

Can we dream of 50% of India's Power in 2030 from Solar PV? Decentralized Approach: Game changer

Technology Day, IICT Hyderabad

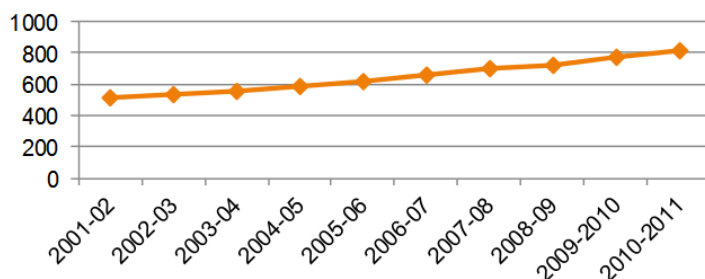
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As India's Economy continues to grow

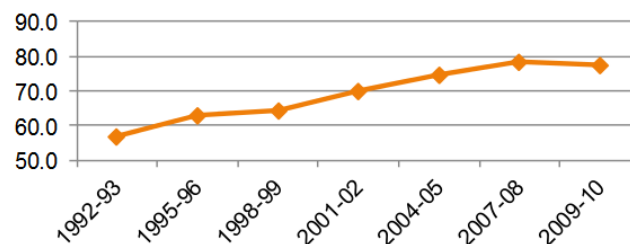
- India's average GDP growth during 2006-09: 8.6%
 - 7% world's GDP with 17% population
 - Increasing demand for energy from a low base
 - But **affordability is the key**: solutions that sell in india have to be at Indian prices
- Generation capacity continues to increase
 - Keeping pace with country's rapid (8 to 9%) economic growth

| Consumption | India | World |
|-------------------------------|-------|-------|
| per-capita electricity (kgOE) | 704 | 2752 |
| average energy (TOE) | 0.53 | 1.82 |

Energy Generated (BU)



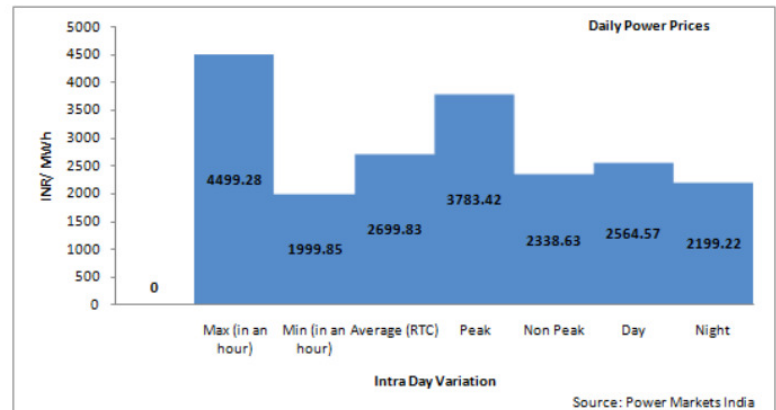
Plant Load Factor (%)



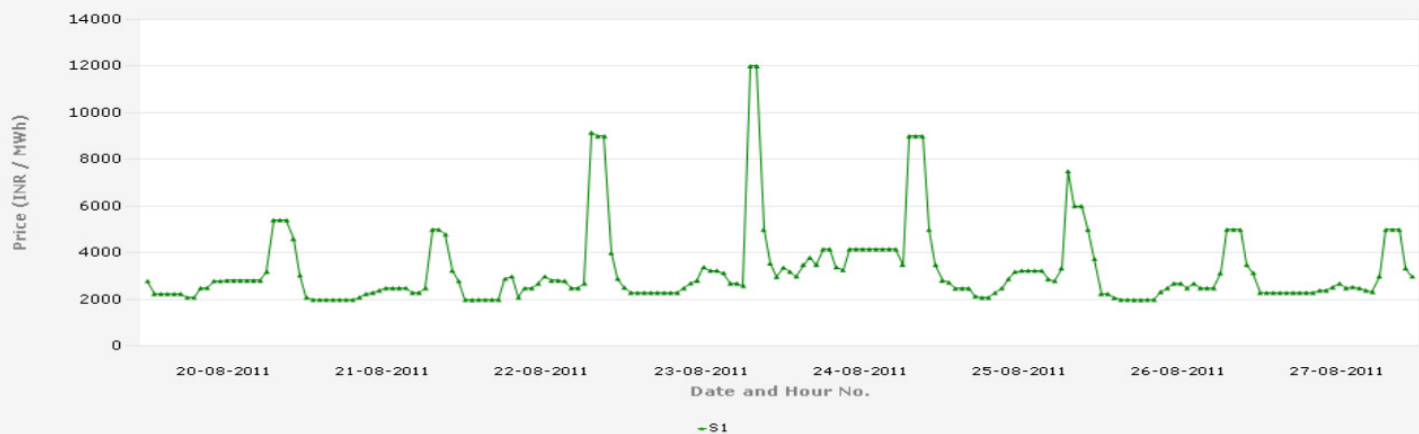
- Even Plant Load Factors have also continued to increase along with generation
 - Plant load factor still low

India's Real Power Deficit

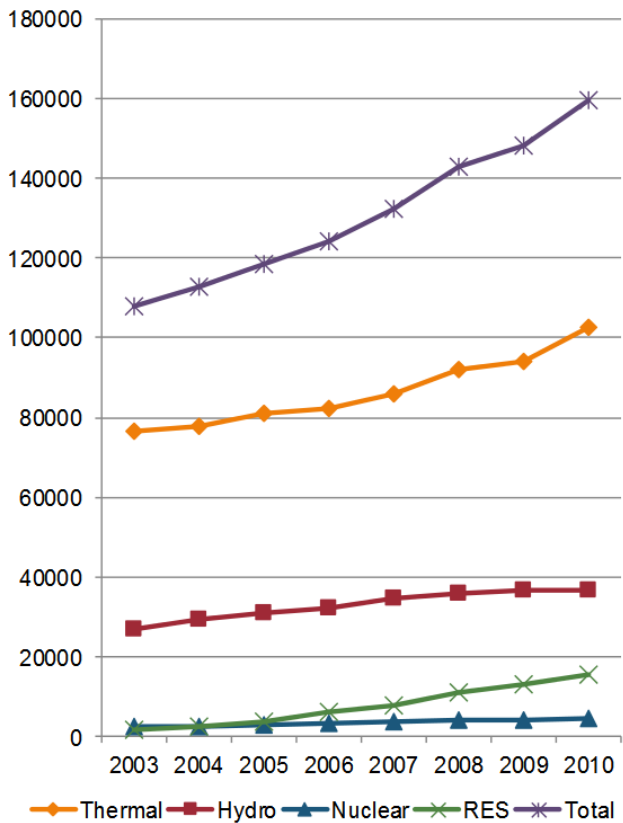
- Huge power shortage during peak hours
 - As evident from the fluctuating prices at Power Markets at source
 - Day variation of Rs 2 to 4.5 per unit
 - Prices vary from Rs 2 to 12 per unit in one week
 - About 50 to 70% needs to be added to the price to account for T&D and operation costs



Prices at Indian Energy Exchange (IEX) INR / MWh



India's Fuel-wise Generation-Capacity (MW)



- **Coal: good for base-load**
 - significant domestic reserves
 - proven reserves of 105 billion tonnes
 - could last 200 years at current production level
 - Not good for environment
- **Natural gas share up from 4.4% to 10% in last 15 years**
 - emit half as much CO₂ per kWh as compared to coal-based plants
- **Hydroelectric potential of 600 billion kWh per annum**
 - Capacity of 148.7 GW
 - only 23% realised so far
 - High initial costs and developmental risks
- **Nuclear: small**

Is there a solution?

Commercial Power Options

- Grid: Rs 5 to 9 per kWh: **ram-bharose (as per god's will)**
- Diesel generator: Rs 23 per unit when at 80% load: **instantaneous**
 - at 40% generator load, costs goes up to Rs 35 per unit
- Electrical battery back-up: storage costs over Rs 12- 15 per kWh
- Solar PV: under Rs 5 per kWh when dc is used: **day time only**
 - Conversion to AC may add Rs 1 per unit; land may add ???

Solar PV power price at DC level

Lead acid battery

| | |
|------------------------|--------------|
| Battery cost (per kWh) | Rs. 6,000.00 |
| discharge | 40% |
| Number of cycles | 1500 |
| interest rate | 14% |
| cycles used per day | 1 |
| Losses | 10% |

| | |
|--------------------------------|---------------|
| Battery cost (to deliver 1kWh) | Rs. 15,000.00 |
| depreciation (years) | 4.11 |
| Storage cost per unit | Rs. 15.35 |



But can DC be used?

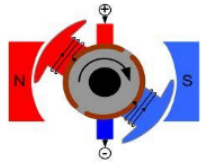
- **Lighting**

- CFL is four times more energy efficient than tungsten bulb and neutral to AC or DC
- LEDs, 4 to 10 times more efficient than CFL, use only DC power



- **Motor: small BLDC motor 2 time energy efficient as compared to AC motor**

- Historically brush replacement needed – but not anymore
- A fan is primarily a motor – a dc fan also allows better speed control
- A refrigerator is essentially a motor
- An air-conditioner has a motor (even-though it involves cooling)
- A washing-machine / grinder is a motor



- **Electronics: all electronics (mobiles/TV/Computers) use low voltage DC**

- Need an ac/dc power adaptor to charge



- **World switched to AC primarily for transmission of power**

- Any ac / dc conversion or vice-versa implies 7 to 15% losses

Has time come to switch back – at least at customer's premises?
solar can then be used directly in buildings

Four Sectors

- Homes
 - Offices and Commercial buildings
 - Agriculture: mostly pump power
 - Industry
-
- To get 50% power from solar, one has to impact all these sectors

Solar DC Homes

- **A large political dilemma**
 - **Tariff increase adversely affects low-income families**
 - **Subsidized tariffs make state electricity boards unviable**
- **How does incentivize home owners to use solar and DC?**
- **Supply a fixed amount (say 100W) DC power at subsidized rate**
 - AC power at market rate
 - On top of it, make DC attractive **as uninterrupted power**
 - whereas AC power supply has power-cuts when there is load-shedding
 - **But what can 100W DC power do?**
 - Three LED light + 2 DC fans + mobile / tablet / laptop charger + LCD TV (with 1 fan)
 - Will encourage use of DC devices
 - Residents can supplement DC power by adding 200W solar and a five hour battery at around Rs15000
 - Will enable a few more devices to be connected
- **Will result into efficiency + solar + viable EBs**

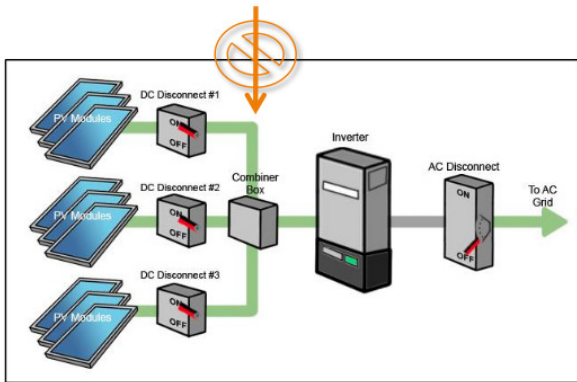
Commercial Buildings: Decentralized Solar PV



- Would be ideal in day time: complement grid
 - Direct usage in offices / shopping malls can reduce the **day time peak load**
 - Makes economic sense today, provided there is space for solar PV installation
 - **Natural Load – demand match for cooling**
 - no additional land cost; T&D losses controlled
 - **Gradual shift to DC usage** will add cost and energy-efficiency
- What about **evening peak loads**? Solar can not help
 - Reducing consumption by **introduction of time of day metering**
 - Can one start and close office early!!
 - Reducing load by enhancing efficiency
 - Using some storage

Solar Deployment for peak shaving

Grid Connected Solar Inverter with MPPT
DC and AC Disconnect Provisions



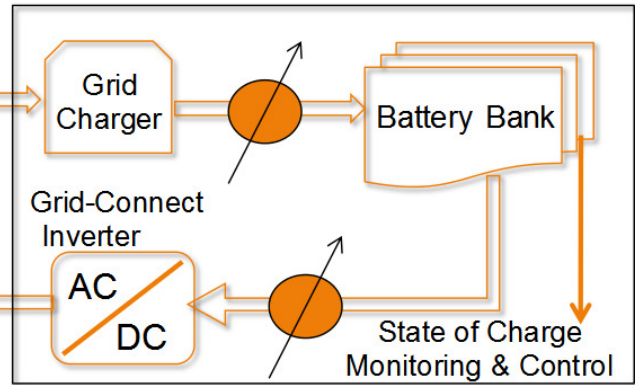
Electrical Load
with Load Control



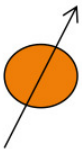
Smart controller for peak shaving – DG turn ON/OFF, battery charge / discharge current, **Load control**



DG with ON/OFF Control



Battery (controlled charge and discharge control)



Solar powering of Agricultural Pumps

- Significant savings possible of subsidized electricity
 - Important that it is **not subsidy driven** but push towards making it commercially viable for farmers
- Current pump-sizing determined by 1-2 hour power availability
 - Solar Agricultural pumps could be run for 10 hours
 - Need much smaller sizing pumps : will pump required water
 - Would reduce solar array size
 - Minimize costs as well as **minimal shaded agricultural land**
- Solar water pumps along with **drip-irrigation desirable**

Industry

- Still in the works
 - Solar generation on roof can certainly play a role
 - Use of DC lighting will help
 - Some of the motors can become more efficient...

TASKS AHEAD

Start implementing use of solar PV at homes, offices, agriculture

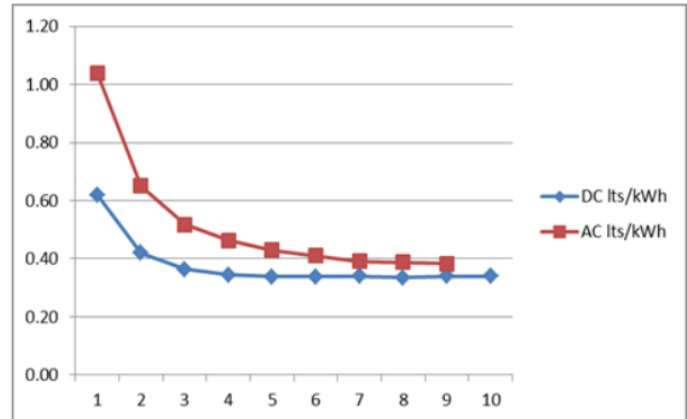
Need Intensive R&D

- Solar panels: leverage world's availability
 - Continuously evolving technology
 - Need R&D to catch up with the world
 - Manufacturers willing to set up solar cell manufacturing in India
- Power Electronics, smart controller, combining grid-solar-battery judiciously, system design, protection
 - India has the ability
 - Need focused work
- Storage
 - Research needed on new electrical batteries
 - Storing energy in other forms: for example heat / coldness storage

DC Sources and Loads

- Diesel generator generates 3 kWh of power per litre of diesel

- only if generator works at 80% load
 - efficiency drops with lower loads
- Not so with **DC diesel generator**
 - May be ideal as evening solution in absence of battery / grid



- **DC Motors**

- BLDC motors for all kinds of applications
- Ferrite and Rare-earth Magnets: efficient power-electronics

- **DC Powered Air-conditioners**

- Solar PV with MPPT and VFD driving
 - New Power electronics and robust motor required
- New type of air-con with energy-efficient DC motors (BLDC or SRM)
 - consumption of 55-60% of regular AC (but 30% more expensive)
 - when sun is brightest, it is expected to be hottest and vice-versa
 - Natural Load – Demand Match

- **Also DC Powered Air-coolers**

DC Sources and Loads

- **DC Powered Cold-Storage:** Technology and Economics
- **Solar Agricultural Pumps** (10 million)
 - Water can be pumped when sun is there
 - More water when sun is strong; during rainy seasons, lesser requirement of water: natural Load-demand match
 - Efficient power-electronics for solar PV to directly drive pumps
- **DC Fans and Lights:** costs and availability
 - Need to figure out right DC voltage
 - Wiring losses: Can they use existing wiring harness? Speed / brightness control
 - DC power protection; earthing
 - Minimize dc-dc conversion – losses and costs
 - Design and proliferate SME for manufacturing and distribution
- **DC Powered-Electronics**
 - What should be the right voltage? Standards?

Work on alternative storage

- Flow-battery may be answer to storage
 - Work required on Redox flow-battery to make it inexpensive
 - Vanadium or Zn- Bromide Redox-flow battery
- Is it possible to store heat / coolness
 - Can even generate during off-peak hours and use it during peak hours.

Policy Issues

- Long-term financing of decentralized solar panels at lower interest rate
 - Such Solar panels should be included in Priority-sector lending
- Subsidy
 - Should enable early commercial viability, rather than making subsidy and end-game
- Time of day metering
 - At least for commercial and industrial load for day time peak
 - Evening peak also to be priced high so as to shift power usage pattern

To sum-up

- Solar PV today is a god-sent opportunity for India
 - A year to two of work can make solar power work for us – dc power usage will help
 - at least in the day time; **storage solution will be another game-changer**
 - Use as much natural load-demand match at possible
- Smart-grids for India
 - Key is to match load with available power
 - At local-level as far as possible – if necessary by selective power-shedding
- Number of technical challenges need to be overcome
 - System design issues are critical
 - pilot deployments are key to prove viability
 - Early pilots are three to four months away
- Policy actions to promote solar PV – instead of subsidy
- One can dream of getting 50% of India's power requirements using **solar PV by the year 2030 or so**
 - Can transform India