
www.csiro.au

# Characterising the Effect of High Penetration Solar Intermittency on Australian Electricity Networks

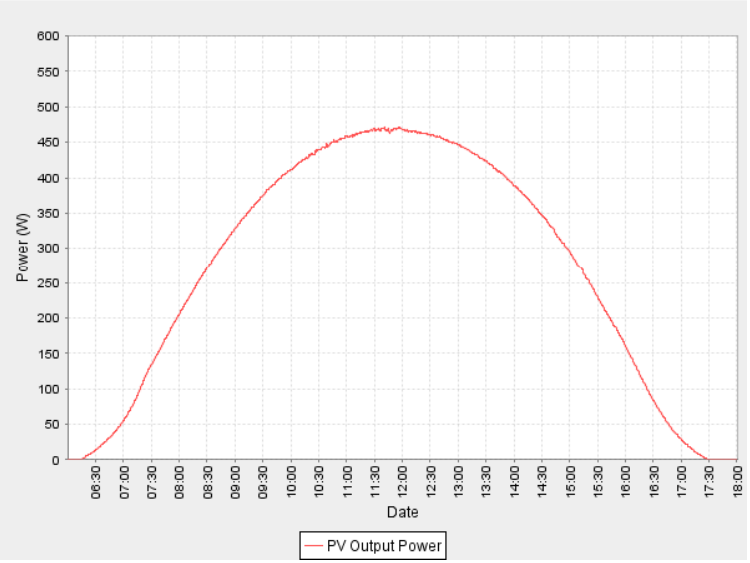
**Dr Saad Sayeef**
**CSIRO Energy Technology**
**November 2011**

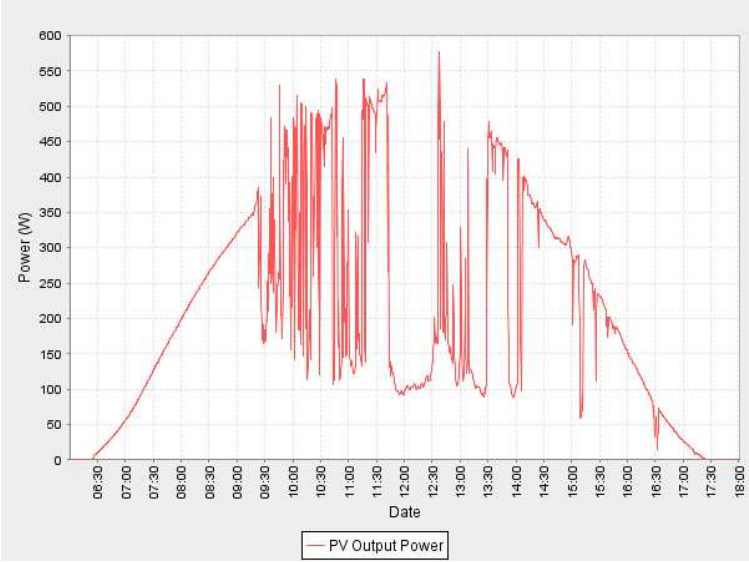
CSIRO

# Problem

- Solar installations are uncontrolled generating systems

Solar power generated on a sunny day



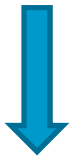

Solar power generated on a cloudy day

National Research FLAGSHIPS CSIRO

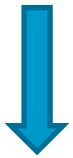
# Problem

- Solar installations are uncontrolled generating systems

Variable output



Large variations in energy supply



Significant potential network impacts

# Objective of study

- To characterise the impact of solar intermittency on Australian electricity networks

- To understand the variability of solar power plants, both PV and CST sources, in order to support the rapid development of high-penetration solar power in the electric power system

# Project activities

- To understand issues being faced due to intermittency and concerns that Australian industry players hold:
  - Industry workshop on the effects of renewable generation intermittency conducted in April 2011
  - Follow-up survey was also conducted

# Key points

- Need to investigate impacts of large numbers of small-scale solar systems in the distribution network and large-scale solar systems in the transmission network separately

- In Australia, very limited solar information is available to study impacts of solar intermittency on the stability of the grid

# Key points

- Different intermittency timescales associated with different impacts, management strategies and costs
  - Dynamic response of system, power quality, frequency stability – sub-second to ten seconds
  - Market specific ancillary service product – seconds to five minutes
  - Load following – minutes to hours
  - Generation dispatch – beyond five minutes
- Can AWEFS and/or ANEMOS be applied to solar forecasting?

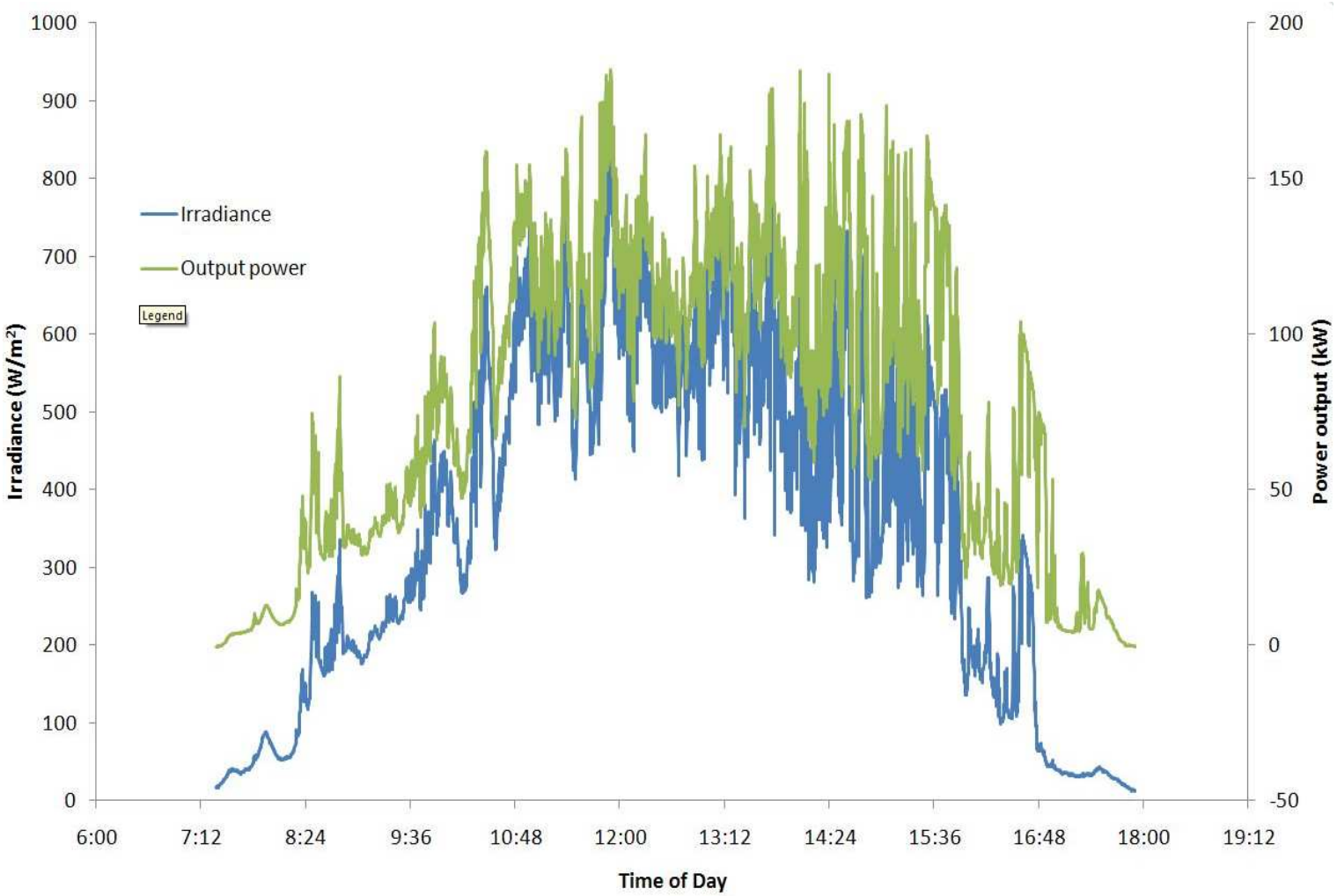
# Australian context – Unique aspects

- Configuration of electricity network different between east and west Australia
- Weather patterns vary greatly across the network
- Distribution impedance is higher compared to Europe and most other nations
- Australian solar resource different to Europe
- Power flows are different – many long and stringy transmission networks
- Different market dynamics
- Different system frequency operating standards

# Intermittency Timescales and Ramp Rates

- 10 months data recorded collected from the Desert Knowledge Australia Solar Centre (DKASC)
- 10-second resolution
- Located in Alice Springs, Central Australia
- Range of commercialised solar power technologies in a number of different configurations
- Total rating of 196kW

# Irradiance and Output Power of PV plant

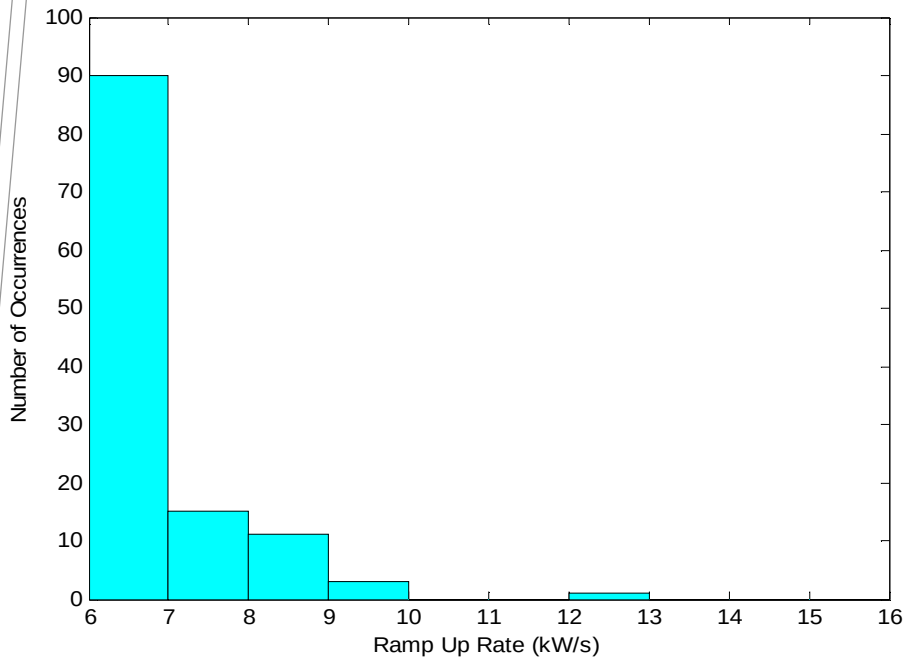


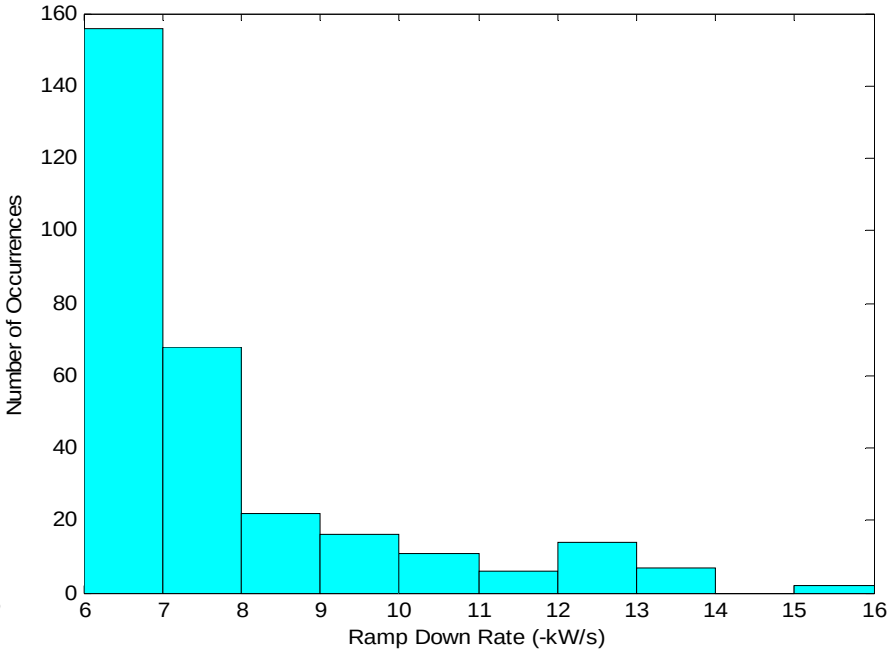

26th May, 2011

National Research FLAGSHIPS CSIRO

# PV output power ramp events

## 10-second ramp events



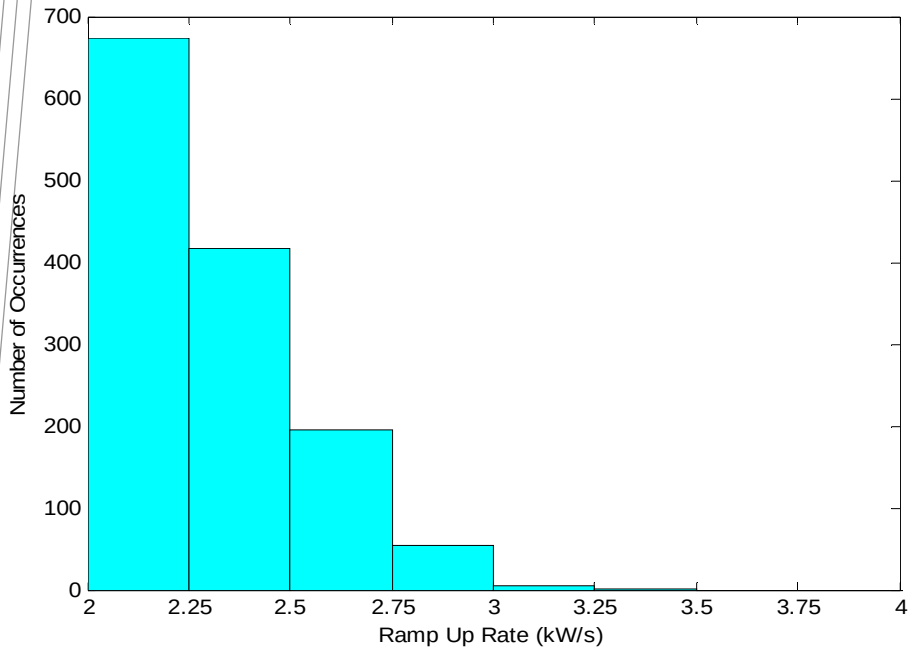

- Ramp up:
- 120 occurrences of 6kW/s or more
- Increase in power of at least 31% in 10 seconds

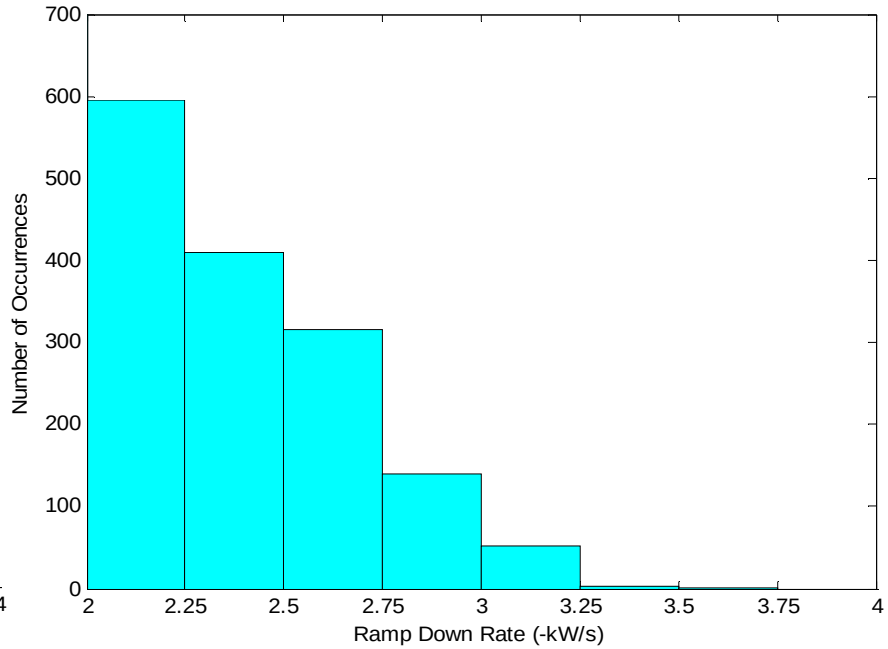
- Ramp down:
- 302 occurrences of 6kW/s or more
- 7 events between 13 and 14kW/s (66-71% drop in power)

National Research FLAGSHIPS CSIRO

# PV output power ramp events

## 50-second ramp events



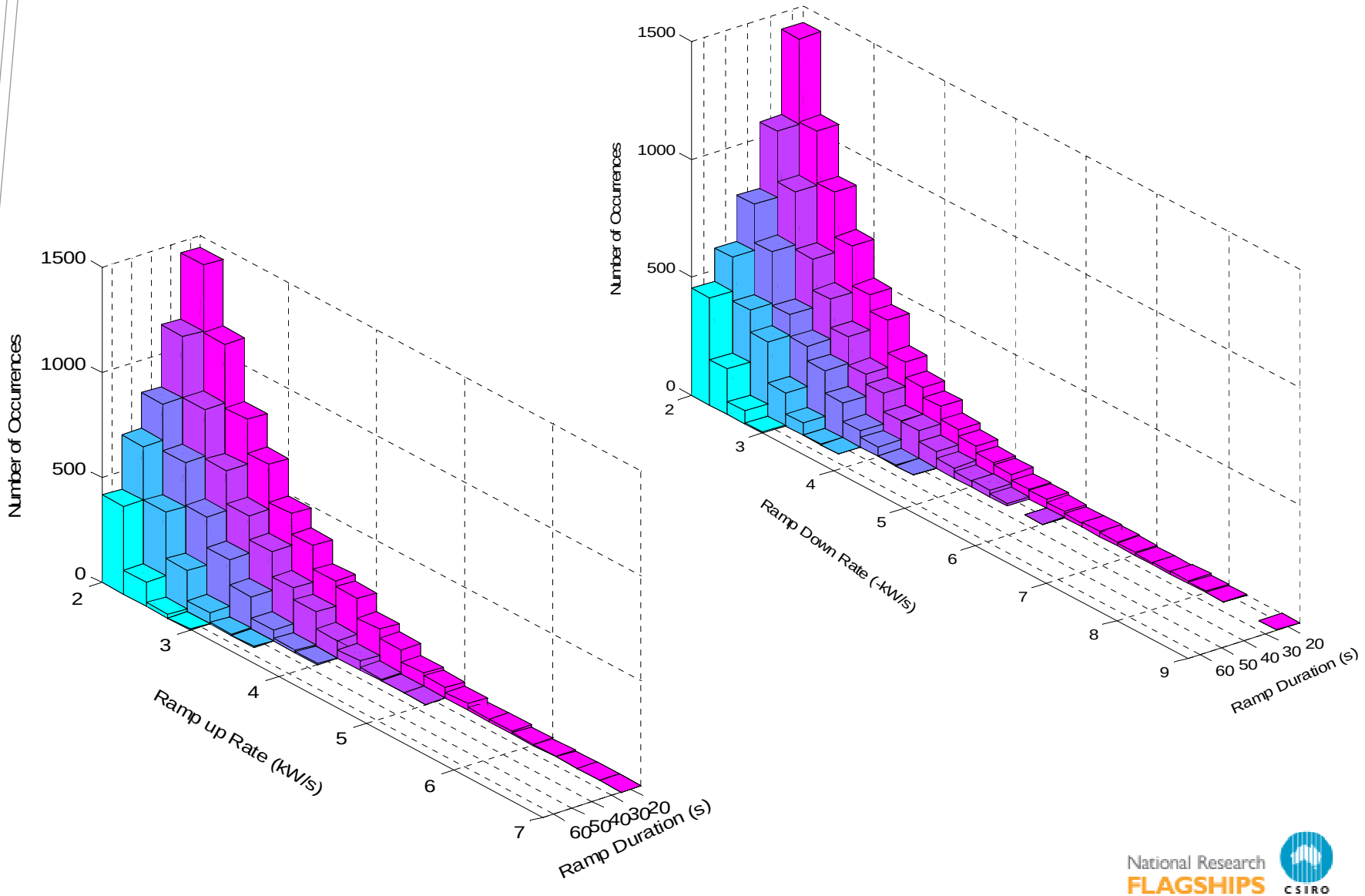




- Ramp up:
- 1344 occurrences of 2kW/s or more
- Increase in output power of at least 51% in 50 seconds

- Ramp down:
- 1515 occurrences of 2kW/s or more
- 54 events of over 3kW/s(>77% drop in power in 50 seconds)

National Research FLAGSHIPS CSIRO

# PV output power ramp events




National Research FLAGSHIPS CSIRO

# PV output power ramp events

## Ramp-up occurrences

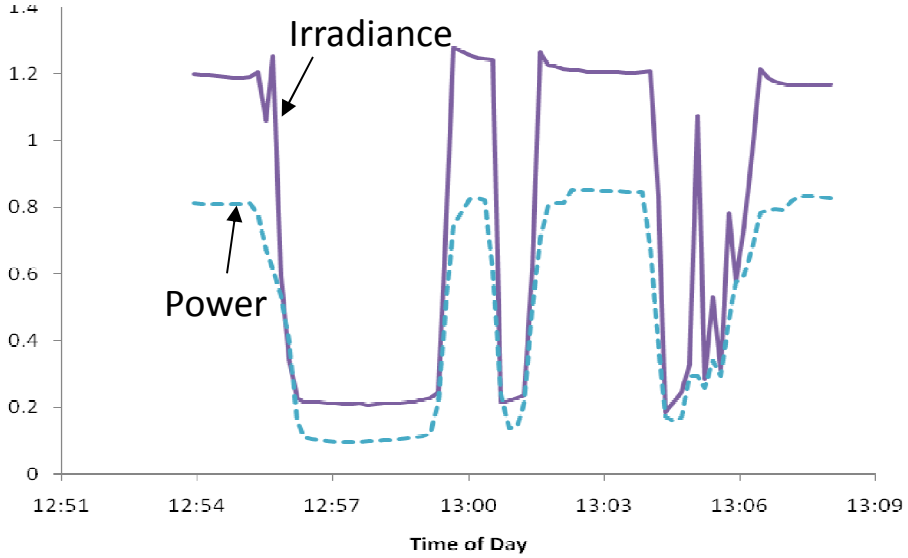
| Timescale | 0-1kW/s | 1-2kW/s | 2-3kW/s | 3-4kW/s | 4-5kW/s | 5-6kW/s | 6-7kW/s | 7-8kW/s | 8-9kW/s | 9kW/s+ |
|---|---|---|---|---|---|---|---|---|---|---|
| 10s | 1282695 | 13127 | 4818 | 2030 | 795 | 309 | 90 | 15 | 11 | 4 |
| 20s | 796460 | 11844 | 4067 | 1413 | 400 | 61 | 5 | 0 | 0 | 0 |
| 30s | 522500 | 9422 | 3050 | 806 | 56 | 0 | 0 | 0 | 0 | 0 |
| 40s | 405357 | 7639 | 2169 | 218 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50s | 349481 | 6131 | 1339 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60s | 313136 | 5013 | 550 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## Ramp-down occurrences

| Timescale | 0-1kW/s | 1-2kW/s | 2-3kW/s | 3-4kW/s | 4-5kW/s | 5-6kW/s | 6-7kW/s | 7-8kW/s | 8-9kW/s | 9kW/s+ |
|---|---|---|---|---|---|---|---|---|---|---|
| 10s | 1213721 | 12794 | 4696 | 2070 | 870 | 372 | 156 | 68 | 22 | 56 |
| 20s | 727960 | 11276 | 4050 | 1480 | 506 | 165 | 64 | 30 | 3 | 0 |
| 30s | 470271 | 8943 | 3011 | 915 | 257 | 37 | 0 | 0 | 0 | 0 |
| 40s | 365293 | 6965 | 2128 | 503 | 5 | 0 | 0 | 0 | 0 | 0 |
| 50s | 315731 | 5309 | 1461 | 54 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60s | 282416 | 4126 | 700 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

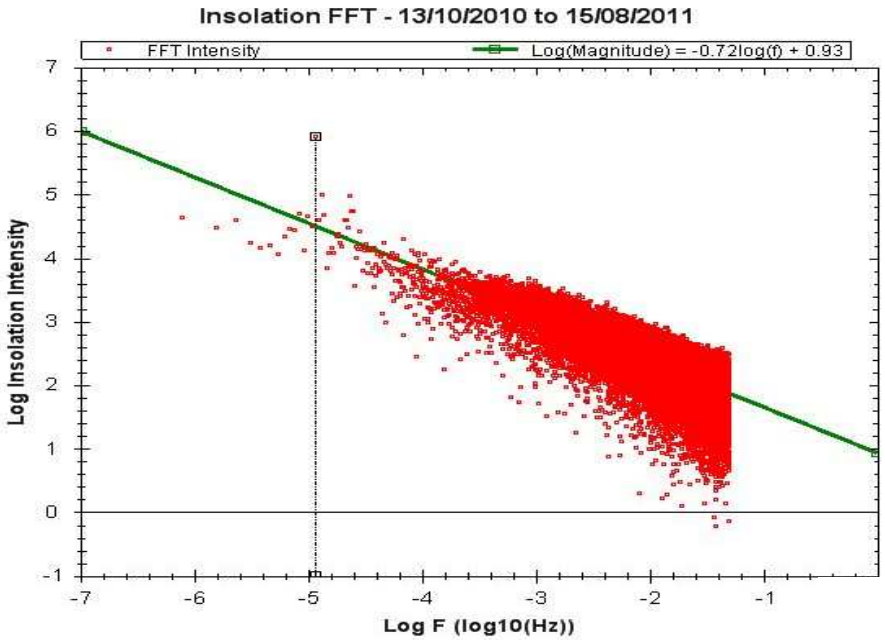
# PV output power and irradiance

- Power curve smoother than irradiance curve
- PV plant power output can be described as the signal output of a low-pass filter. Input: incident irradiance
- First order filter whose pole value is a function of the PV plant area



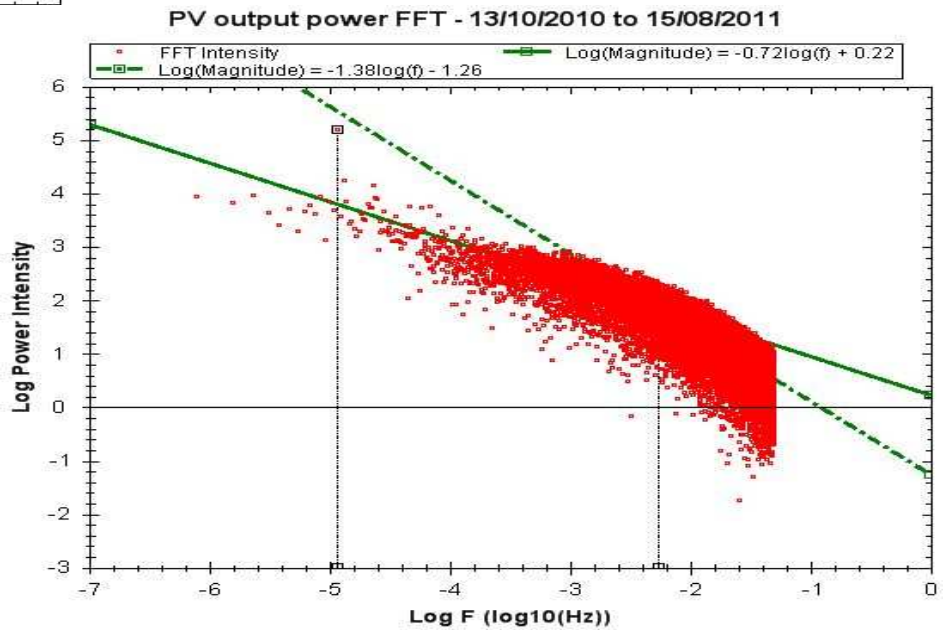

National Research FLAGSHIPS CSIRO

# PV output power and irradiance

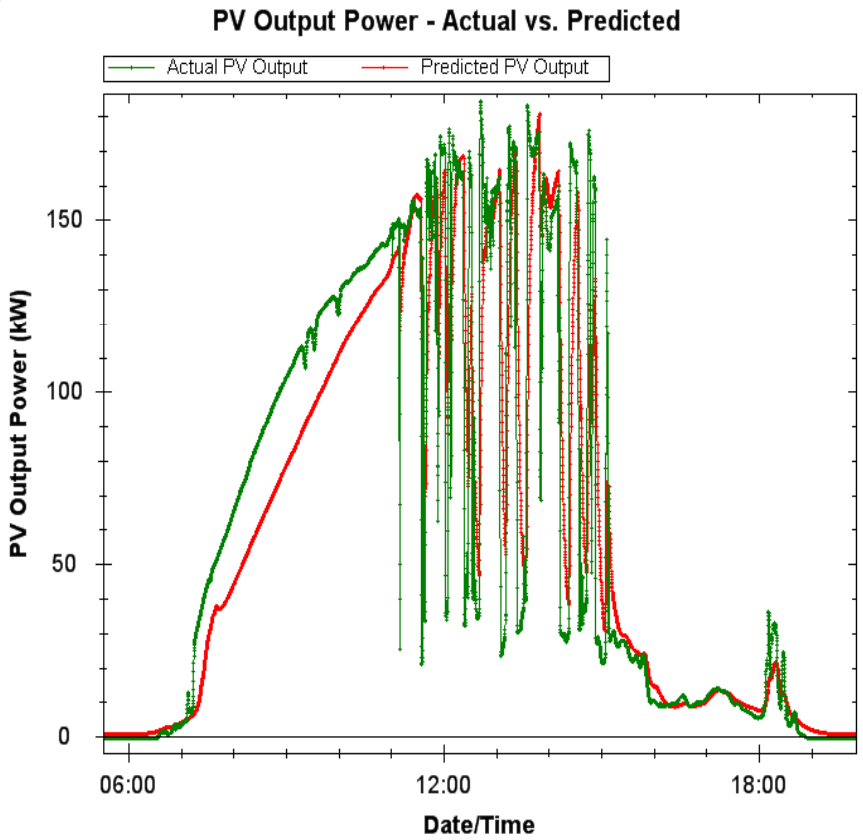


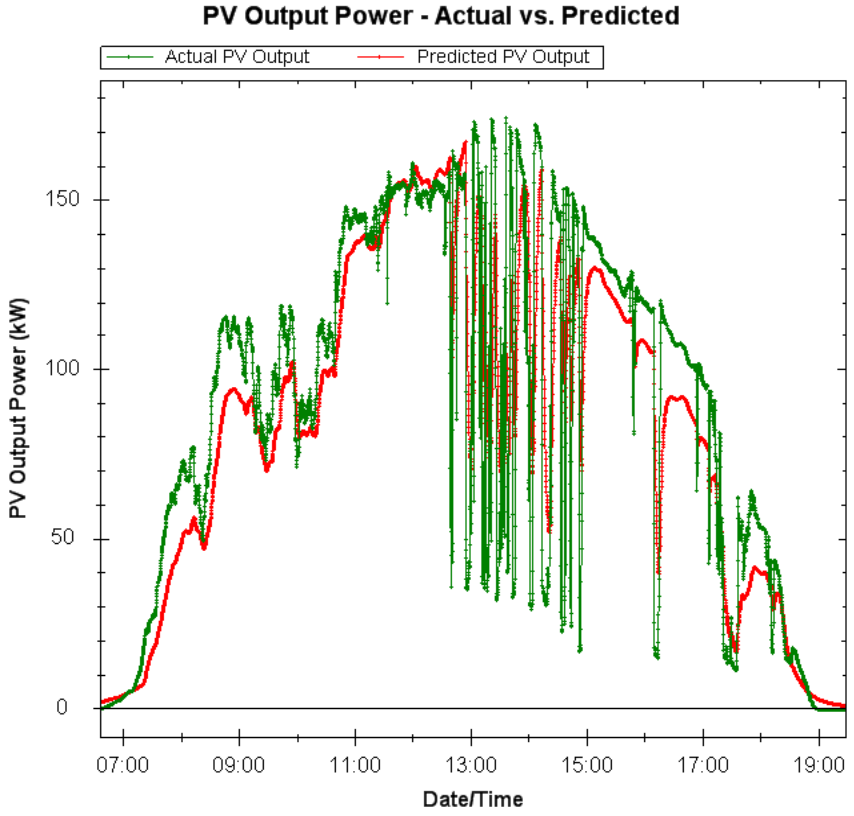

Spectrum of irradiance

Spectrum of output power



# PV output power estimate

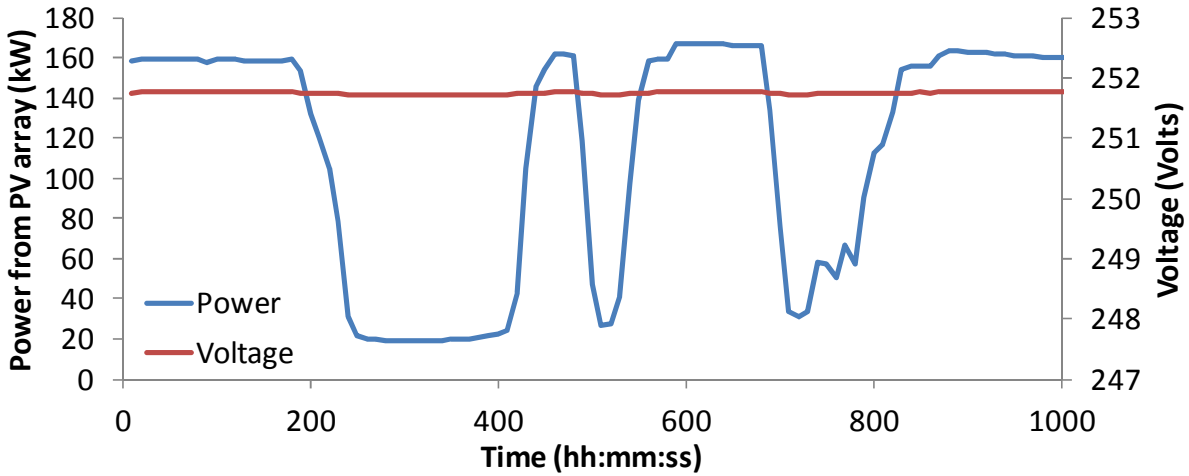



17th and 18th February, 2011

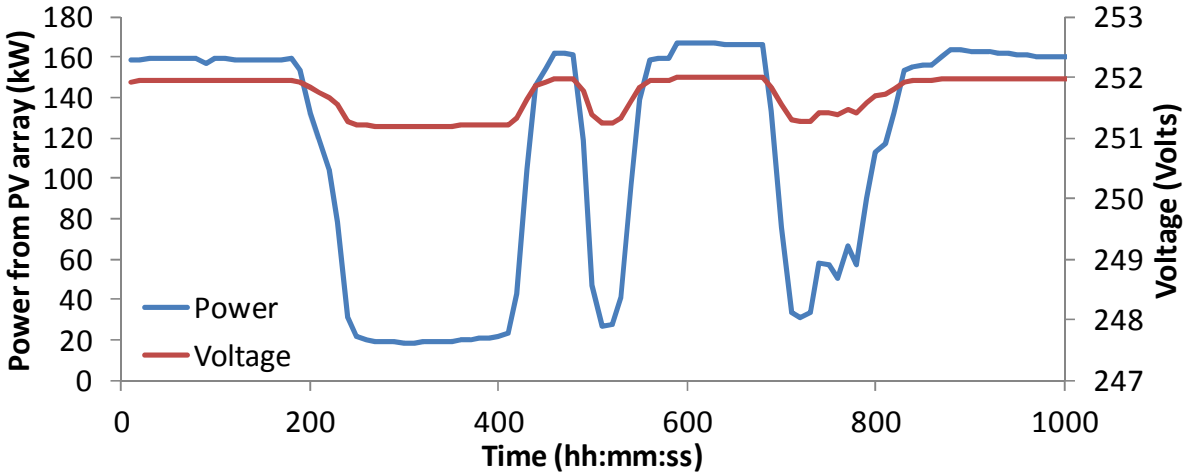
National Research FLAGSHIPS CSIRO

# Network effects of PV power variability



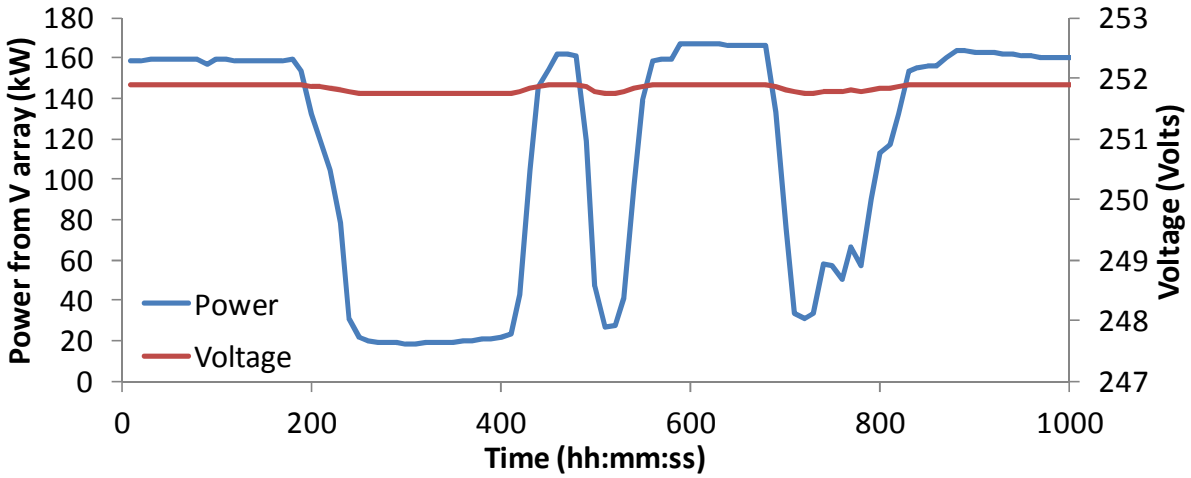

**Low PV penetration and strong grid**

**Low PV penetration and weak grid**



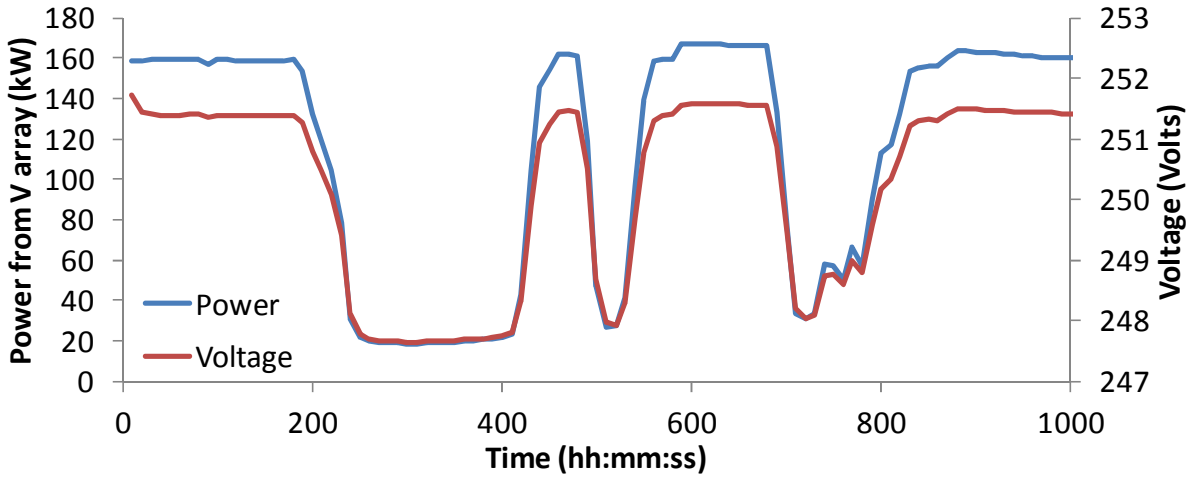

National Research FLAGSHIPS CSIRO

# Network effects of PV power variability




**High PV penetration and strong grid**

**High PV penetration and weak grid**




National Research FLAGSHIPS CSIRO

# Summary

- Issues due to intermittency and concerns that Australian industry players hold gathered
- Solar intermittency ramp rates and timescales analysed
- Model developed to link solar irradiance and PV output power
- Simulation of likely solar intermittency impacts on different types of electricity networks presented
- Current work:
  - Current state of worldwide research on renewable generation intermittency
  - Solar vs. wind intermittency
  - Relevance of worldwide research to the Australian market

**Energy Transformed Flagship**
Dr Saad Sayeef
Research Scientist

Phone: +61 2 4960 6131
Email: saad.sayeef@csiro.au
Web: www.csiro.au

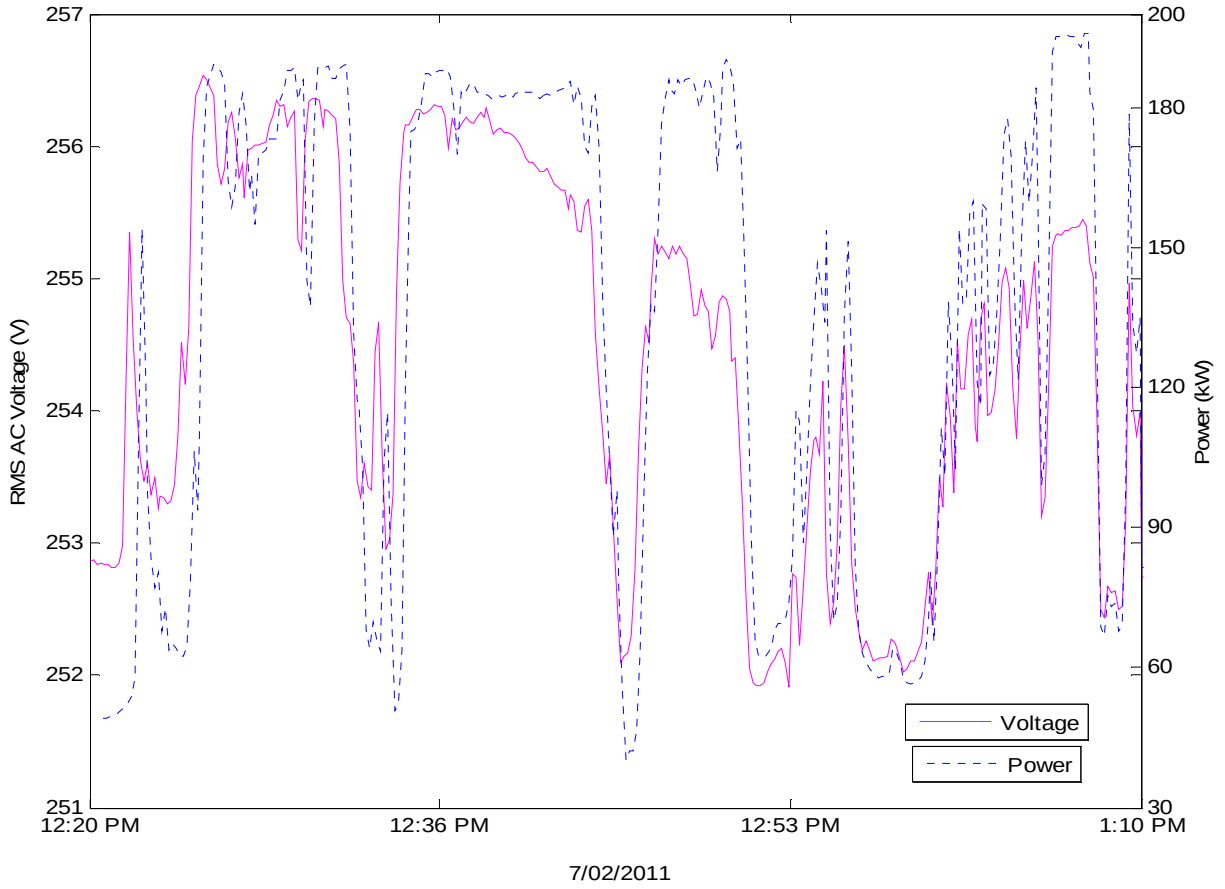
www.csiro.au

# Thank you

**Contact Us**
Phone: 1300 363 400 or +61 3 9545 2176
Email: enquiries@csiro.au Web: www.csiro.au

CSIRO

# PV output power and voltage




National Research FLAGSHIPS CSIRO