Real-Time PV Power Forecasting

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TEP Utility Scale PV Variability

EMS aggregate 2013-10-09

45 MW / 30 min
25 MW / 2 min
TEP Utility Scale PV Variability

Yesterday
TEP Behind the Meter DG Variability

Yesterday
Real-time data sources map

+ Black Mountain

+ Springerville

Utility scale PV
Sensor or DG PV
TFS to UA 1 min warning

Technicians for Sustainability
Local PV installer

UA Physics and Atmospheric Sciences
TFS to UA 1 min warning
TFS to UA 1 min warning
Network-based Forecasts

Retrospective forecasts based on data from 100 rooftops

Building system to do this in real-time

Lonij et al., Solar Energy 97 58 (2013)
Network-based Forecasts

Retrospective forecasts based on data from 100 rooftops

Building system to do this in real-time
Real time clearness maps
Yesterday’s network forecasts
Yesterday’s network forecasts
Hybrid forecasting

Measured Power
Power Under Clear Sky

Normalized Power Output (kW/kWpeak)

6:00 9:00 12:00 15:00 18:00
7/18/11

Measured Cloud Derating
WRF Forecast
Ground Sensor Forecast
ANN Forecast
Presistence Forecast
Maximum Likelihood Forecast

Derating Due To Clouds

6:00 9:00 12:00 15:00 18:00
7/18/11
Hybrid method for irradiance forecasting

- WRF Model
- Irradiance Sensors
- DG Metering Data
- Sky Cameras

PV Assets Map

PV Power Forecast

Forecast GUI For Utilities

Utility Co.

- Operations
- Marketing
- Resource Planning

Reserve Policy

ACE Scenario Simulations

For Utilities

Irradiance Sensors

DG Metering Data

Sky Cameras

WRF Model

Hybrid forecasting utility integration
ATMO Wind forecasting for TEP
Solar forecasting for TEP

Correct features, only wrong by 1 hour
Website for TEP

Forecasts for TEP EMS sites, irradiance sensors, and rooftop PV

EMS aggregate 11/21/13 17:17:37

- EMS aggregate
- WRF avg
- 800: Western Wind
- 801: Macho Springs Wind
- 901: FRV
- 902: NRG
- 903: Solon2
- 904: Astrosol
- 905: Prairie Fire
- 906: EON
- 907: Solon1
- 908: Amonix
- 909: EON Valencia
- 910: Black Mountain
- 911: DM Soaring Heights
- 912: Springerville Solar

Power (MW)

Time of Day (hr)
Website for TEP

Forecasts for TEP EMS sites, irradiance sensors, and rooftop PV

Home page and feedback form
Maps
- Full dataset
- Tucson
- Tucson animated
- UA-STEP
- Google map

Aggregate plots
- EMS Aggregate
- EMS Solar Aggregate
- EMS Wind Aggregate
- DG Aggregate
- Total Aggregate

TEP EMS data
- EMS Aggregate
- EMS Solar Aggregate
- EMS Wind Aggregate
- 9: iSensor v1.0
- 901: FRV
- 902: NRG
- 903: Solon2
- 904: Astrosol
- 905: Prairie Fire
Website for TEP

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Ramp rates of MW and kW systems and battery sizing

Cormode et al., PVSC 2013

<table>
<thead>
<tr>
<th>Maximum allowed ramp rate ($\Delta P/\Delta t$)</th>
<th>Battery power for 100% compliance</th>
<th>Battery power for 99.5% compliance</th>
<th>Battery power for 98% compliance</th>
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<tbody>
<tr>
<td>100% / 10 min</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20% / 2 min</td>
<td>47 %</td>
<td>37 %</td>
<td>14 %</td>
</tr>
<tr>
<td>10% / 1 min</td>
<td>55 %</td>
<td>45 %</td>
<td>23 %</td>
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<tr>
<td>5% / 30 sec</td>
<td>59 %</td>
<td>48 %</td>
<td>26 %</td>
</tr>
<tr>
<td>1% / 6 sec</td>
<td>60 %</td>
<td>50 %</td>
<td>27 %</td>
</tr>
<tr>
<td>0.16% / 1 sec</td>
<td>64 %</td>
<td>52 %</td>
<td>27 %</td>
</tr>
</tbody>
</table>

![Graph showing ramp rates and battery sizing data.](image1)

![Graph showing occurrence of ramp rates.](image2)

![Graph showing distribution of ramp rate.](image3)
Low cost irradiance sensors