U.S. DEPARTMENT OF ENERGY SOLAR DECATHLON 2011

# Integration of PV and Electric Vehicles on the distribution grid

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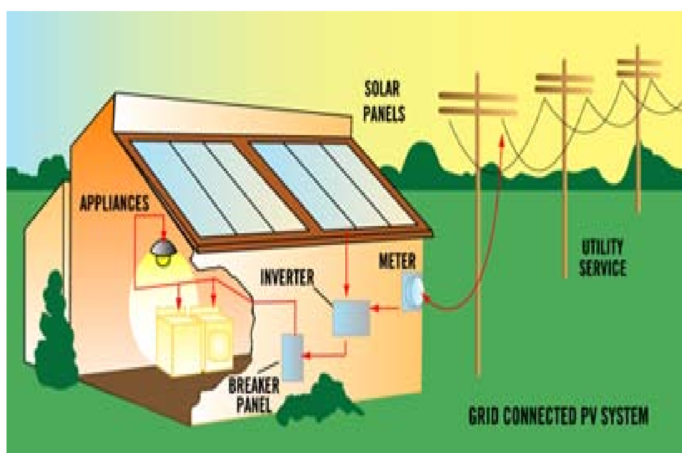
Time to shine.

# Agenda

- Challenges of renewable energy resources
- Technical challenges of IEEE 1547 based Inverters
- V2G
- Energy Storage devices
- Q & A

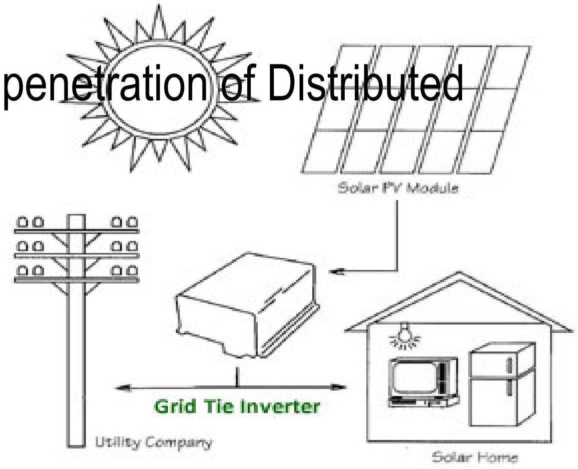
# Challenges of Renewable Energy Resources

- Demand for electricity is dynamic, changing with time-of-day, and seasonal climate.
- Electricity generated are dependent on weather
- Power generated may not match the load profile of the customers on the feeder.
- Energy produced can cause voltage fluctuations
- Renewable energy sources output rises and drops off faster than typical firm energy generators – they can ramp up and down




# Technical challenges of current inverters (IEEE 1547)

- IEEE 1547 based inverters vs dynamic inverters
  - Most grid-tie inverters are designed based on UL 1741 which is harmonized with IEEE1547
  - IEEE 1547 has not been updated to account for high penetration of Distributed Resources
    - Cold load pickup
    - Voltage Regulation control
    - Ramp Rate and Voltage Flicker
    - Anti – islanding (Low Voltage Ride through)

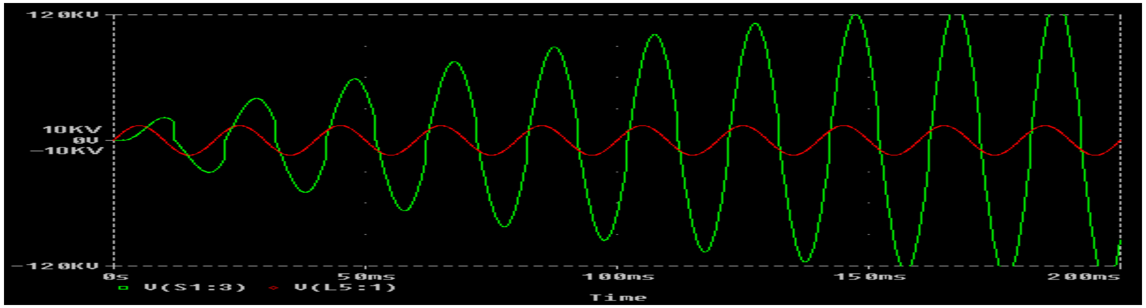



- Dynamic inverters
  - Can allow the utility to accommodate a higher level of penetration of PV
  - With proper set up and communications inverters can participate in ancillary services and voltage regulation at the POI, LVRT (Low Voltage Ride Through), etc

# Technical difficulties of IEEE 1547 based inverters

## Voltage Regulation limitations

- During low load conditions in high PV penetration areas, pockets of high voltage can develop due to injection of power to the grid by the combined output of all the solar systems in an area.
- High voltages are not permitted and can reduce the life of electrical equipment and cause PV or wind inverters to trip off line.




## Dynamic inverter

- With curtailment control and dynamic var control, utilities will be able to adjust real and reactive power output of inverters where necessary to maintain reasonable voltage levels

# Technical challenges (continuation)

## Cold Load Pickup

- IEEE 1547 requires that inverters have a fixed or adjustable 5 minute delay (usually fixed) before grid tie reconnection after grid disturbances. (outage).
- The demand on any system is typically the highest during the first few minutes after grid power is back on after an extended outage (Motors).
  - All load that is usually fed by the PV units will serve to increase the demand on the system.

## With new functionality (dynamic inverters)

- When 1547.8 is approved, it would be anticipated that new inverters could have new functionality including LVRT so that the PV generation will come back on quickly (may require transfer trip be installed).

# Technical challenges (continuation)

## Low Voltage Ride Through

- Voltage drops are at times momentary losses due to temporary faults on the system (i.e squirrel on distribution lines)
- Current IEEE 1547 anti-islanding philosophy calls for the PV inverter to disconnect from the Electric Power System if there is a fault or significant voltage drop

### Dynamic inverter

- Electric Utilities could be able to request that inverters stay on-line during a voltage drop to help with grid stability when there are faults in other circuits but drop off when there are faults on their supply

# Technical difficulties of IEEE 1547 based inverters

## Voltage Flicker issues due to Ramp Rate

- Variations in PV output (cloud, shading) could cause fluctuations in customer service voltage in an area electric power system.

  This can cause flicker in light bulbs which can become irritating to the humans and customer appliances to operate incorrectly
- Existing models used to predict the size of PV that can be connected to a point on a feeder without causing unacceptable voltage fluctuation can limit the size of the interconnection

## Dynamic inverter

- Dynamic inverters will be able to operate at a slightly reduced efficiency that will reduce the amount of voltage flicker in the inverter output.

# Vehicle to Grid/ Vehicle to Building

- According to a recent DOE study the US generation capacity is adequate to handle a substantial deployment of PEVs/PHEVs (>70% of US vehicles) if they are charged at off peak hours.
- Peak load Leveling.

  Vehicles can charge during off-peak hours and discharge to grid during peak hours.

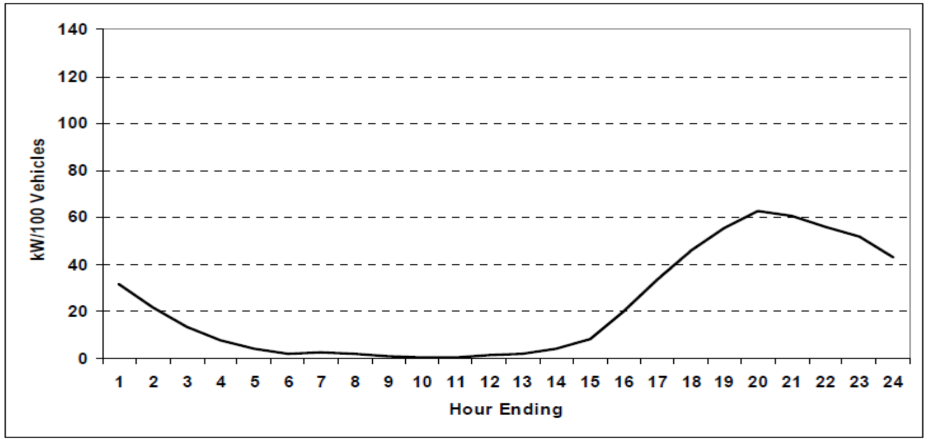
  - Power fed into the grid from the PEVs/PHEVs during peak hours can be used for Demand Response by the utility
  - Power fed into the grid from the PEVs/PHEVs during peak hours can also be used by businesses and buildings to curtail demand prices

  - Ancillary services
    - Because the output of PHEVs can be controlled (in aggregate) they can be used Frequency Regulation and possibly Spinning Reserve

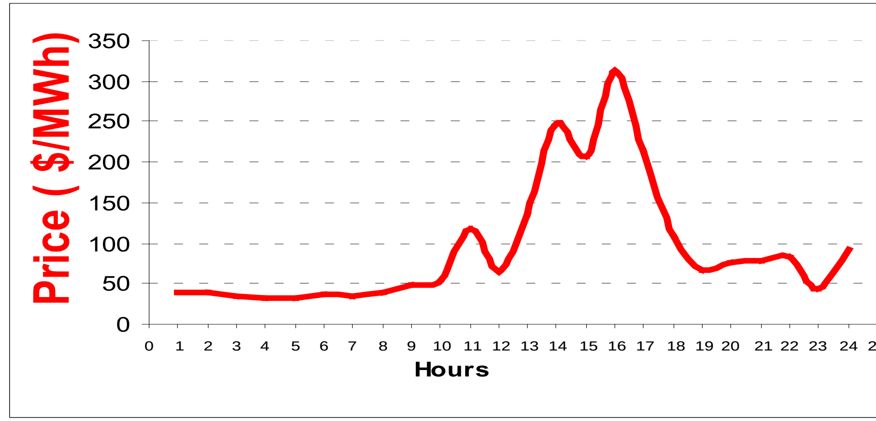
**Potential issues**

- Arbitrage – charging low, exporting power when price is higher
- Battery life cycle impact from V2G cycling
- Standardization of communication protocol & mechanism

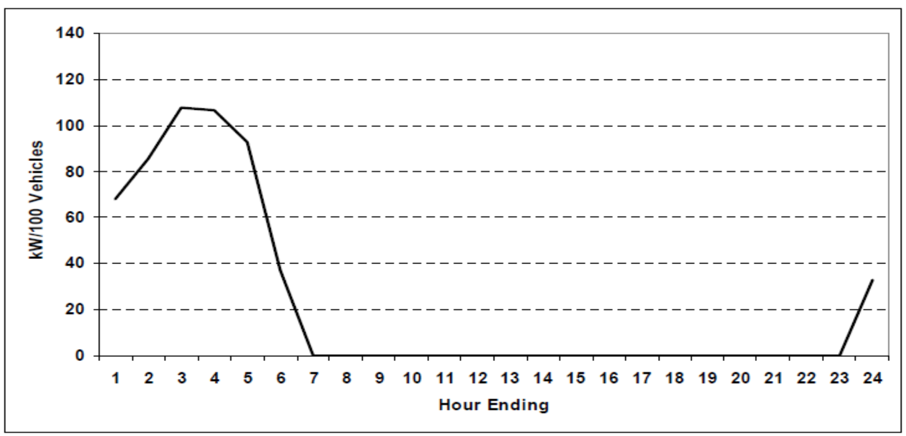
## Uncontrolled EV Charging



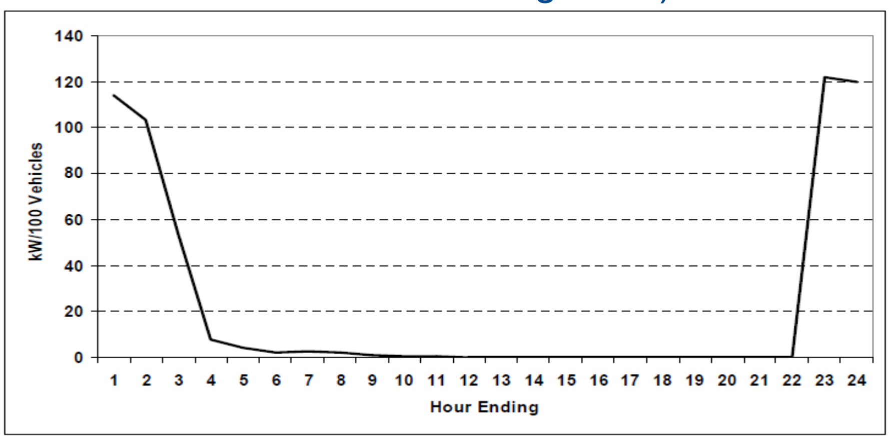

## Real time Pricing with Forecasted and Actual system Load – (one of the PJM region – Aug 1st) 2011




## Delayed EV Charging (Timer Controlled)




## Off-Peak Charging (Utility Controlled requires Smart Grid Integration)



# Energy Storage Devices

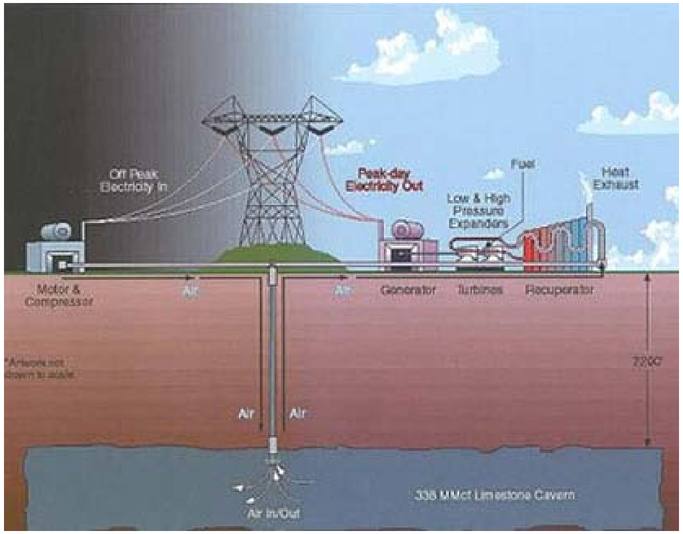
## Commercially Available Energy Storage

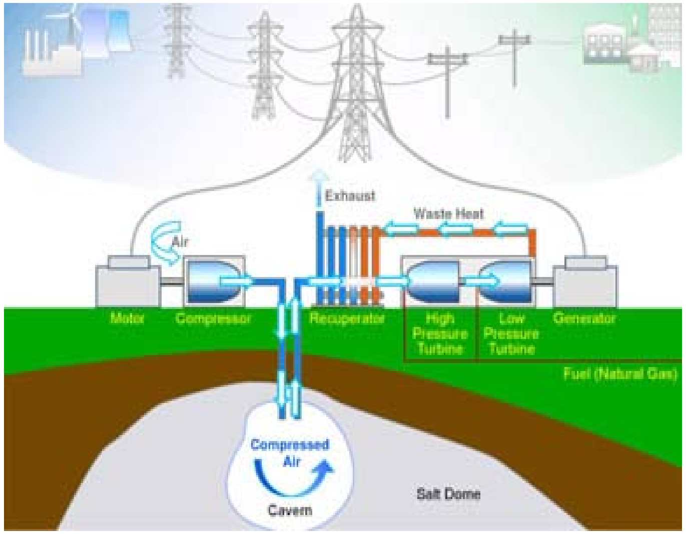
| Technology | Pumped Storage Hydroelectric | Compressed Air Storage (CAES) | Batteries | Flywheel |
|---|---|---|---|---|
| Method | Pump water and stores as potential energy in reservoirs, and spins through turbines to generate electricity | Use electricity to compress air and store air and release into generator turbine to produce electricity | Convert electricity into chemical energy and releases it when needed | A rotating mechanical device that draws power to accelerate in speed and reverse to drive generator when energy is released |
| Storage Capacity | 22,000 MWh | 2,400 MWh | 50-250 MWh | 5 MWh |
| Duration of Discharge | ~12 hours | 4-24 hours | 1-8 hours | <1hour |
| Lifetime | 30 years | 30 years | 5-15 years | 20 years |
| Power Related Cost | $600/kW | $425-$480/kW | $200-$300/kW | $300/kW |
| Energy Related Cost | $0-$20/kWh | $3-$10/kWh | $175-$250/kWh | $200-$300/kWh |

# Energy Storage Devices

## How Energy Storage Can Help

- **Load Leveling /Peak shaving**– store excess energy by shifting energy demand from off peak hours to peak hours to reduce the demand/demand charges. (similar to load leveling).
- **Ramp Rate from Renewable Sources** – storage with the help of power factor absorption can alleviate.
- **Voltage regulation** – energy storage can help maintain a stable voltage output.



# Energy Storage Devices