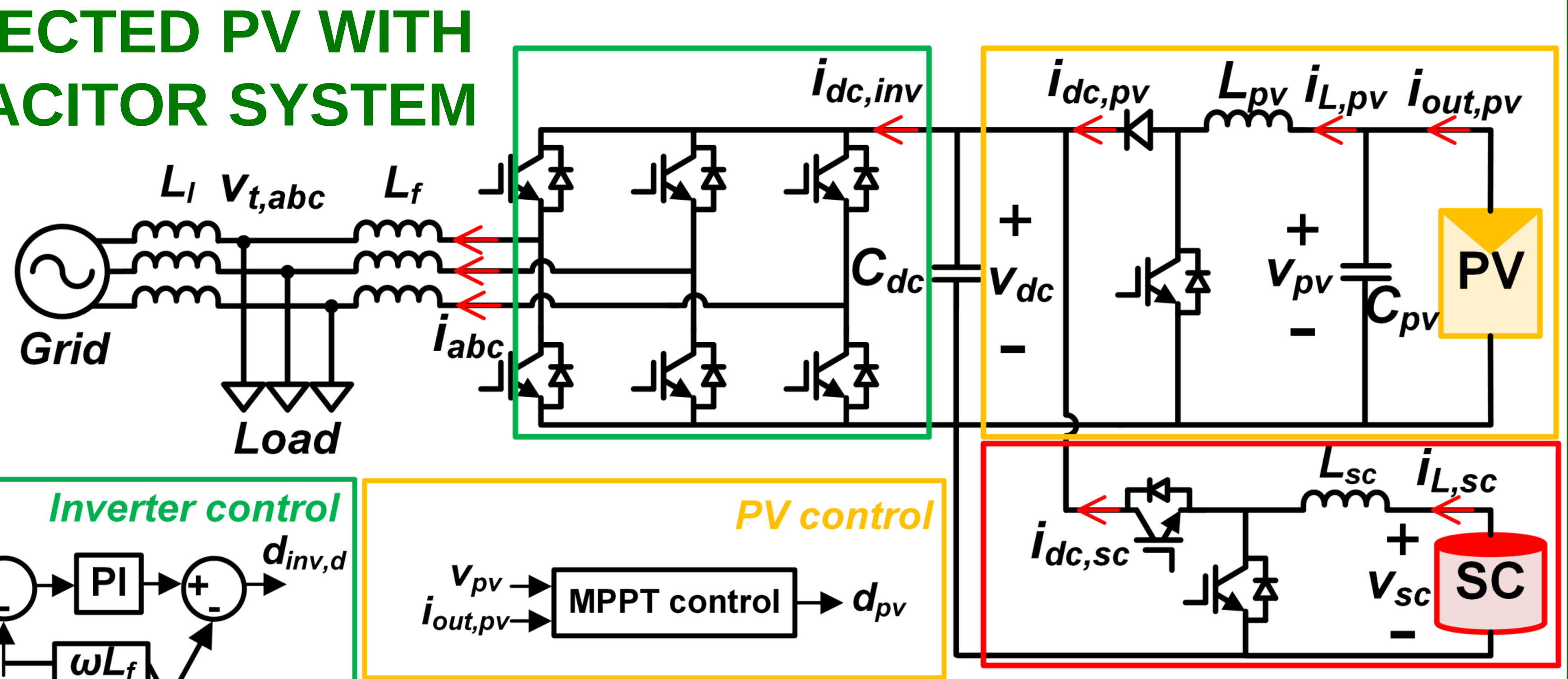
BACKGROUND

- Frequency regulation has become a challenge with higher integration of inverter-based resources (IBRs) in power grids.
  - Reduction in grid's inertia → high rate of change of frequency ($ROCOF$).
  - Fluctuation in grid's frequency.
- Grid code requires IBRs to provide fast frequency support including inertia emulation and frequency regulation to power grids.
- IBRs should be able to provide fast frequency support efficiently.
  - Power oscillations during the support due to high inertia coefficient with limited improvement of $ROCOF$.
- Dynamics of IBRs during the frequency event should be investigated.

GRID-CONNECTED PV WITH SUPERCAPACITOR SYSTEM (PVSS)



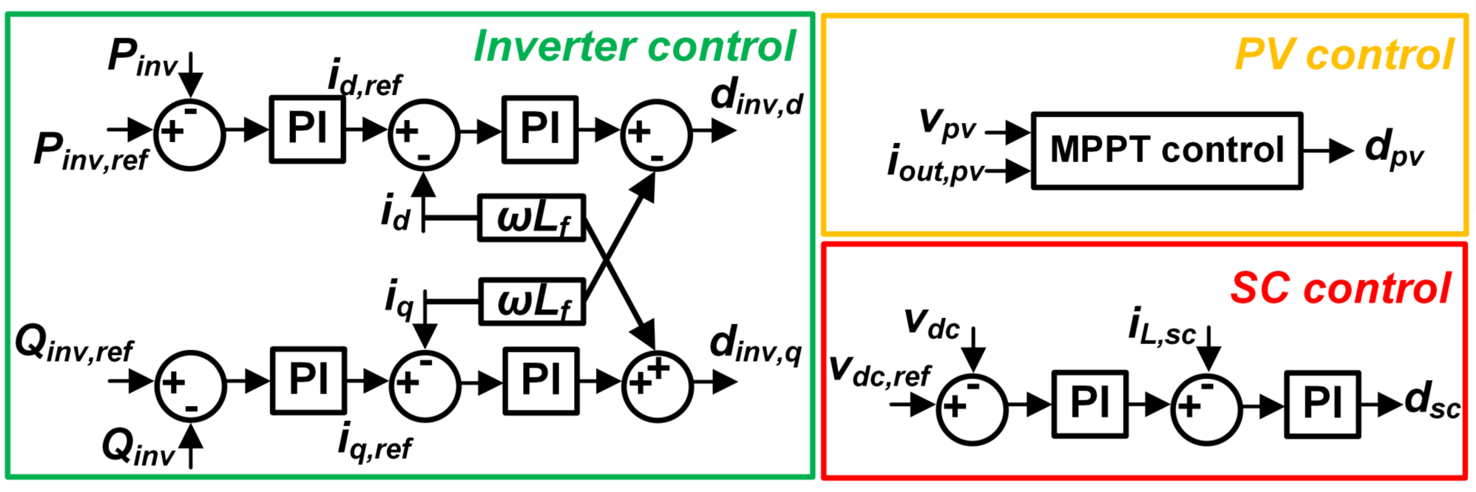


Table I. PVSS's Parameters.

Parameters	Values	Parameters	Values
SC energy capacity	0.35 kWh	SC power capacity	63.18 kW
PV power rating	50 kW	Inverter power rating	55 kVA

OBJECTIVE

- Demonstrate the PVSS dynamics during frequency events on the hardware testbed (HTB).
  - Frequency drop and frequency recovery.
- Investigate the inertia responses based on different inertia coefficients (k_{iner}).
- Maximize the inertia support while reducing power oscillations during the event.

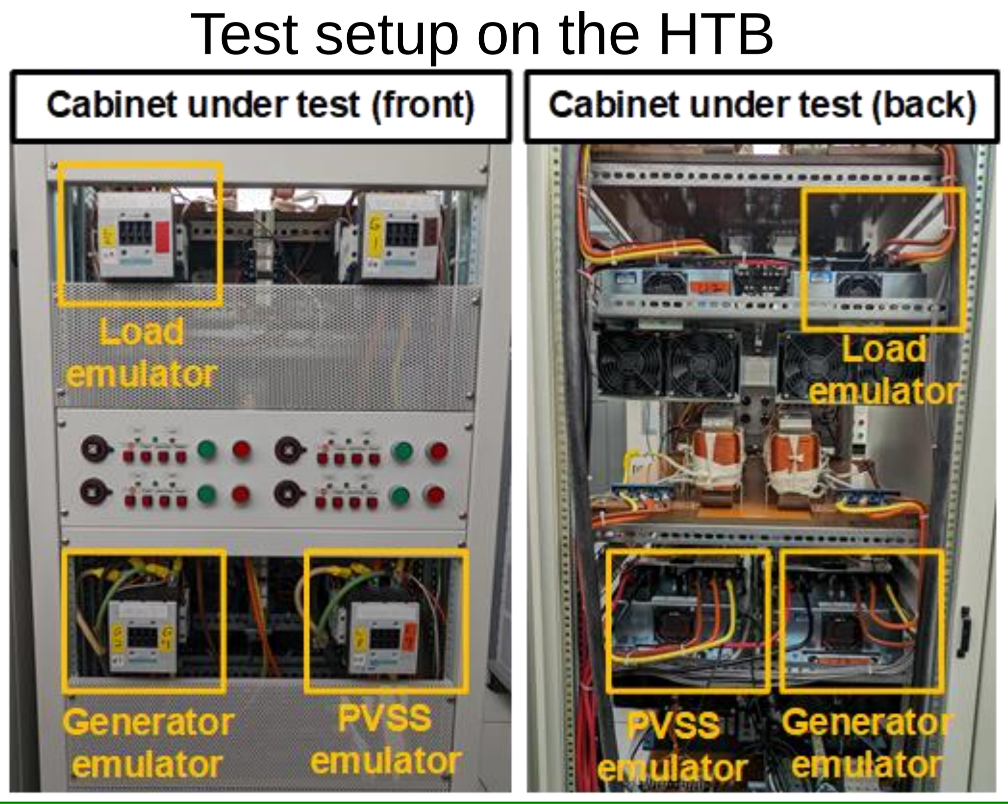
TECHNICAL APPROACHES

- Change of k_{iner} to reduce power oscillations.
- Bang-bang control to provide fast frequency recovery
- Calculate $ROCOF$ based on the moving average.
- The change in active power reference (ΔP_{fre}) during grid frequency support:

$$\Delta P_{fre} = k_{iner} ROCOF + k_f \Delta f$$

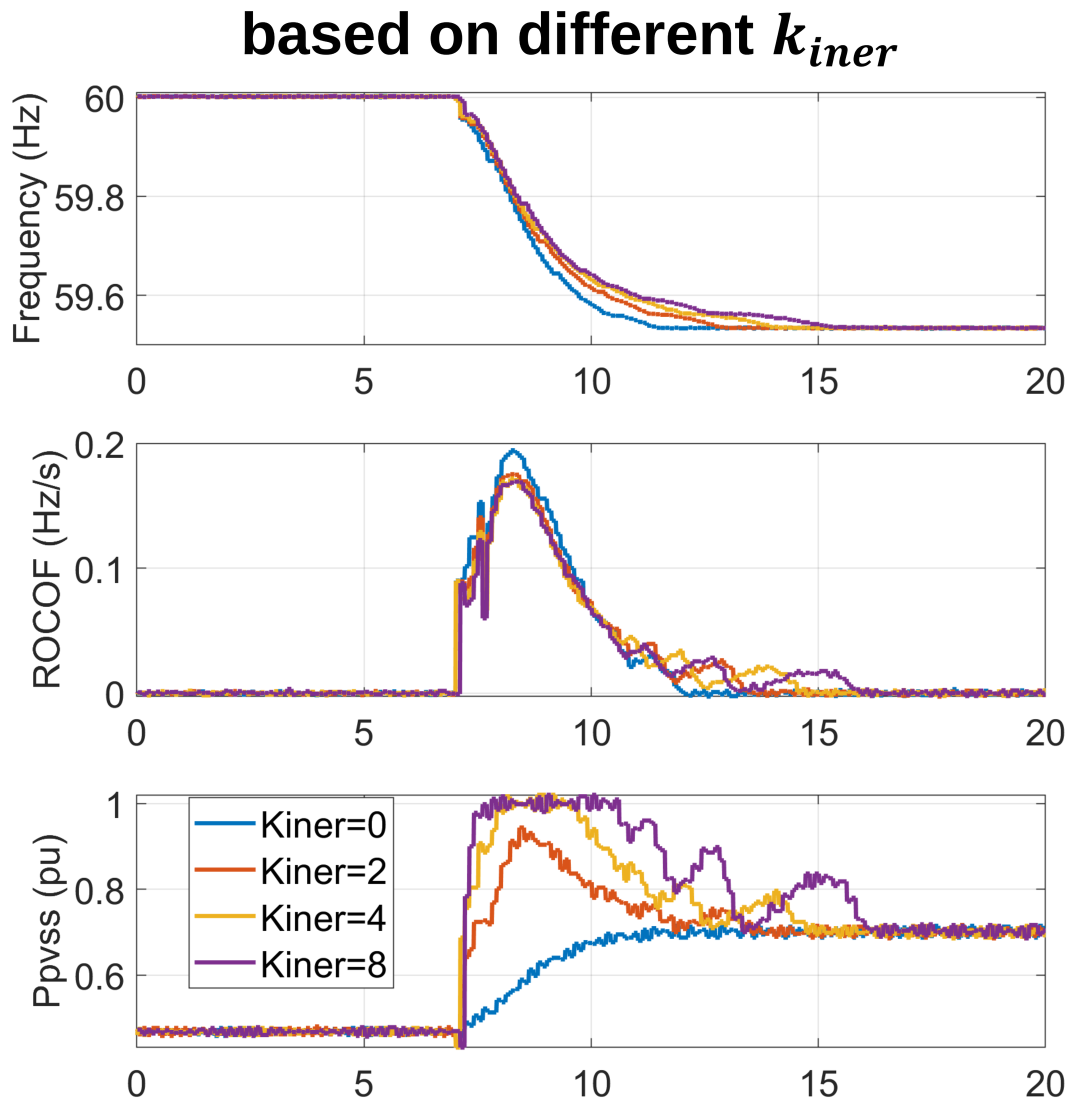
Δf: the change in frequency during the disturbance.
k_{iner}: inertia control loop coefficients.
k_f: frequency control loop coefficients at 0.5 for all tests.

Test setup on the HTB



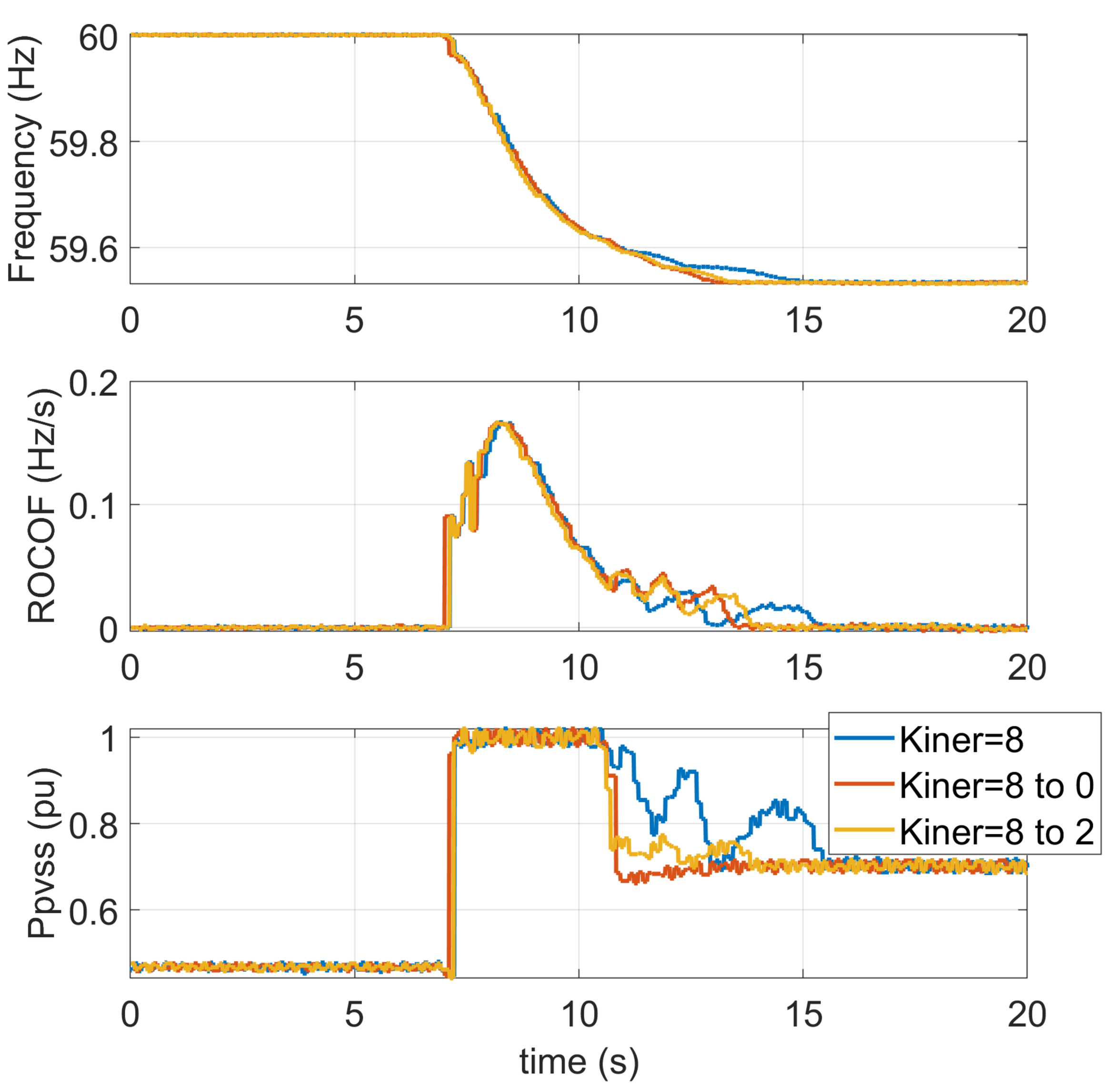
EXPERIMENTAL EMULATION

Frequency dynamics based on different k_{iner}



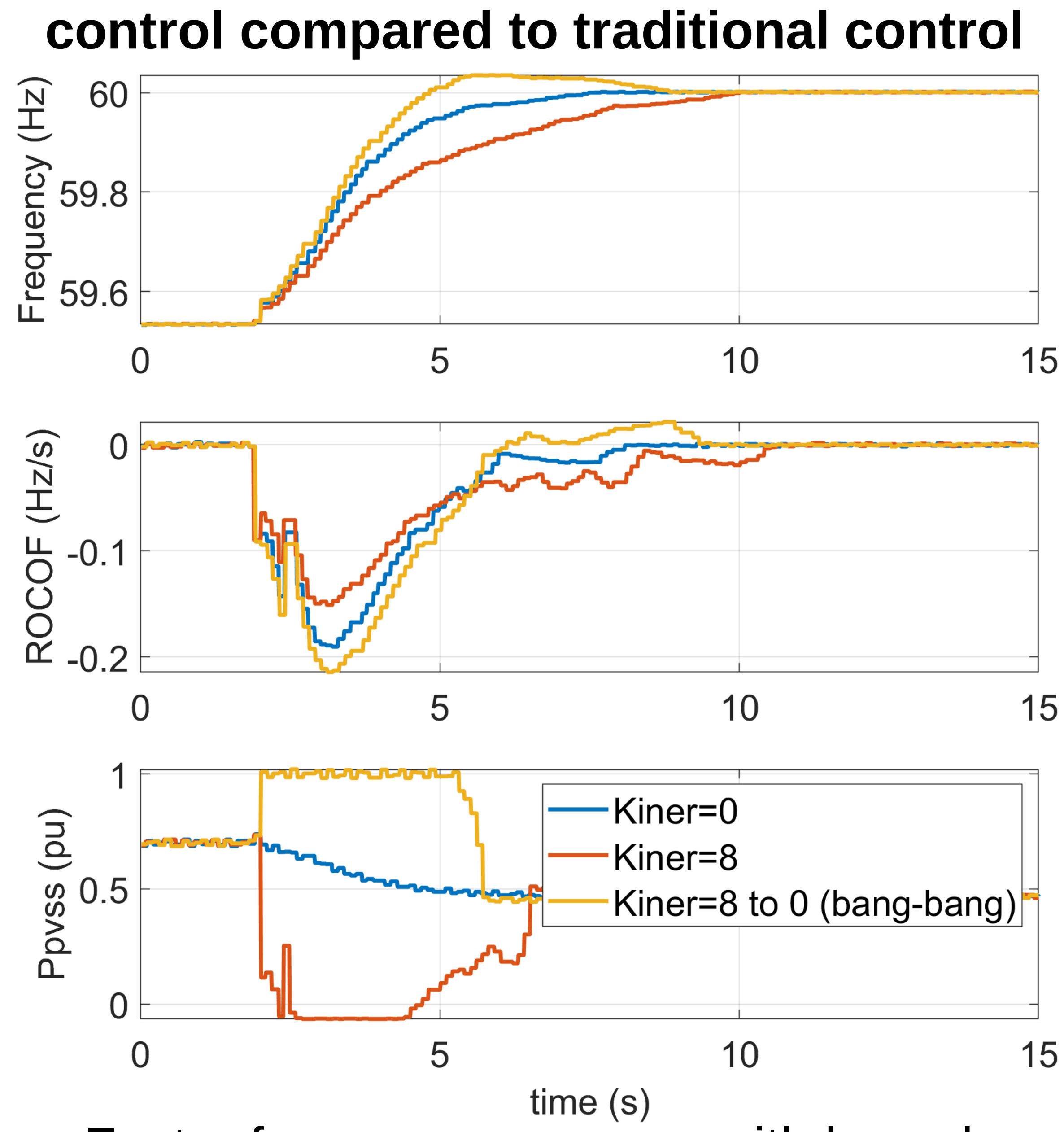
- Higher k_{iner} improves the $ROCOF$.
- Power oscillations of high k_{iner} provide no improvement of $ROCOF$.

Change of k_{iner} during the event



- Reduce power oscillations by changing k_{iner} to be low value when the $ROCOF$ is getting close to 0 Hz/s during the support.

Frequency recovery based on bang-bang control compared to traditional control



- Faster frequency recovery with bang-bang control (injecting power during the frequency recovery period).

CONCLUSION

- Demonstrate the PVSS dynamics during fast frequency support on HTB.
- Investigate the response of the PVSS based on different inertia coefficients.
- Reduce power oscillations of high k_{iner} to improve SC utilization during the event.
- Improve frequency recovery by adopting bang-bang control.

FUTURE WORK

- Improve the frequency dynamics during the recovery period.

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