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)

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\textsubscript{iner}).
  • Maximize the inertia support while reducing power oscillations during the event.

TECHNICAL APPROACHES

• Change of k\textsubscript{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\textsubscript{fre}) during grid frequency support:
    \[ ΔP_{fre} = k_{iner} \cdot ROCOF + k_f \Delta f \]
    \[ \Delta f: \text{the change in frequency during the disturbance.} \]
    \[ k_{iner}: \text{inertia control loop coefficients.} \]
    \[ k_f: \text{frequency control loop coefficients at 0.5 for all tests.} \]

EXPERIMENTAL EMULATION

Frequency dynamics based on different k\textsubscript{iner}

Change of k\textsubscript{iner} during the event

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

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\textsubscript{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.

Table I. PVSS's Parameters.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
<th>Parameters</th>
<th>Values</th>
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<tbody>
<tr>
<td>SC energy capacity</td>
<td>0.35 kWh</td>
<td>SC power capacity</td>
<td>63.18 kW</td>
</tr>
<tr>
<td>PV power rating</td>
<td>50 kW</td>
<td>Inverter power rating</td>
<td>55 kVA</td>
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**SC CONTROL**

- Higher k\textsubscript{iner} improves the ROCOF.
- Power oscillations of high k\textsubscript{iner} provide no improvement of ROCOF.

**Change of k\textsubscript{iner} during the event**

- Reduce power oscillations by changing k\textsubscript{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).