

# Scaled adoption of DC power-line in India

## Homes, offices and village micro-grids

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# In first week of December 2015

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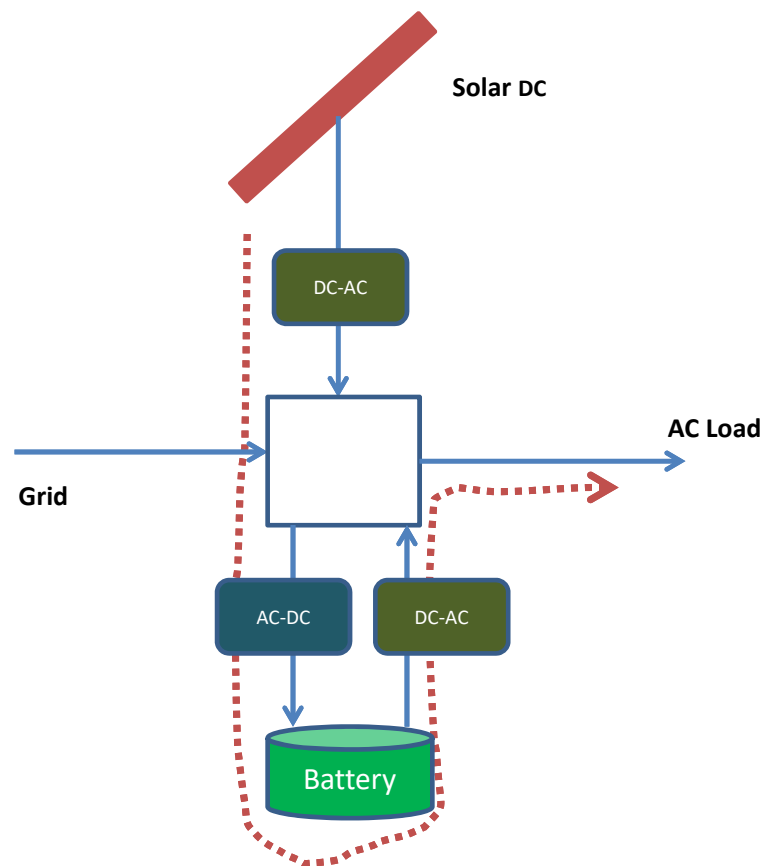
- When whole of the Chennai city had no power for 75 hours
  - Even 1 MW solar plant at IITM failed to provide any power
- There was one home at IITM which continued to have lights and fans and cell-phone / lap-top charger
  - 125W solar panel + 0.5 kWh of battery
  - Two tube-lights, a bulb and a fan + laptop and cell-phone charged some 15 times
  - Fails to add up
- Solar DC Inverterless
  - Full DC wiring, all Loads DC, solar and battery connected on DC line, input grid power converted to DC

# But AC Power won 125 years ago!

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- In an **AC Vs DC** power-line debate between **Tesla** (for AC) and Thomas **Edison** (for DC) in 1880's
  - AC won decisively due to **transformer's** ability to step-up and step-down voltages easily
    - And reduce line losses
- **AC dominated** ever-since
  - Transmission lines became all AC
  - Homes and offices were wired on AC line (230V AC in India)
  - All appliances became AC
  - All R&D focused on AC: **R&D on DC virtually stopped**
- So why are we talking about DC today?

# Decentralised Solar Power at Homes



- Solar PV gives DC Power
  - But load is AC
  - Needs a DC-AC converter
- Now if we add a battery
  - Battery stores only DC
    - Require an AC-DC converter for charging
    - Require a DC-AC converter during discharging
- For *low power (say 100W)*, each converter can have **10 to 15% loss**
  - Solar with battery may have up to 45% loss + battery loss

# And it gets Worse

- As one realises that home-loads have been slowly **moving towards DC**

Fans	AC fan	BLDC fan
At full Speed	72W	30W
At speed 1	60W	9W
Lighting	CFL Tube light	LED tube
At Max. Intensity	36W	15W
At Lowest Intensity	NA	4W

Volume prices  
similar for fans

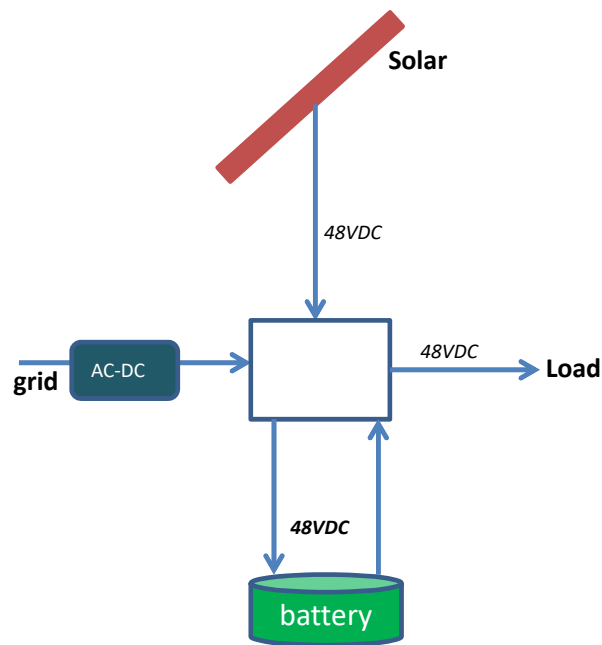


LED tube life much longer (DC  
powering enhances reliability)

- All Electronics devices work on **low-voltage DC**
  - TV (LED/LCD), laptops. Cell-phones, speaker-phones, tablets, speakers
    - AC to DC conversion has losses from 20% to 50% in each device
- Even the refrigerators, air-conditioners, washing machines are now using BLDC or SR motors
- DC-powered DC-appliances are energy-efficient
  - Consumption **down by 50%**

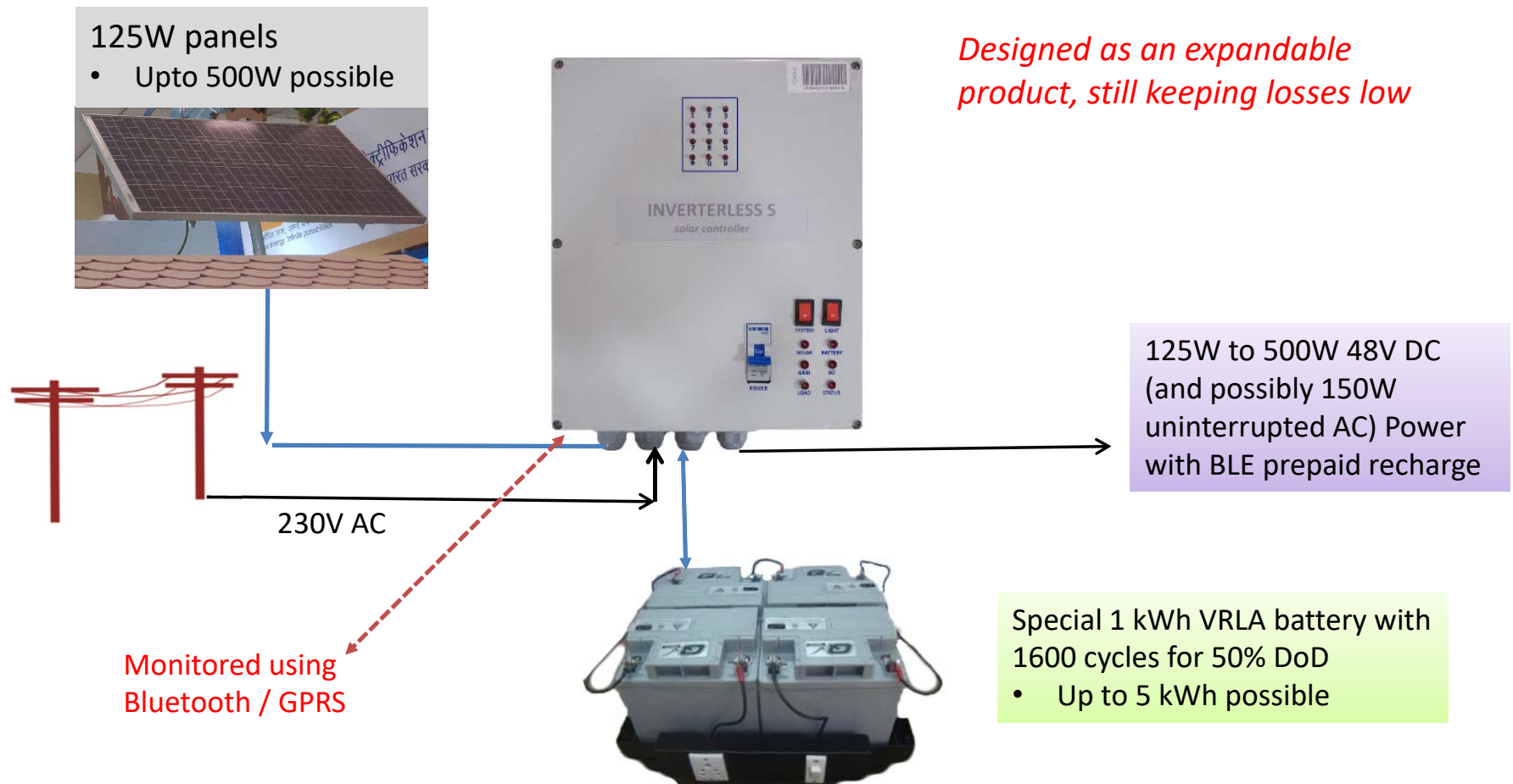


# *Are we ready to take a leap* and move to Solar-DC



- DC Micro-grid connecting
  - Solar Panel
  - Battery
  - DC Appliances
- **Highly efficient usage of Power**
  - Low-power from grid alone converted from AC-DC
- 48V DC chosen due to
  - Safety considerations
  - Lower cable losses compared to 12V/24V DC systems
- **But design non-trivial**
  - Solar MPPT voltage varies
  - Battery needs independent charge voltage
  - Load is at some fixed voltage
  - DC-DC converters will add similar losses

# DC Microgrid for home: Solar-DC Inverterless



# And worked with start-ups to build Appliances



## LED Bulb

- 5W instead of 30W bulb



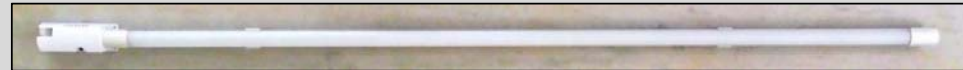
## Cell phone Charger/Socket

- DC charger with USB port



## BLDC Fan

- 30W instead of 72W AC fan
- 9W at lowest speed



## LED Tube light

- 15W - dimmable to 4W, instead of 36W fluorescent tube



## Remote Control for Fan & Tube light

- ON/OFF and for dimming

*Cost: ₹20000 for 125W SP + 1 kWh Battery+ appliances*

# Energy-efficient DC appliances being expanded



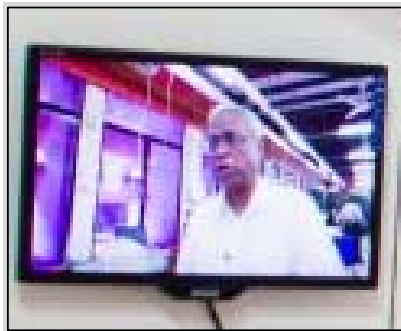
## **DC Desert Cooler**

- Consumes 120W instead of 180W AC cooler



## **DC Mixers**

- Consumes 150W, whereas AC Mixers consume 350W



## **DC-powered Colour TV**

- Consumes 30W along with set-top box

## **Butter-churner and atta-chakki, sewing machines, roti-machines**

- getting ready

## **Refrigerator, charkha and Stove**

- Still experimental

# Solar-DC deployment in 15000 homes

- Electrified 4000 off-grid homes in Jodhpur and Jaisalmer districts of Rajasthan
  - Tough terrain, no road connectivity, sandstorms, lack of local resources
- 7500 homes in Assam being taken up in hills
  - 12000 more homes being take up



# Other 48V DC deployments

- 12000 DC homes in Bihar through grid
- 10000 homes in Assam through grid
- **Grid-connected** solar-DC installations in states of Orissa, Karnataka, Tamil Nadu, Telangana, Andhra, where power cuts exceed 8 hours /day
  - 215 homes in Belagavadi, Karnataka
  - 380 homes in Devarakonda, Telangana
  - 27 installations in Trichy, Tamil Nadu
- Solar-DC off-grid deployments
  - 87 homes and a school in Trimal, Odisha
  - 20 homes in Kundithal, Nilgiri Forests, Tamil Nadu
  - 30 installations in Irukkam Islands, Andhra Pradesh
  - 28 installations in Sudhuktha thanda, Vikarabad, Telanga



# Polytechnic students learning how to deploy



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# Changing lives in deserts



IEEE awards solar-DC as 2017 Technology of the year in service of humanity

# Villagers thrilled

- *“Apne Vidyarthiyon ko ghar ka kaam dene laga hu. Khush hu ki is baar garmiyon mein bhi bachhe mann laga kar padhai karenge.” [now I give my students home-work. Happy that even in summer they will now be able to study]*

- Masterji

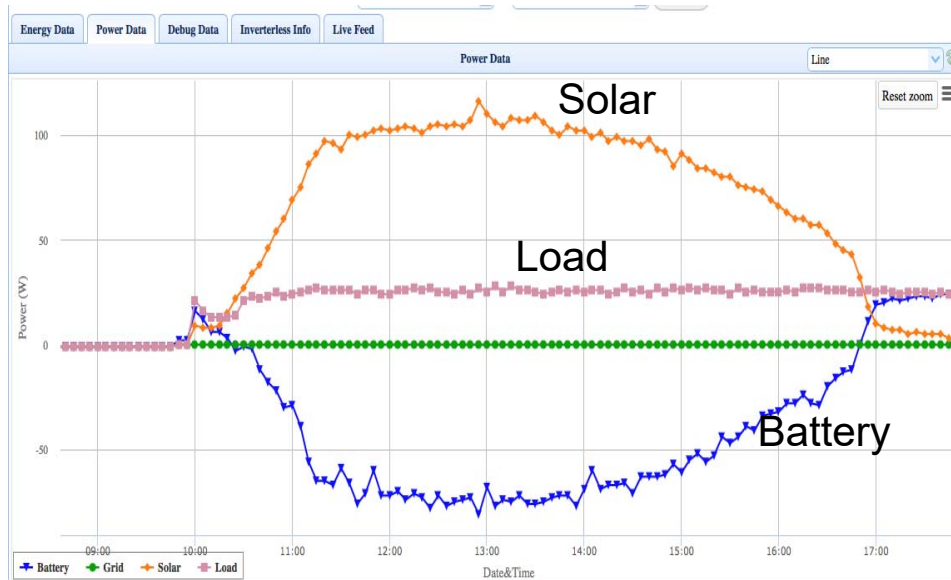
- *“Sab ko utshah se apne ghar ka Solar system dikhata hu ji, hamare ghar mein bhi pankha, light aur remote hai” [show my solar system to everyone at home. Have fan, light and remote]*

- Dunga Ram

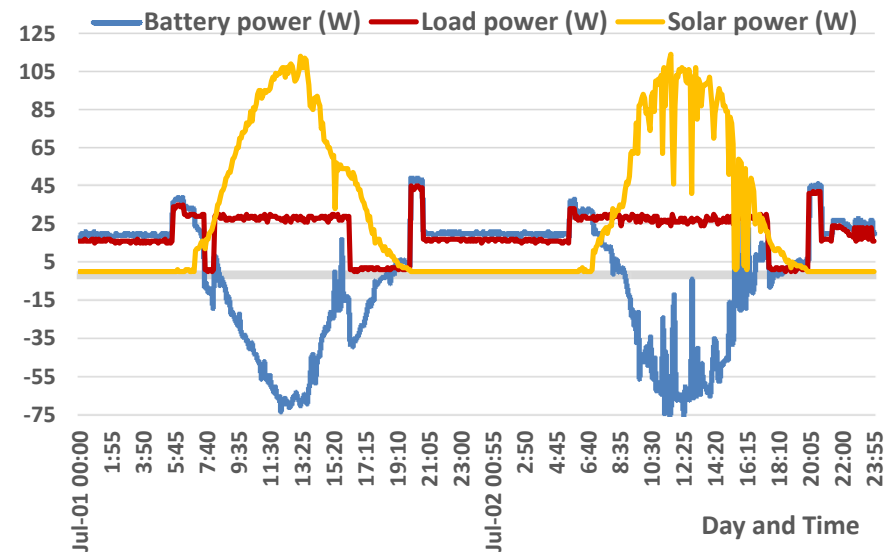
- feedback: <https://youtu.be/NF6EgdRsBXk>



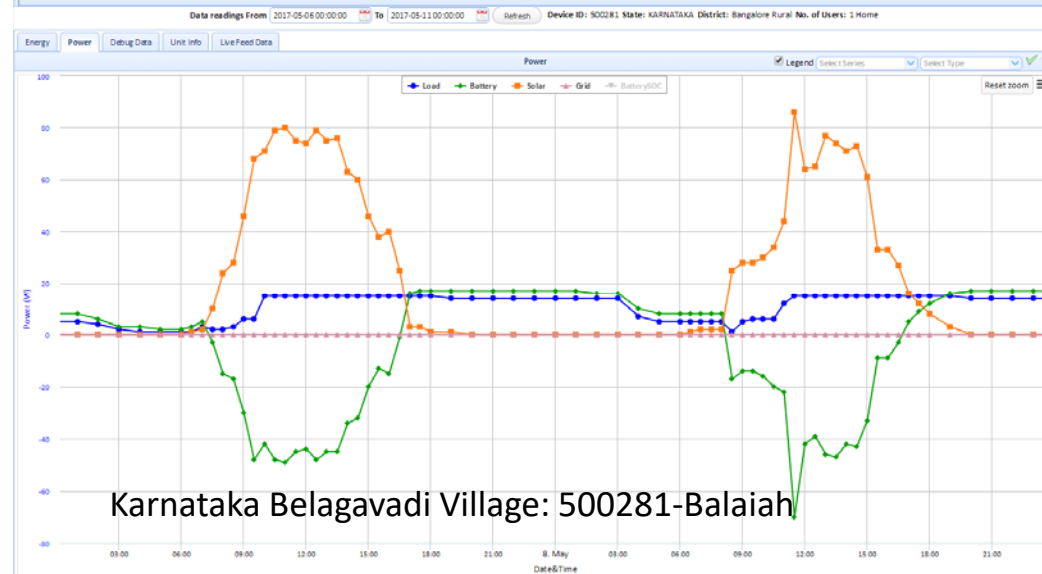
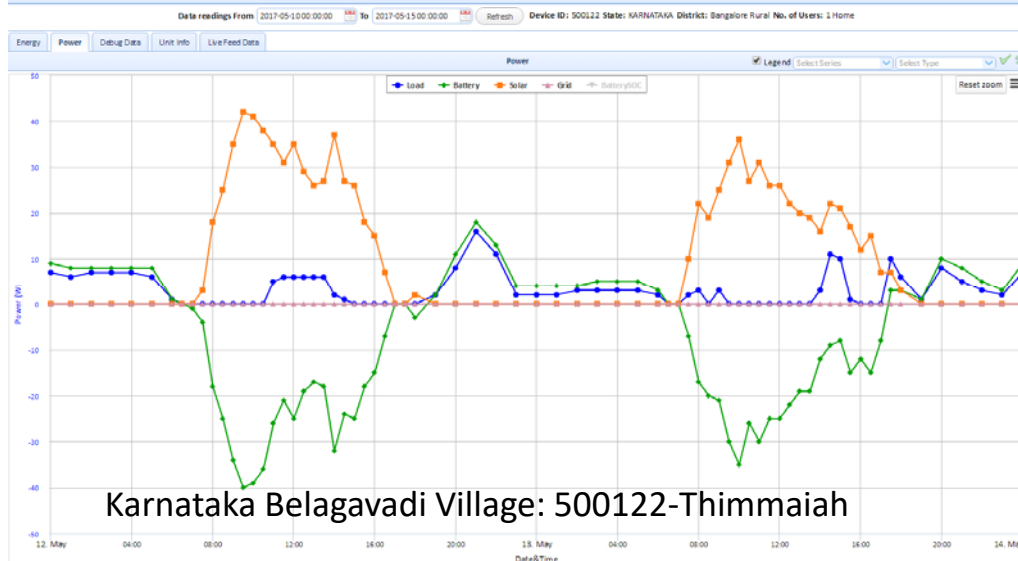
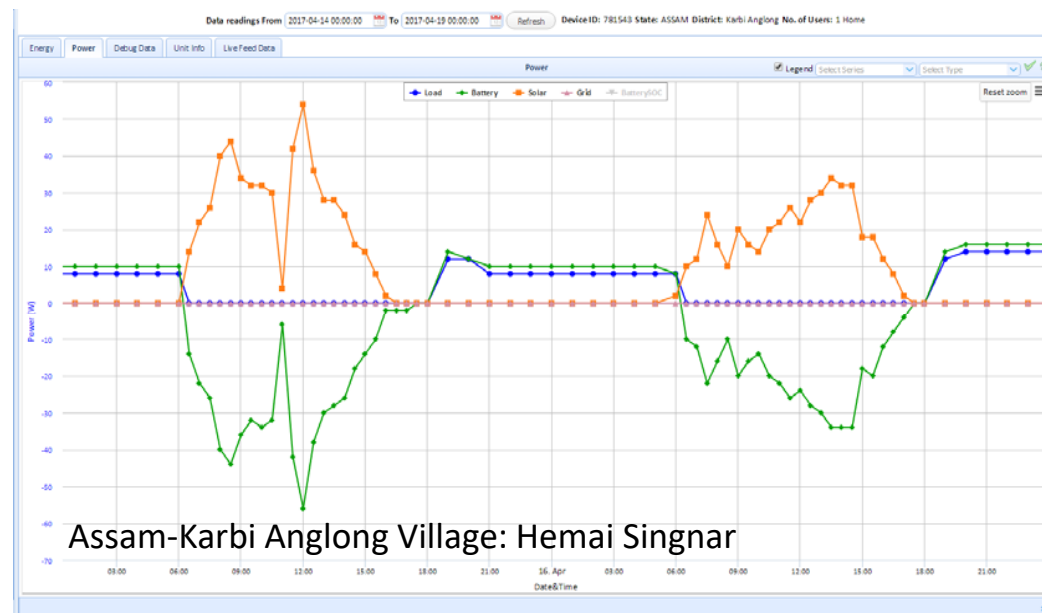
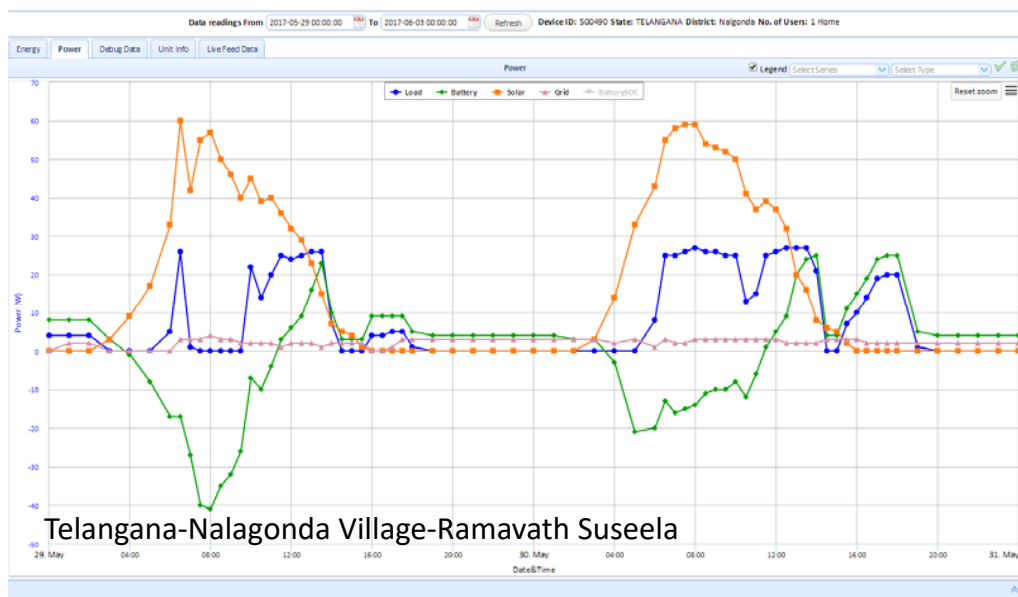
# Monitoring to ensure health



Measurements from a home in Bhom Ji ka Gaon, Jodhpur from 9am to 5pm



- Understanding use of **solar Power and losses**
- Is customer using more than what solar provides? Is she using less? Is power being **wasted**?
- Grid-power usage to **be minimised**



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16

# But what can one do with 100 Watts?

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- 100 Watts DC: Can support 3 lights + 2 fans + cell-phone charging
  - Or 3 lights + 1 fan + TV (24" LED/LCD) + cell-phone charging
- Equally important for grid-connected homes: huge cost savings
  - Draws less from grid: reduces power-bill
  - Provides back-up power: frees homes from load-shedding, grid-fault
  - Enables decentralised roof-top solar to become affordable
- 500W solar power (50 sqft) with DC appliances can take care of most essential loads in middle class homes
  - Except washing machines, air-conditioners
- 240M homes with 500W solar panel produces close to total domestic consumption in India in a year
  - $240M \times 0.5 \text{ kW} \times 1550 \text{ solar hrs/year} = 190,000 \text{ GWh /year}$



# Small AC / DC Home Power Costs

Device	Numbers deployed	Operation hrs/ day
Tubelights	2	6
Fans	2	12
Bulbs	2	10
Phones	1	4
TV	1	10

Cost / day includes depreciation and interest for solar panel and battery assuming grid costs of ₹5 per unit

	AC Home		DC Home	
	Energy/ day kWh	Cost per day ₹	Energy / day kWh	Cost per day ₹
AC Grid + 0 LS	3.27	16.3	1.29	6.45
AC +Battery + Solar + 4h LS	3.75	28.9	1.35	7.3
off-grid + Battery + Solar	4.9	50.6	1.33	12.6

Off-grid home power-costs with solar-DC (₹12.6 per day) less than the cost of on-grid AC homes with no power-cuts (₹16.3 per day)

# Solar-DC: Equally important for grid-connected homes

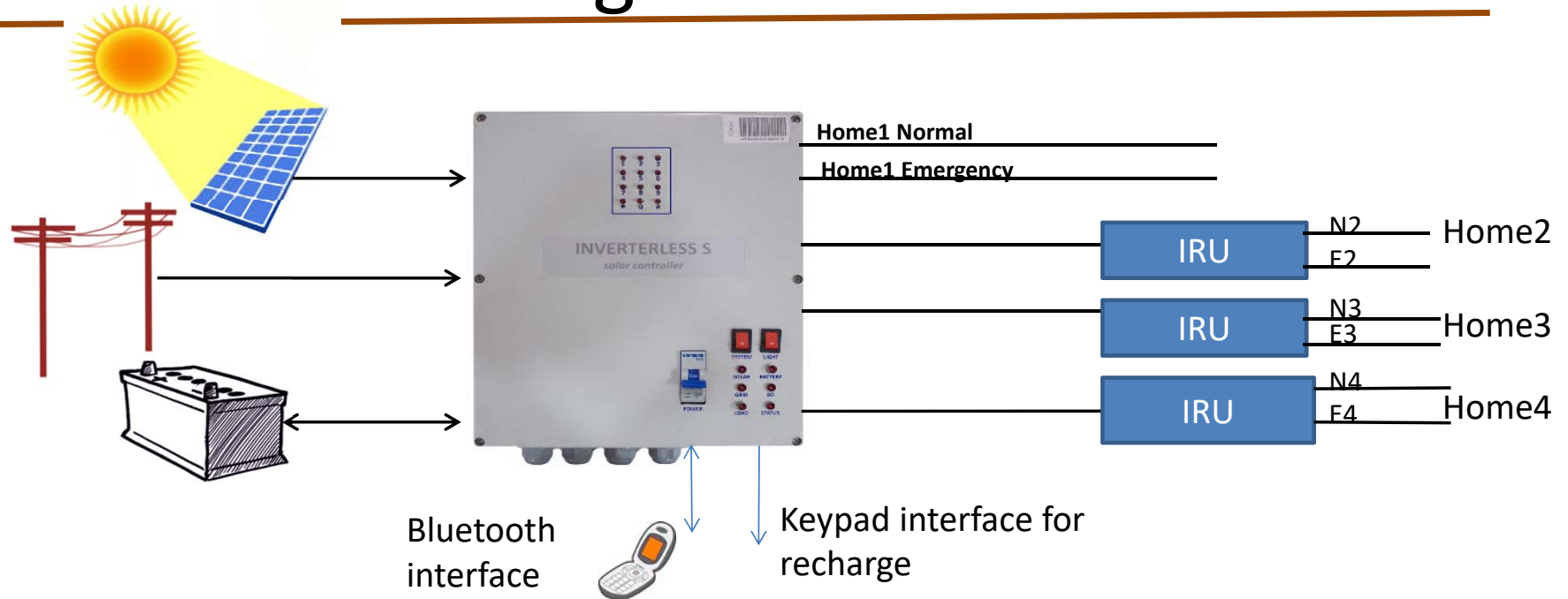
- Solar-DC Inverterless + DC power line + DC appliances: **huge cost savings**
  - Draws less from grid: **reduces power-bill**
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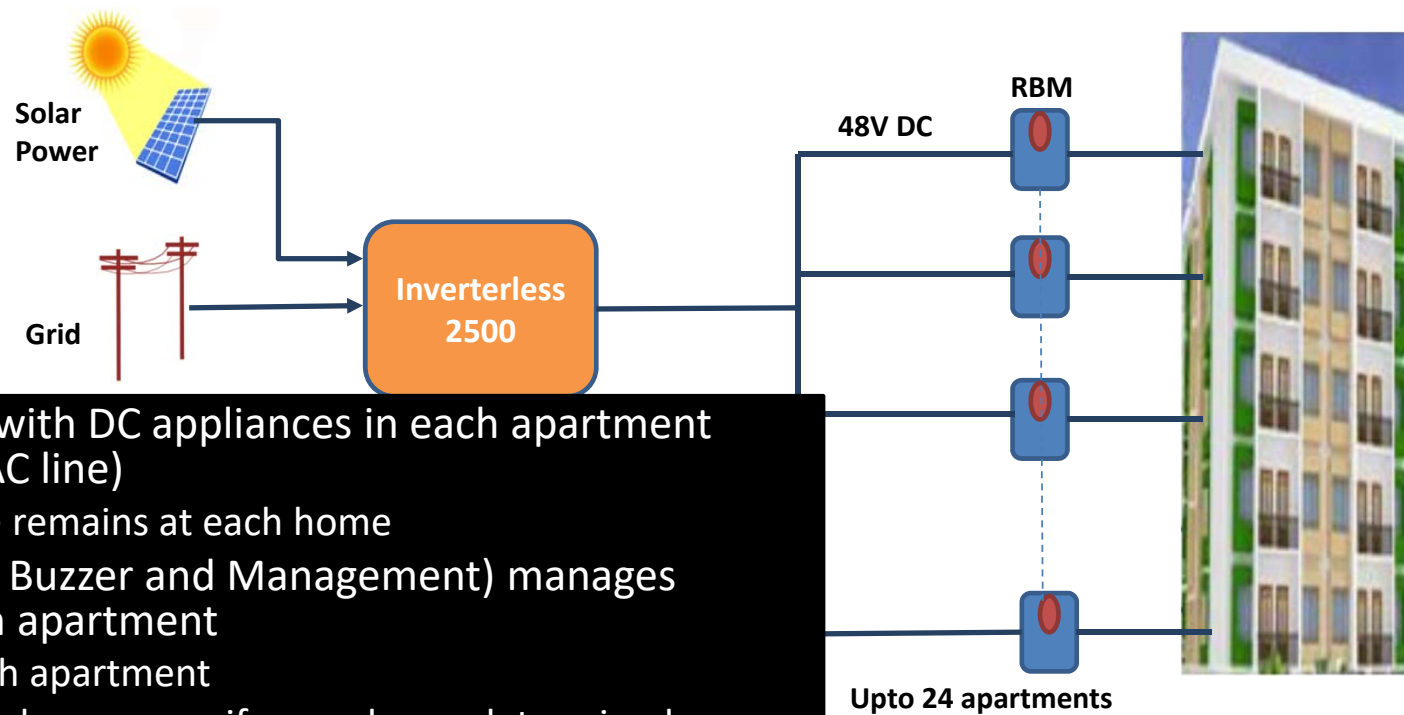
# MULTI-HOME DC MICROGRIDS

# Solar-DC micro-grid for 4 home cluster

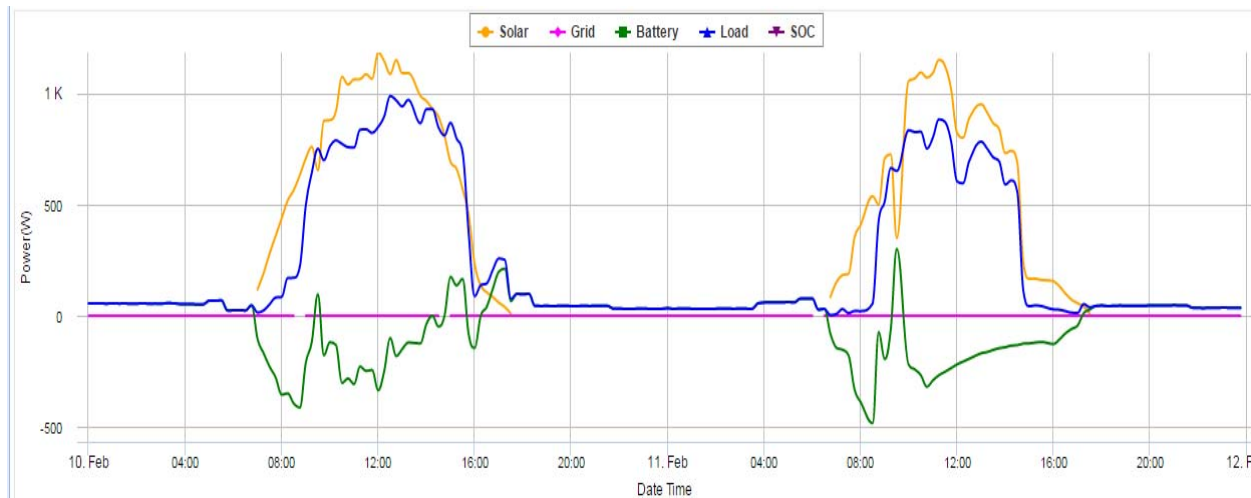


- Enables sharing of Solar and Battery Resources amongst multiple homes
  - Taking advantage of **non-concurrent and unequal usages**
  - each home metered and cut-off

# Solar-DC micro-grid for 12/24 Home Apartment Complex

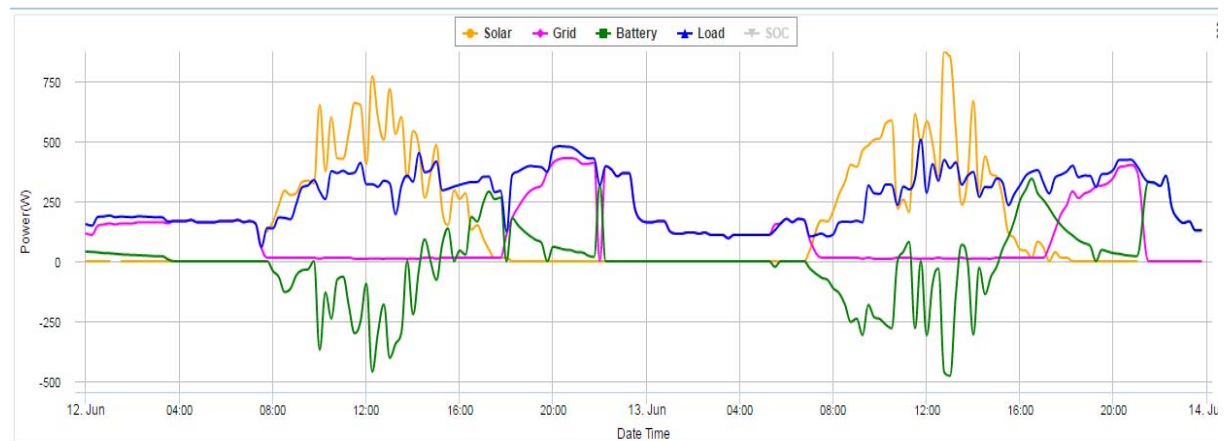


- DC Microgrid with DC appliances in each apartment (replaces 5A AC line)
  - 15A AC line remains at each home
- RBM (Remote Buzzer and Management) manages power to each apartment
  - Meters each apartment
  - Cuts out back-up power if exceeds pre-determined amount
- Can replace generator and provides huge energy conservation and savings



**DC Micro-grid at Govt Girls School, Chennai, solar 1.5kWp, Battery 10 kWh, Feb 2017**

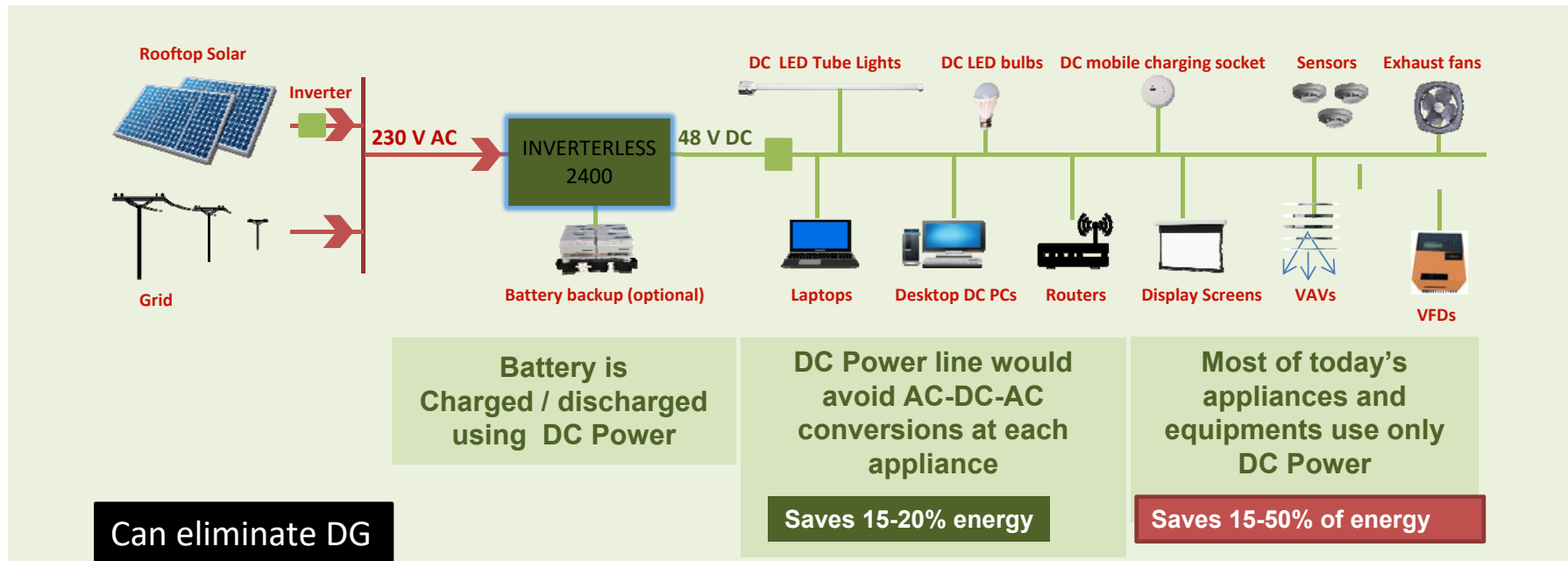
**DC Micro-grid at Police Station, Seliyur, 1.25 kWp solar, 5kWh battery, June 2017**



# DC Power-line can play equally important role

- In Offices, Commercial Complexes, high-rise buildings, hospitals and educational institutes
  - In driving **decentralised solar** to power them
  - Most **loads** have anyway become **DC**
- **Not just** in powering Appliances
  - But also in air-conditioning, cooling systems, lifts and pumps

# Similarly DC-Powered Smart Buildings



APPLICATIONS:



Apartments



Offices



Hospitals

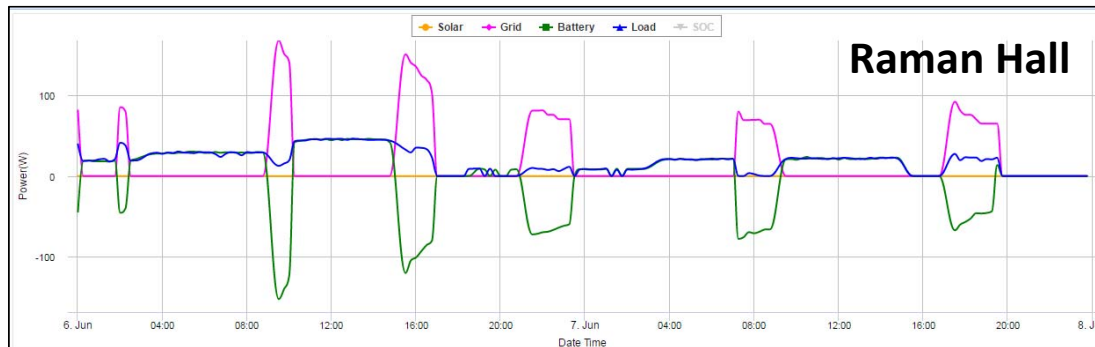
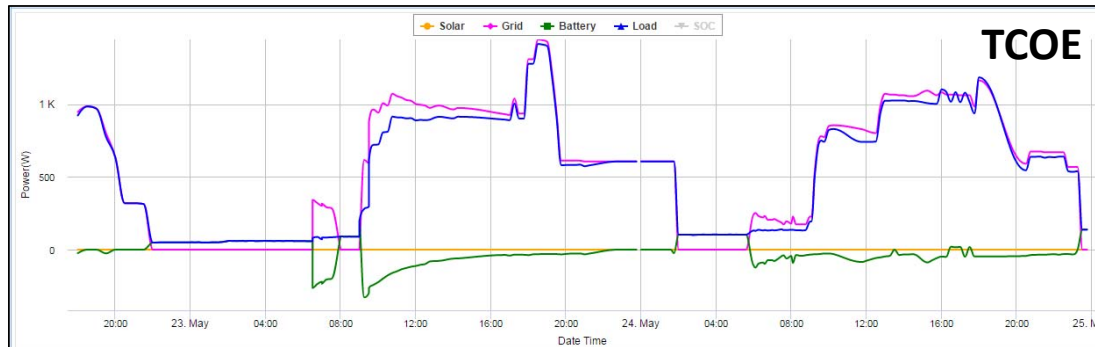


Commercial Complex



Educational Institutes

# DC Micro-grid in IITMRP



800K sq ft building with DC wiring throughout

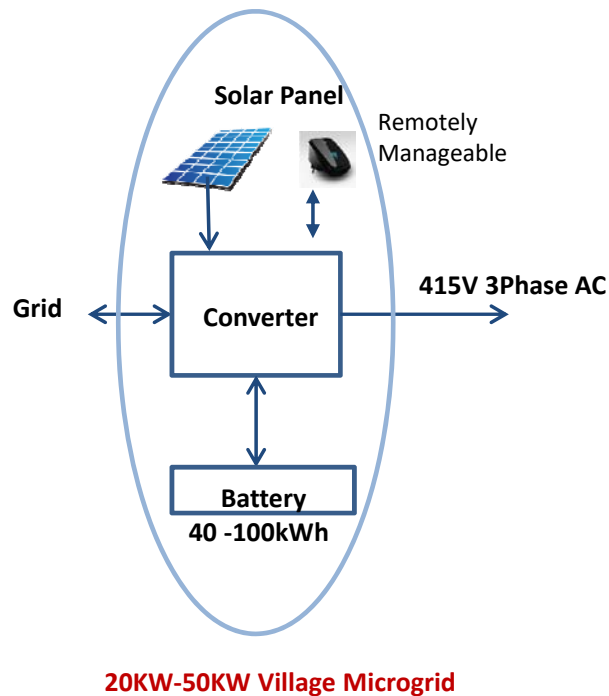


# VILLAGE MICRO-GRIDS

June 2017

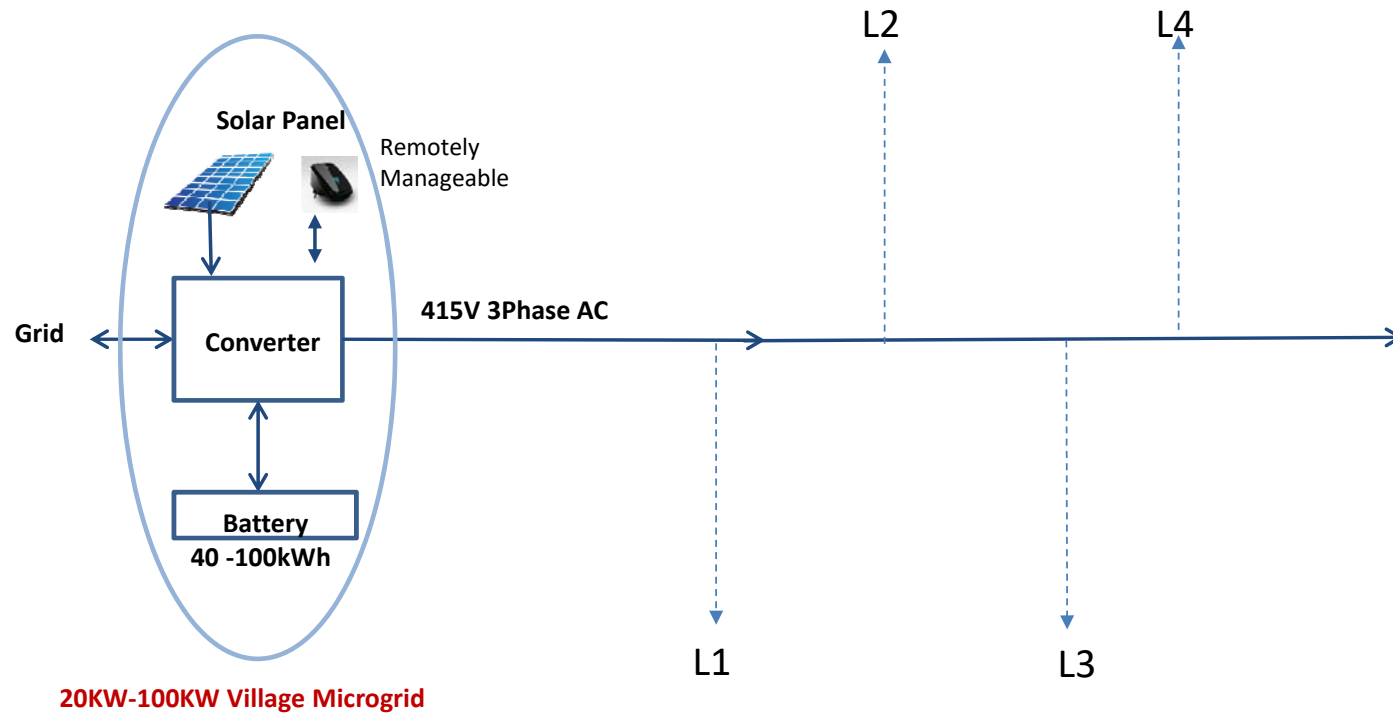
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# Village Solar Micro-grid

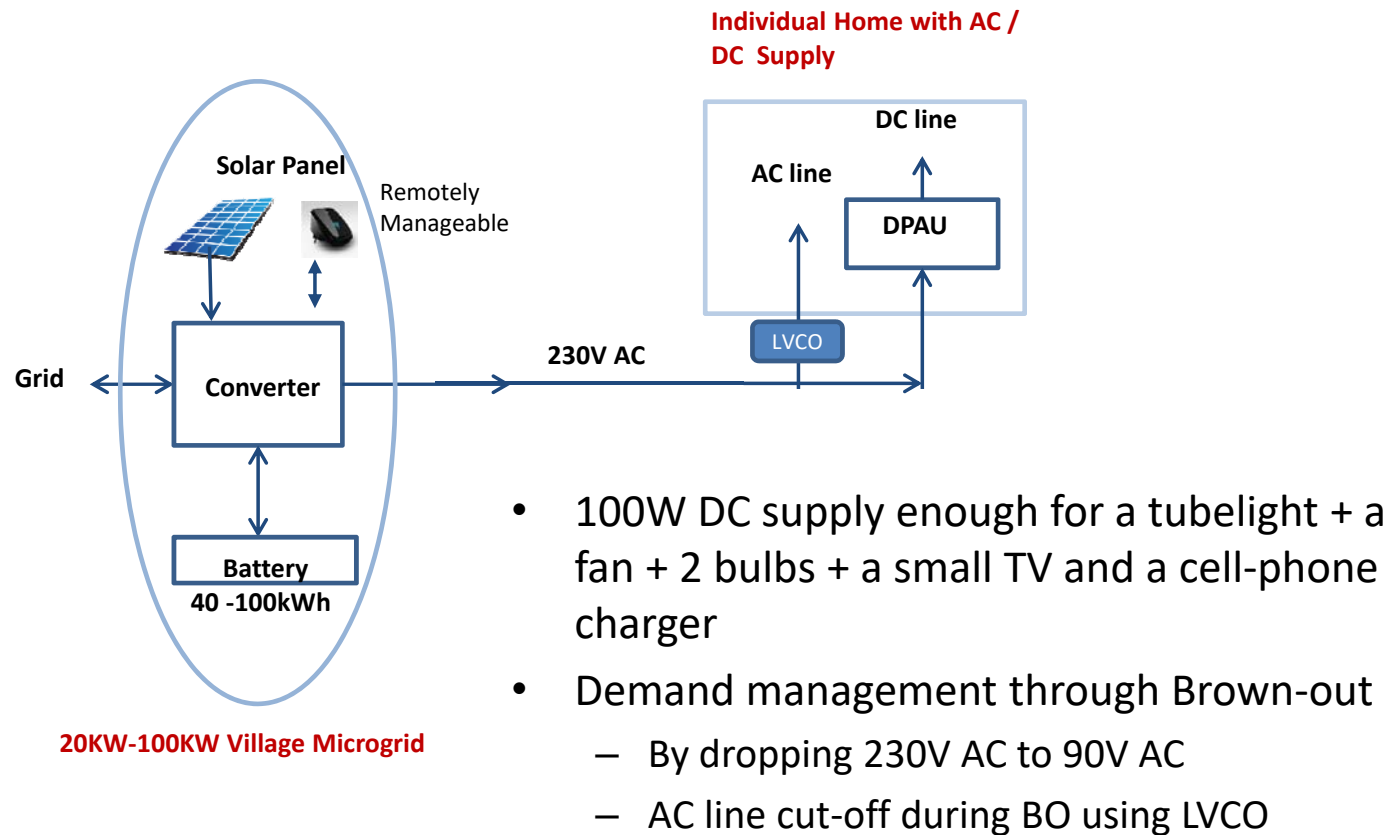


- A village power plant with 20 to 50 kW(p) solar panel
  - With storage of 40 to 100 kWh
  - **Three phase** AC input grid (output of a distribution transformer)
    - With two-way power-exchange
  - Three phase AC output to power village loads
    - Would switch to 380V DC when mature
  - **Remotely Manageable**

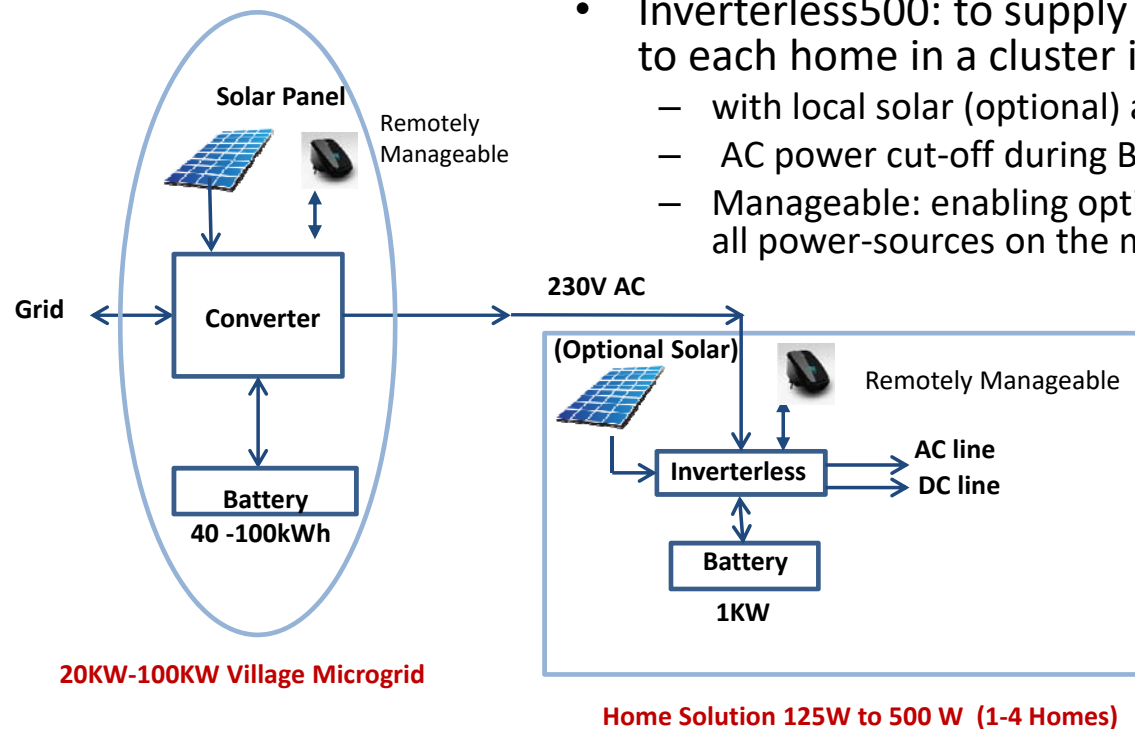
# Driving 4 kinds of Loads



# L1: Homes with AC / DC (100W) Supply

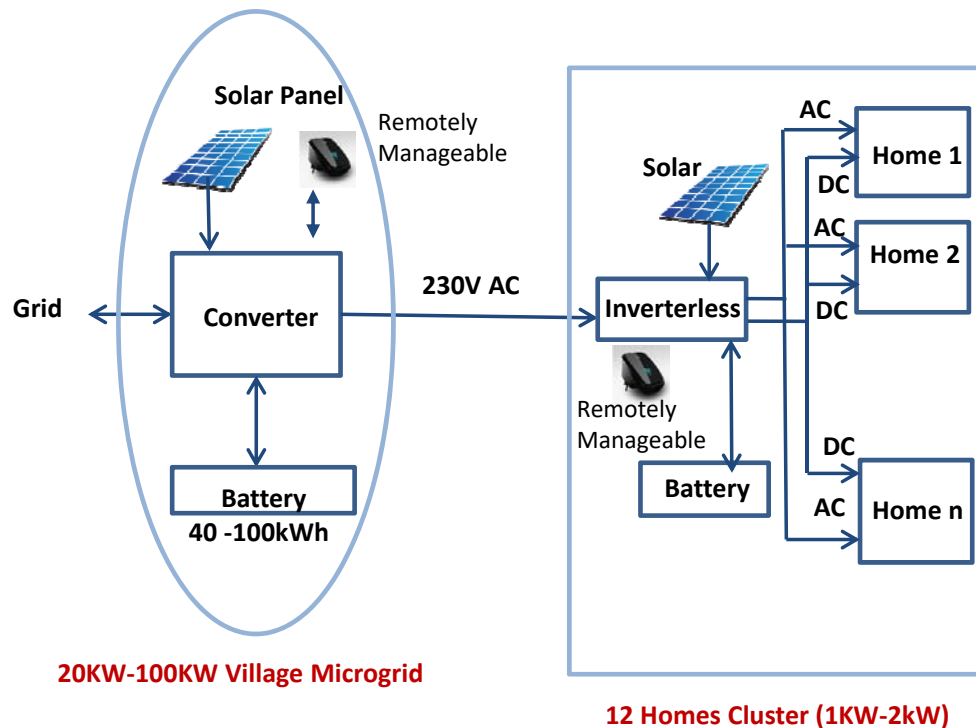


## L2: Homes with AC / DC (100W) Supply



- Inverterless500: to supply 100W DC power to each home in a cluster in addition to AC
  - with local solar (optional) and battery
  - AC power cut-off during Brown-out
  - Manageable: enabling optimal management of all power-sources on the micro-grid

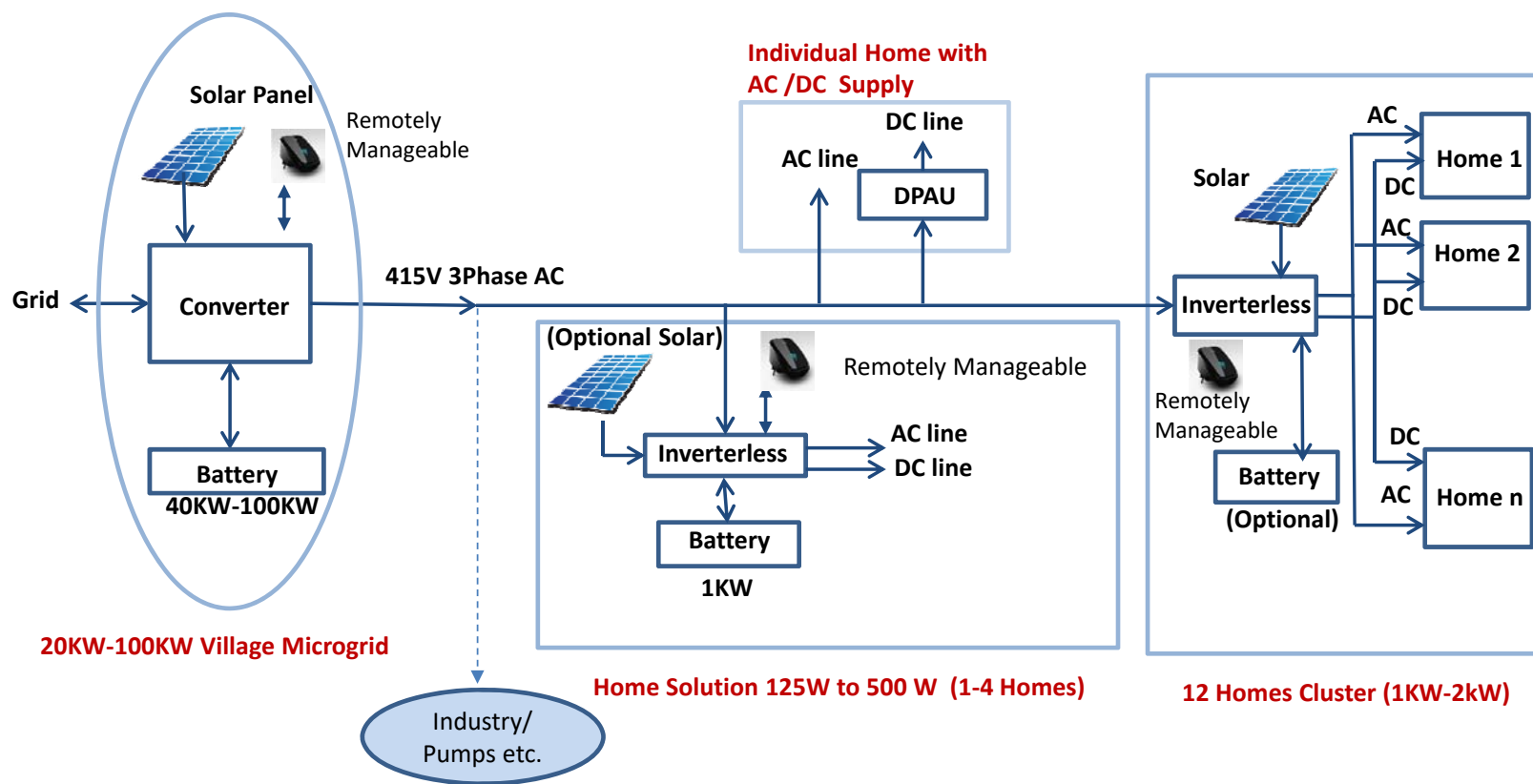
# L3: 12 / 24 home-cluster



- Inverterless 2500: to supply 100 to 200W DC power to each home in a cluster in addition to AC
  - with solar and battery
  - AC power cut-off during Brown-out
  - **Metering and power-control for each home**
  - Manageable: enabling optimal management of all power-sources on the micro-grid
- Highly cost-effective

# Village Micro-Grid: L4 is industry and pumps with LVCO

Joint project with ABB  
in Jharkhand, India



Tomorrow 3 phase AC in grid may be replaced by 380V DC

# Can Solar-DC drive Rural Industry?

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- Lack of **quality power** a big bottleneck for rural industry
- Electricity in most industry is **motor-centric**
  - Use of Brushless DC (BLDC) Motors or better still Switched Reluctance (SR) Motors could reduce power requirement by 30 to 40%
    - SR motors in volume not expensive
  - Can be driven by solar power / grid / stored power
  - Can make the whole system become **affordable**

# Solar Water Pumps

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- **Agricultural-water** can be pumped throughout the day
  - When sun is available
  - At low power early in morning, peaking at noon and again falling off
  - **Solar-DC** powered VFD driving Induction motor pumps ideal
    - Or solar-driven BLDC or SR motor pumps
  - Water may be stored in a sump and used when needed
- Key is to have low-cost and easily maintainable in rural areas
  - Pump Sizing: pump only required water in a full sunny day

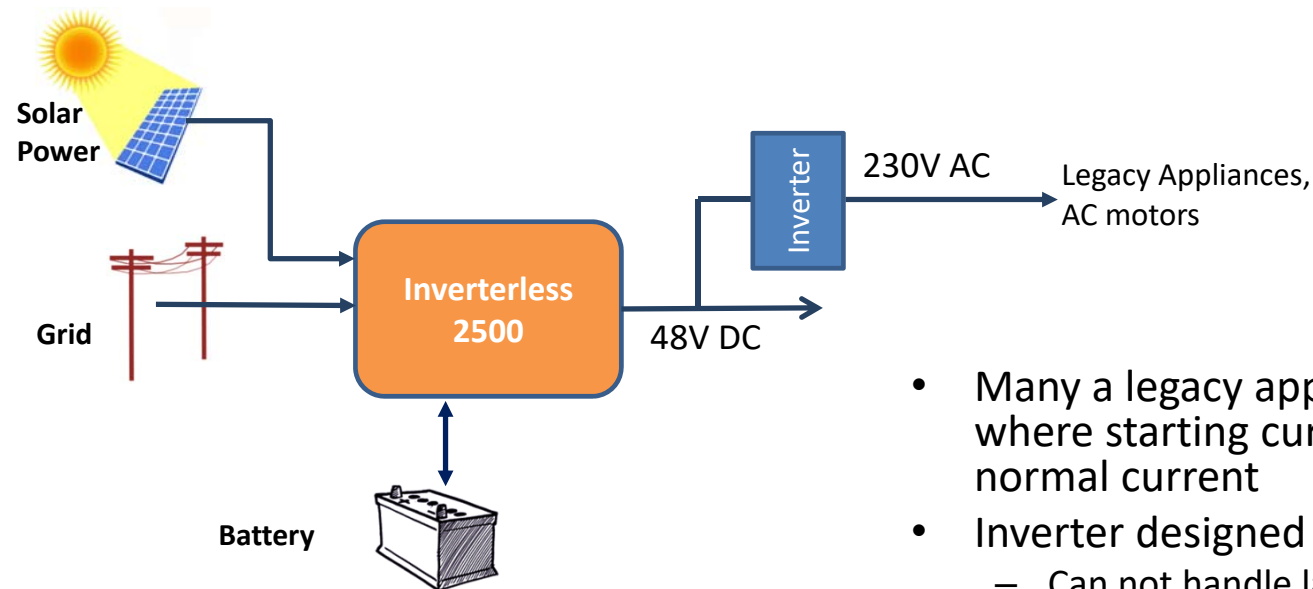




All kinds of Legacy Appliances, Equipment and Machines in large numbers

**BUT NOT ALWAYS POSSIBLE TO CONVERT ALL LOADS  
TO DC (even though substantial DC loads can be used)**

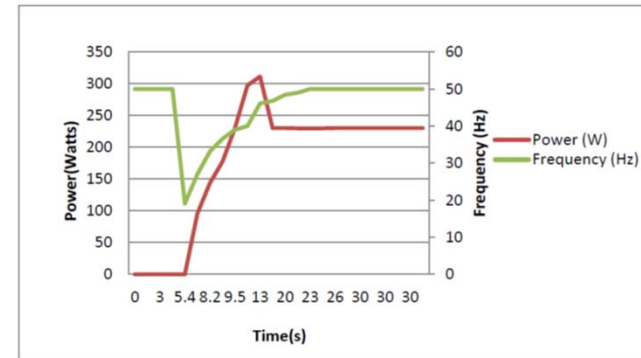
# Why not simply add an Inverter (DC to AC)



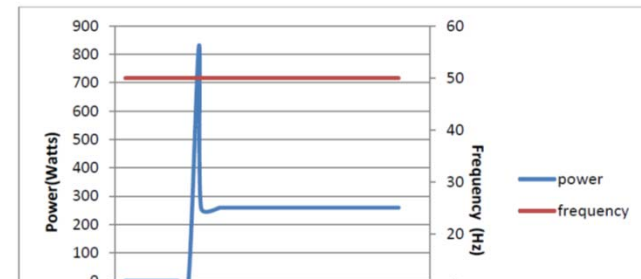
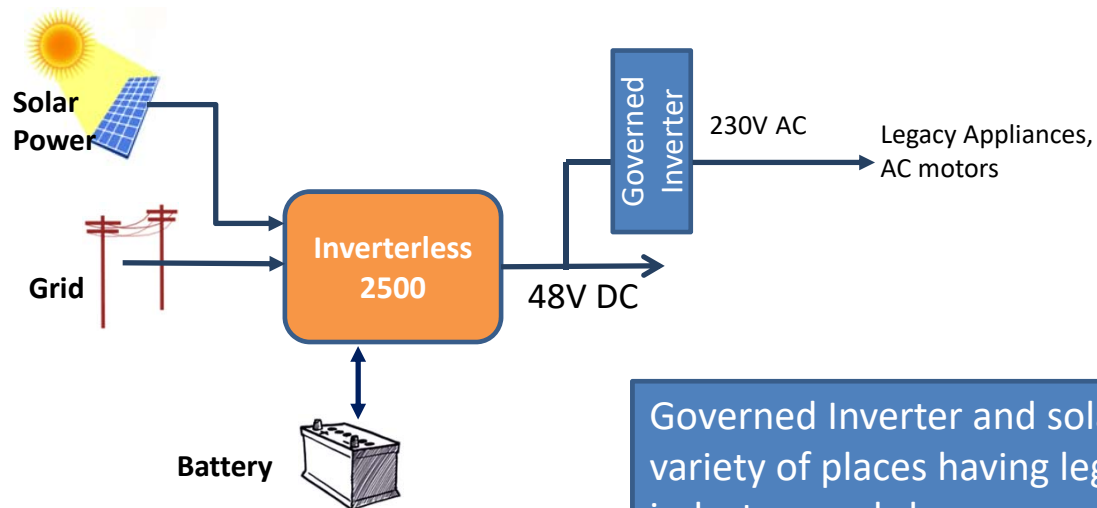
- Many a legacy appliances have AC motor load, where starting current is 5 to 10 times the normal current
- Inverter designed for normal load
  - Can not handle large starting current
- If Inverter designed to handle 5 times normal load, after starting, operation is at 20% capacity
  - Poor efficiency

# Answer is Governed Inverter

- If current output of a Inverter exceeds maximum specified
  - reduce output frequency
  - For an AC motor, power reduces as cube of frequency
- Once motor starts, frequency goes back to normal



With Governed Converter the starting power requirement is limited to 311W.



Governed Inverter and solar-DC replaces diesel generators in a whole variety of places having legacy AC appliances like atta-chakki, hotels, rural industry, workshops

# Scaling needs Standardisation

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- **Bureau of Indian Standards** has standardised 48V DC for home and office use
  - Has presented **48V DC** as standards for in IEC
- A precursor to **larger eco-system** of DC-powered DC appliances
- Need
  - standardisation for 380V DC for higher power loads
  - inexpensive 380V to 48V as well as 48V to 380V DC-DC converters

# To Conclude

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- **DC Microgrids** and **DC appliances** scaling in India because
  - Makes **economic sense**
    - By enabling off-grid low income homes to have electricity
      - 50M homes not connected to grid; 50M homes have power for less than 15 hrs / day
    - take power 24 x7 and more affordable to middle-income homes
  - Bring in **higher efficiencies**
  - Integrates well with **roof-top solar and storage**
- Communication interfaces in these new DC microgrids enable grid to use distributed storages
  - Thereby promoting growth of **renewables**