Centre for Energy and Environmental Markets

IEA PVPS Task 14 – high penetration of PV systems in electricity grids

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Solar 2011 Conference

APVA Stream

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www.ceem.unsw.edu.au

Centre for Energy and Environmental Markets

Task 14 participation

- 14 Countries… with more coming

- Australian participation through APVA with ASI funding support for international collaboration
- Australian contributions to date from Partners including APVA, CEEM – SPVRE – EE&T UNSW, CSIRO, NT Power and Water Corporation, Horizon Power, CAT Projects

Overall Goal of this international collaboration

- Promote the use of grid connected PV as an important source in electric power systems also on a high penetration level where additional efforts may be necessary to integrate the dispersed generators in an optimum manner.
- Develop and verify mainly technical requirements for PV and electric power systems to allow for high penetrations of PV systems interconnected with the grid
- Discuss the active role of PV systems related to energy management and system control of electricity grids

High Penetration PV Definition by Task 14

- High penetration situation exists if additional efforts are (would be) necessary to integrate the (planned) PV generation in an optimum manner.
- The aim of these efforts is to reduce the technical barriers to achieve high penetration levels of distributed renewable energy systems on the electric power system.
- A growing appreciation that
  - *the issues are increasingly economic, commercial and regulatory, rather than strictly technical*
  - *Emerging PV challenges are more a symptom than cause; most electricity industries around the world have disfunctional retail market arrangements that do not provide a level playing field for disruptive technologies; eg.* ***air-conditioning****, EVs*

Technical issues tackled by Task 14

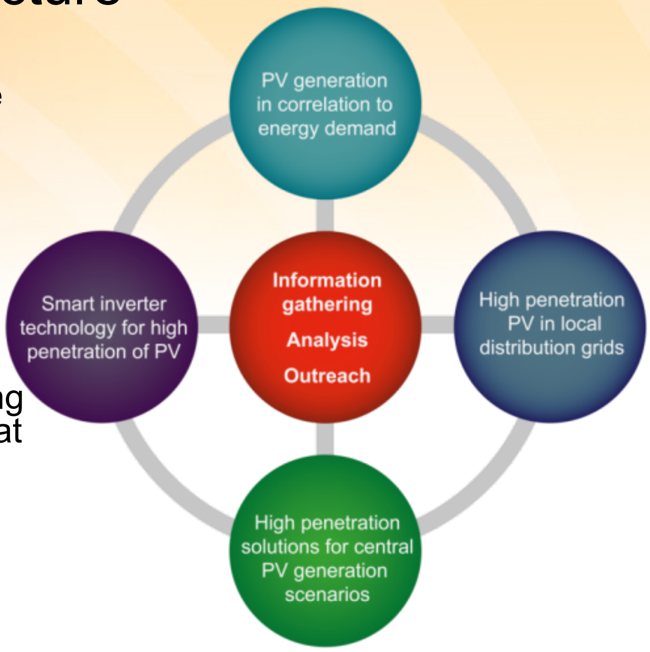
- Aspects related to the fluctuating nature of PV in relation to electricity demand
- Grid interaction and penetration related aspects related to local distribution grids and
- Central PV generation scenarios.
- Inverters with multifunctional characteristics as smart interface between the source and the electricity network.
- Modeling and simulation techniques to evaluate the aforementioned technical issues.

Desired Task 14 Outcomes

- Provide access to more transparent technical analyses in order for industry, network operators, energy planners as well as authorities in the energy business to decide on steps to be taken and strategies to be developed on a sound basis.
- provide comprehensive international studies for high penetration PV
- Reports, (Utility) Workshops, Conferences, Providing objective and neutral high-quality Information…

IEA PVPS - Task 14
Organization and structure

- PV generation in correlation to energy demand focusing on the consumer behavior to be better linked to the generation profile
- The effects on PV generation to the local grid as well as to the general electricity system
- Smart inverter technology dealing with requirements for inverters at high PV penetration
- Convincing case studies, Best practice examples



Largest PV plants operating, under construction, in development

(NREL, *IEA PVPS Task 14 Presentation*, 2011)

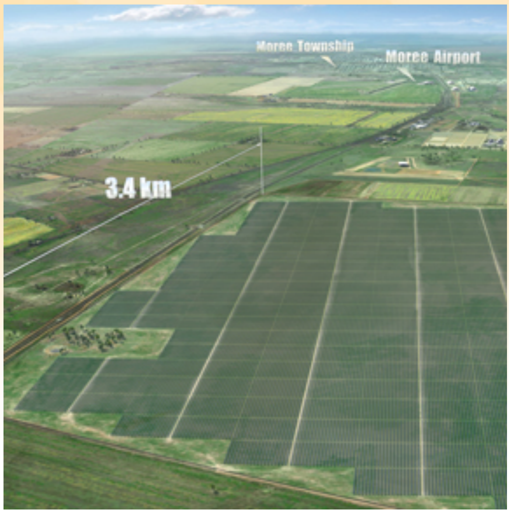
World's largest PV plants in operation

Rank	Capacity (MW-DC)	Country	Project	Technology
1	92*1	Canada	Sarnia Solar Farm	Cadmium telluride
2	85	Italy	Montalto di Castro Solar Power Plant	Crystalline silicon
3	81	Germany	Solarpark Finsterwalde I, II and III	Crystalline silicon
4	70	Italy	Rovigo Solar Power Plant	Crystalline silicon
5	60	Spain	Parque Fotovoltaico Olmedilla de Alarcón	–
6	55*3	USA	Copper Mountain Solar I	Cadmium telluride
7	54	Germany	Solarpark Straßkirchen	Crystalline silicon
8	53	Germany	Solarpark Lieberose	Cadmium telluride
9	52	Spain	Puertollano I	Crystalline silicon
10	46	Portugal	Amareleja Photovoltaic Plant	Crystalline silicon

World's largest PV plants under construction

Rank	Capacity (MW-DC)	Country	Project	Technology
1	334*1	USA	Agua Caliente Solar Project	Cadmium telluride
2	285*3	USA	Copper Mountain Solar I and II	Cadmium telluride
3	166	China	Kunming Solar Park	Crystalline silicon
4	84	Thailand	Lop Buri Solar Farm	–
5	81	Germany	Solarpark Briest	Crystalline silicon
6	76	France	Gabardan PV Power Plant	Cadmium telluride
7	60	USA	Pflugerville Solar Power Plant	Crystalline silicon
8	46*1	Thailand	–	–
9	37	USA	Long Island Solar Farm	Crystalline silicon
10	36	Canada	Stardale	Crystalline silicon

Solar Flagships
Moree Solar Farm

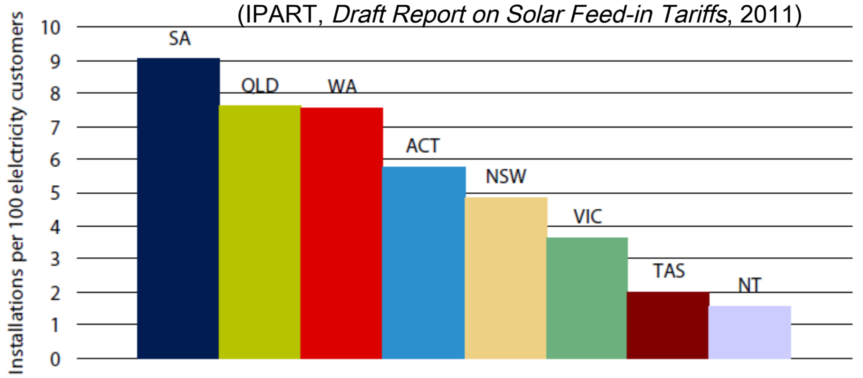


- Funding for the development of large scale solar power in Australia: demonstration of the potential of solar energy in Australia, including efficient integration and operation of large scale solar power in Australia's energy markets.
- 150MW capacity - Poly-crystalline panels
- Single axis tracking
- A$600-700m estimated cost
- Construction to commence mid 2012
- Significant research funding component being led by CSIRO

www.moreesolarfarm.com.au

FRV FOTOWATIO RENEWABLE VENTURES · PacificHydro · bp solar

Figure F.2 Number of PV installations per 100 electricity customers as at 30 October 2011



Kauai, Hawaii

- 1.2MW PV system installed
- System represents 100% penetration on clear days

(NREL, *IEA PVPS Task 14 Presentation*, 2011)

中国大规模发展光伏发电势在必行
Large-scale development of PV in China is imperative

□**实现20年装机目标**：2020年光伏装机**50GW**,从10年初至20年底,年均新增**5GW**

Target of 2020: PV capacity 50GW in 2020, annual new inatallation 5GW from 2010 to 2020

… growing issues

Solar dream gets caught in gridlock

Peter Hall

THE solar power revolution is in danger of stalling, with the State Government admitting the electricity grid is failing to cope with its green vision.

Energy Minister Stephen Robertson confirmed new applications for rooftop solar systems were being rejected in areas where Queensland's high uptake threatened the safety and reliability of its network.

Thousands of homeowners hoping for promised power savings of up to $540 via a 1.5kW system are in limbo, with those wanting larger systems even being asked to pay more than $20,000 to help cover local upgrades.

Energex said the state's electricity network since the 1950s had been designed to deliver power from the station to the home and the voltage now heading "the other way" was causing a huge dilemma.

more than 107,000 Queensland households have jumped at the Solar Bonus Scheme, launched in 2008, exporting 72.5 million kW hours back to the grid.

However, unless significant, costly upgrades are completed, many who might want to add solar panels in the future may not be able to.

Energex is warning Queenslanders considering installing solar to make applications well before entering a contract with an installer in case they are not able to proceed.

Spokesman Mike Swanston told *The Courier-Mail* about 600 local distribution transformer zones on the Gold Coast, Brisbane Valley and Sunshine Coast had reached saturation.

Mr Swanston said, at this stage, only a handful of applications had been "rejected outright", but he confirmed that 30 per cent saturation was the "trigger" for applications to be being examined closely."

Mudgeeraba resident Andries Kaden was stunned when his application for a 10kW system was knocked back.

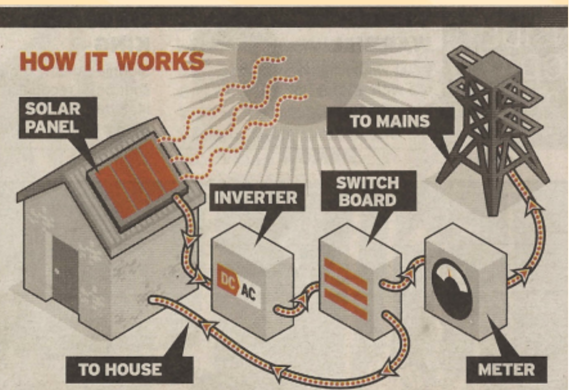
Mr Kaden was told there were enough solar systems in the area and the transformer would have to be upgraded for him to install one.

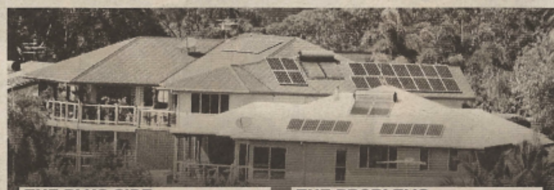
"Energex told me if I wanted to proceed I would have to pay between $20,000 and $30,000 for an upgrade," he said.

"I couldn't believe it because we have all been told to grab this, but it's not possible. You had better get in quick if you want solar is all I can say.

"I fought this all the way to the minister and they have since said I can have the system but I am a guinea pig to see if the network can handle it."

Mr Robertson advised Mr Kaden he was to be part of a trial "to see if the electricity network can operate at higher penetration levels".





THE PLUS SIDE

- Photovoltaic cells (PV) generate DC electricity when exposed to sunlight.
- The DC electricity is fed into a solar inverter which converts it to 240V 50Hz AC electricity for use in the home
- Surplus electricity is fed back into the main grid
- The value of the surplus power is credited to the household electricity account at 44¢ for every kW. On a 1.5kW system this can mean a credit of up to $540 a year

THE PROBLEMS

- Since the 1950s, the state's electricity network has been designed to deliver power from power stations to homes and businesses. The grid is unable to cope with the amount of power now heading the other way
- 600 Queensland local distribution zones – of about 50 homes each – already have hit saturation point. Areas include the Gold Coast, Sunshine Coast and Brisbane Valley

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- Grid Codes
  - BDEW: Technical Conditions for the Connection to the **medium voltage network.**
  - FNN: VDE Interim Solution for the connection to the **low voltage network** (04/2011 to 08/2011)
  - FNN: Technical Conditions for the Connection to the **low voltage network.**

Connection to Medium Voltage Network:

- Application of droop function at 50.2 Hz
- Permits increasing output power as long as frequency exceeds 50.05 Hz,

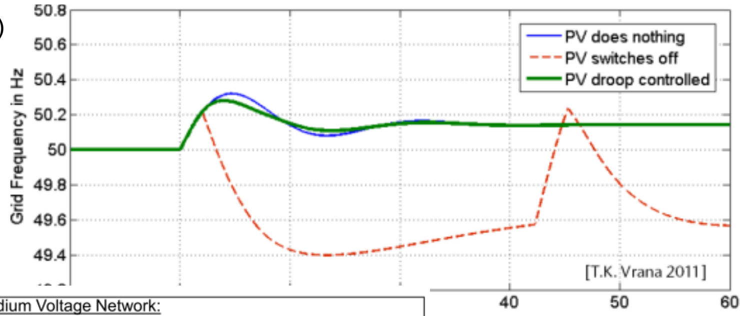
VDE Interim Solution for Low Voltage Networks:

- Application of droop function at 50.2 Hz
- Disconnection at over-frequency: Inverter manufaturers have to implement treshold values between 50.3 Hz and 51.5 Hz (uniformly distributed)

Connection to Low Voltage Networks:

- Application of droop function at 50.2 Hz

(Braun, *IEA PVPS Task 14 Presentation*, 2011)



- Grid Codes
  - BDEW: Technical Conditions for the Connection to the **medium voltage network.**
  - FNN: Technical Conditions for the Connection to the **low voltage network.**

Connection to Medium Voltage Network:

- Minimum power factor: 0.95 leading and lagging
- Reactive power provision methods:
  - Fixed power factor
  - Power factor depending on actual feed-in (cosφ(P))
  - Reactive power depending on local voltage magnitude (Q(U))
  - Online Set-Values

Connection to Low Voltage Networks:

- Minimum power factor: 0.95 (S_{max}<13.8 kVA) or 0.9 (S_{max}> =13.8 kVA)
- PV systems with S_{max}>3.68 → Reactive power method set by DSO

UNSW THE UNIVERSITY OF NEW SOUTH WALES SYDNEY • AUSTRALIA

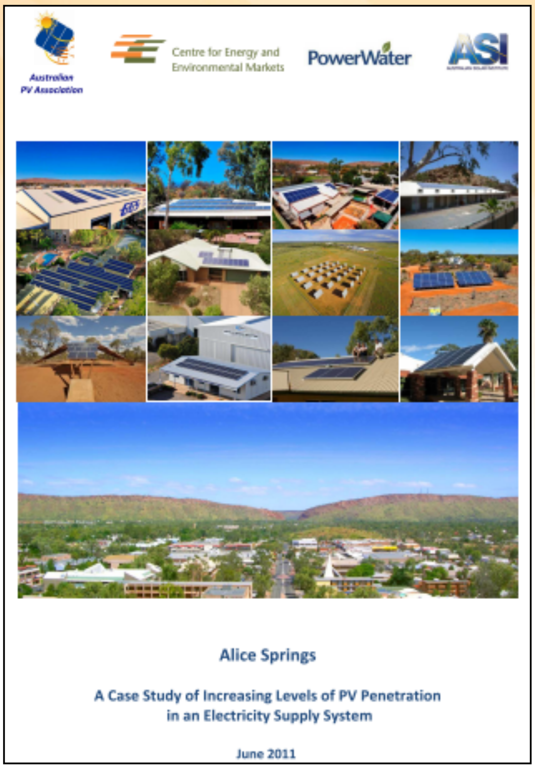
Some Potential Australian High PV Case Studies

- Alice Springs Solar City
  - Regional (50MW) grid with gas-fired generation and 3MW of PV,
  - *Case study now completed in partnership with PowerWater*
- High PV penetration diesel mini-grids
  - *Carnarvon Case Study now underway in partnership with Horizon Power*
- Townsville Solar City
  - PV with major demand management initiative
- Urban contexts
  - Some preliminary analysis for Solar Cities Blacktown

Wider objectives for case studies

- Engaging key stakeholders for appropriately facilitating high PV penetrations
- An emphasis on successful innovation for PV
- Case studies of
  - Key issues arising from high PV penetrations in a range of Australian contexts
  - successful management of these high PV penetrations
  - Identification of future issues and options that support more proactive management in emerging high PV penetrations

Alice Springs Case Study



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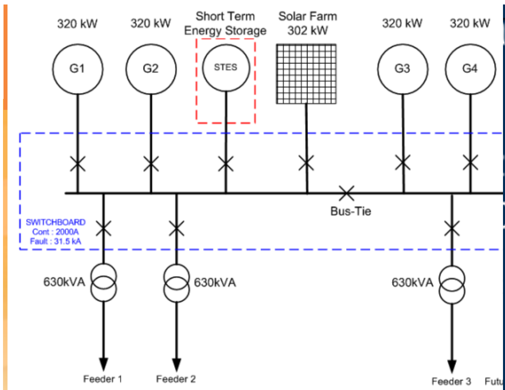

High PV mini-grids

(Darbyshire, *Presentation to Energy Storage Forum, 2011*, Adelaide)

Marble Bar	
Diesel Generation	4 x 400 kW Detroit 60 e
PV Modules	1350 x SunPower 225
PV Mounting System	135 x T20 Single -Axis
PV Inverters	45 – SMC 7000HV
Short Term Energy Inverter	ABB PCS100 ESS
Short Term Energy Storage	Pillar Flywheel

- Worlds first high penetration solar/diesel hybrid stations
- Largest single axis tracking arrays in Australia
- 80% day time load from solar energy
- 30% annual load from solar energy

Some related high PV penetration efforts

- Solar forecasting
  - Universities, CSIRO, commercial providers
  - Australian Energy Market Operator (AEMO) interest
- Smart grids
  - Distribution network service provider pilot programs
  - Smart grid, smart city (Ausgrid, Fed. Govt, CSIRO, technology providers)
- PV integration (case studies)
  - Range of universities, CSIRO
  - A growing number of DNSPs
- PV inverter and connection standards
  - Some revisions drawing on international & local experience