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DISTRIBUTED SOLAR ENERGY SYSTEMS

Decentralised electricity generation or dispersed generation based on renewable energy can be the right solution for power-stressed regions like southern India that receive ample solar insolation for more than 300 days in a year. Smart grid technology, coupled with supportive government policies, can indeed help the region tide over its power problems.

Solar power installed capacity has increased from only 3.7 MW in 2005 to about 5248 MW in 2016. The Government of India has an ambitious policy—Jawaharlal Nehru National Solar Mission, launched in 2010, of expanding solar capacity to 175 GW by 2022 through solar parks, ultra mega solar power projects, canal top solar projects, 100,000 solar pumps for farmers, and, solarisation of petrol pumps. Decentralised generation of electricity at the distribution side of the power supply network or closer to the load centre itself, can play pivotal role in meeting electricity demand in a reliable and environment-friendly way.

Dispersed or decentralised generation exploits locally available energy resources and reduces the exploitation of conventional energy resources and the congestion in generating units. Decentralised generation based on renewable energy (RE) sources promotes higher penetration of RE resources into the grid. These plants have the unique advantage of operating in islanded mode (grid isolation mode), during an outage of the central grid. In such cases, grid connection can easily be restored as the grid is energised and electricity can either be transferred to the grid or drawn from the grid.

Micro grids are the building units of dispersed generation, which essentially exploits locally available RE resources. The micro grid is an emerging technology and is a smart grid with high reliability, limited greenhouse gas (GHG) emission, reduced transmission and distribution (T&D) losses. The smart grid architecture is in its infancy, and integrates RE based distributed generation with the conventional system using control strategies over a two-way communication link.

India has one of the biggest power supply networks, with an installed capacity of more than 298 GW. Though electricity is one of the cleaner energy forms, 69 per cent of India's generation, amounting to 201 GW is from thermal power plants.

In July 2012, the Indian power sector witnessed one of the biggest blackouts; this was primarily due to peak power shortfall of 12,159 MW, amounting to 9 per cent and an 8.7 per cent energy shortage amounting to 86,905 GWh during 2012-13 (Load Generation Balance Report 2014-15).

Distributed electricity generation through RE sources can help in strengthening the power system to tide over such outages and also reduce the carbon footprint of energy generation. The associated economic benefits of decentralised generation are reduced operation and maintenance costs, increased productivity, reduction in fuel costs and increased efficiency.

Southern India currently harvests electricity from hydro and limited coal resources, from Nevyeli in Tamil Nadu. With three metropolitan cities in Bangalore, Chennai and Hyderabad, and many industrial, agriculture and commercial consumers, there is high demand for energy. The region has been facing very high energy (59,297 GWh, 19.1 per cent) and peak power (11,669 MW, 26.1 per cent) crisis over the years, which has, in turn, resulted in decreased power quality and load shedding, as admitted by the Central Electricity Authority (CEA) as per its Local Generating Balance Report, 2013-14.

Several studies have looked into the prospects of RE for decentralised generation (Ramachandra & Krishnadas, 2012; Ramachandra & Shruthi, 2005), micro grid (Ramachandra, et al., 2014; Ramachandra et al., 2014) and stand-alone generation of remote area electrification (Hafez & Bhattacharya, 2012; Ibrahim,et al., 2002, Balamurugan et al., 2009). Energy potential analysis using spatial data are also carried out by researchers which gave new avenue for energy research (Kanase-Patil et al., 2009; Kumaravel & Ashok, 2012). However, most of the studies were done for a specified application in a region or for a cluster of villages. The present study analyses the solar energy potential for all of southern India. The solar energy potential of the region ranges from 5.2 to 6.0 kWh/m^2/day annually. Taluk wise RE resources assessment has been carried out considering the seasonal variability of the resources and clustering high energy yielding regions.

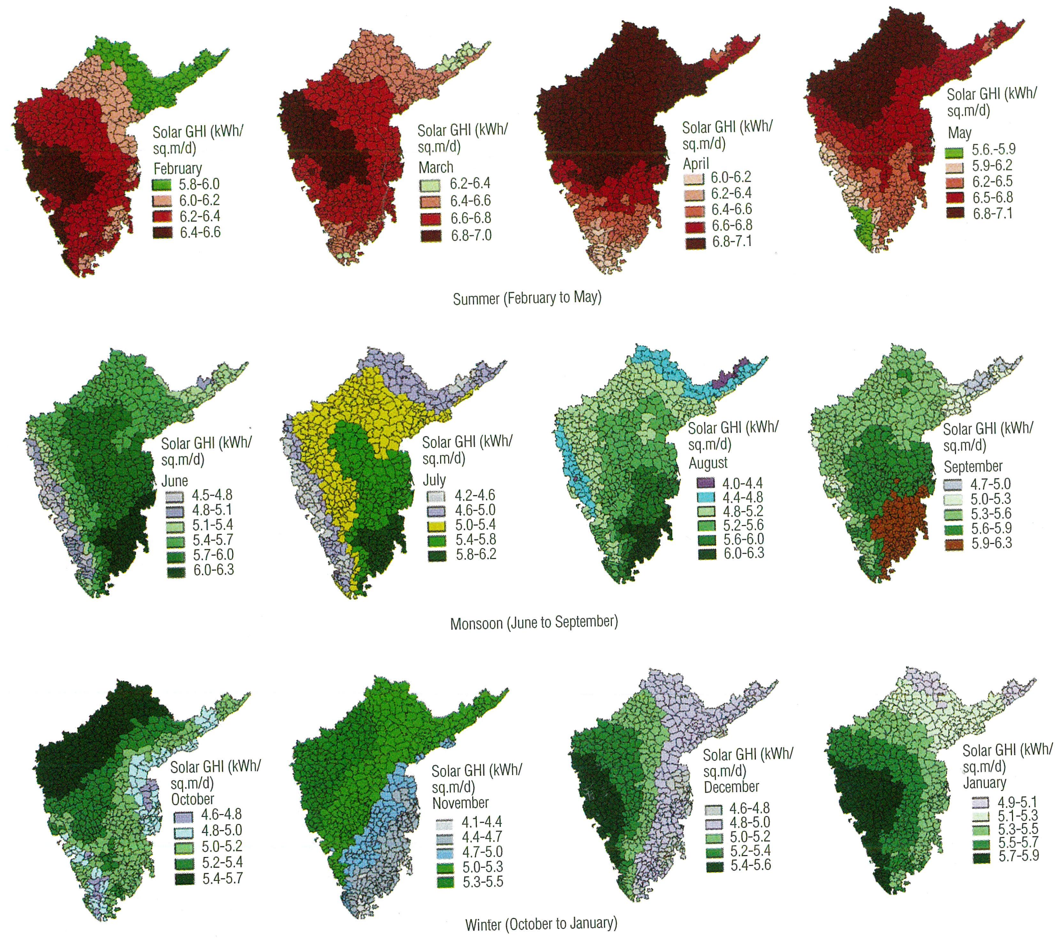
Study area and method

The Indian power sector comprises five regional load despatch centers (RLDCs). These are the northern, western, eastern, north-eastern and southern RLDCs with a National Load Despatch Center (NLDC) at Delhi. The Southern load despatch center (SRLDC) monitors the electric energy scheduling and load balancing of Karnataka, Andhra Pradesh, Kerala, Tamil Nadu and Pondicherry (four states and a Union territory). SRLDC covers the third largest geographical area of other RLDCs, which includes about 22 per cent of the country's total population and 29 per cent of total installed capacity. However, the installed capacity of RE based power plants is lesser in the region (7521 MW, 15 per cent), indicating lower exploitation of RE potential (Local Generating Balance Report, (CEA), 2013-14).

Long term spatio-temporal data are used to analyse the available RE potential in open source GIS platform. The assessment also gives the seasonal and geographical variability of the energy resources. Long term data sets acquired from NASA, SSE and Climate Research Unit (CRU) are reliable and depict the seasonal variability which is closely correlated with ground measurement.

NASA SSE Global insolation datasets are obtained from a physical model based on the radiative transfer in the atmosphere considering its absorption and scattering properties. The model considers visible and infrared radiation, cloud and surface properties, temperature, perceptible water, column ozone amounts and also the atmospheric variables includes temperature and pressure measured using various satellite instruments. The long wave and shortwave solar radiations recorded in the satellite sensors along with the effecting parameters are studied to generate global insola-

Fig. 1: Taluk wise seasonal variation of solar energy potential



The taluk wise seasonal variation of solar energy potential in southern states is computed in the above graphics. During summer (February to May), solar energy reception varies from 5.6 to 7.1 kWh/m^2/day. Insolation (GHI) maps at taluk level were based on the interpolation of global insolation data.

Fig. 2: Taluk wise solar energy density distribution

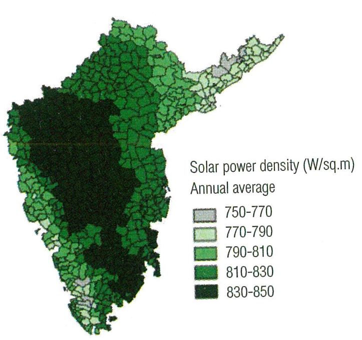
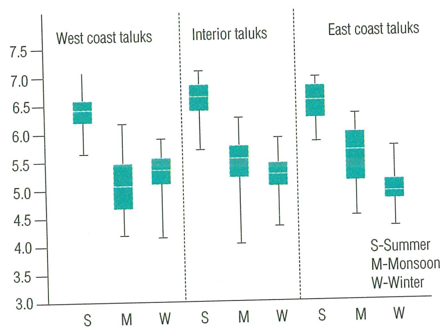
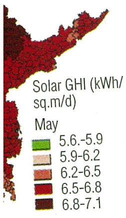
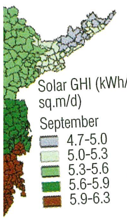
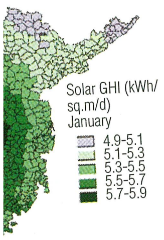


Fig. 3: Seasonal variability of solar energy potential









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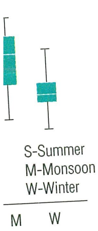

India has an installed capacity of more than 298 GW. Out of this 69 per cent of India's generation amounting to 201 GW is from thermal power plants.

tion for different locations and durations. The 0.1° x 0.1° spatial resolution SSE global insolation data derived from NASA SSE web portal (http://eosweb.larc.nasa.gov/sse/), for a period of 22 years (July 1, 1983 to June 30, 2005) were validated (RMSE of 10.28 per cent) with Baseline Surface Radiation Network (BSRN) data available as daily, monthly and annual averages obtained from measured values every three hours (Ramachandra et al., 2011; Guide to Meteorological Instrument and Observing Practices, 1964). Further, grids which essentially cover the entire southern region of the country are extracted and a geo-statistical Inverse Distance Weighting (IDW) interpolation is employed to produce monthly average Global Hourly Insolation (GHI) maps for the region. Taluk wise availability of solar potential is computed by over laying the delineated taluk boundary map.

Findings and analysis

Figure 1 shows the taluk wise seasonal variation of solar energy potential in southern states. During summer (February to May), solar energy reception varies from 5.6 to 7.1 kWh/m^2/day. The region receives the highest insolation in April, while taluks in the northern and central region receive insolation of more than 6.8 kWh/m^2/day. Solar insolation reception decreases as the southwest monsoon arrives during June and continues till mid-September (monsoon season). Taluks of the west coast are immediately affected by the monsoon, and receive lower insolation (4.2-5.0 kWh/m^2/day) throughout the season. Even otherwise, insolation received in all the taluks is lesser during monsoon months, which slowly increases as the winter approaches. During winter (October to January), western and interior taluks receive higher insolation (5.3-5.9 kWh/m^2/day) compared to the east coast taluks (4.1-5.1 kWh/m^2/day).

Figure 2 shows the solar power density map for the region. Solar power density varies from 750 to 850 kW/m^2 in the region where, interior taluks receive higher solar power (810-850 W/m^2) compared to the coastal taluks (750-810 W/m^2). Distributed generation and micro grid planning can be done with this knowledge which also helps in predicting the probable energy output of the region.

Seasonal variability analysis is carried out, dividing the entire area into three regions, that is, the west coast, the east coast and interior taluks, depending upon the geography of the region. Figure 3 depicts the variation in solar insolation across the seasons for all three regions. Insolation reception is highly variable in monsoon and winter due to cloud movements in all regions. However, insolation is less variable during summer in all the regions and west coast shows lesser variability of insolation in all seasons.

Solar technologies, one finds, have the potential to offset a huge volume of GHG emissions and help realise a low carbon economy. They can also create numerous employment opportunities at the village level. Learning from other developing countries as well as its own past experience, India can be a world leader in solar power generation. With an ambitious solar mission, and positively evolving policy instruments, the nation can easily earn the epithet of a 'Solar India' in the near future.

Decentralised generation of electricity through rooftop SPV can help meet the electricity demand of households, apart from avoiding transmission and distribution (T&D) losses. Generation based incentives (GBI) can help decentralised electricity generation, and boost the regional economy. To encourage decentralised power generations, several incentives could be introduced. These incentives could be:

- Rs. 4.00 per unit for first five years (comparable to subsidies granted to mini hydro projects, the power purchase at Rs 3.40) and Rs. 3.50 for the next two years for the electricity generated from roof top solar PV. Several state governments (Karnataka, Tamil Nadu, and Andhra Pradesh) have recently come up with an attractive generation-based incentive scheme, which has given a boost to solar based systems.
- Buyback programmes for the electricity gener-

ated at household level and in micro grid-GBI of Rs. 5 to be provided for solar electricity photovoltaic (< 5 kW) feeding the grid.

- Implementation of solar rooftops in all new government and local body buildings could be done in a phased manner.
- Commercial lighting in advertisement boards should only be from RE sources, with a complete ban on usage of grid electricity for these purposes.
- Impetus to energy research through generous funding for research and development to ensure further improvements in the grid technologies, two way communication energy meters (to connect rooftop generation with existing grid), efficient luminaries' production, low cost wiring, switchgears and appliances.
- Energy education (focusing mainly on RE technologies, end-use energy efficiency improvements, energy conservation) at all levels.
- Awareness about energy independence and the necessity of RE for consumers.
- Capacity building of youth through technical education for installation and servicing of solar photovoltaic panels.
- Setting up service centers in block development offices for service support for RE technologies (solar, biogas, and energy-efficient chulhas).

Smart Grid and New Energy Sources

Smart grid is an intelligent system which integrates all components of the power system (generation, transmission and distribution network, end users) for reliable, efficient and environment friendly energy supply. It also plays a key role in demand response, peak load management, and unit commitment to have an effective renewable mix in installed capacity. Well established information and communication technology and control networks are the backbone of a smart grid, which also needs a supportive grid network (Ten Minute Climatology, Vijayapriya & Kothari, 2011).

Power sector in India is evolving and adopting modern grid technologies such as supervisory control and data acquisition (SCADA), energy management system (EMS), distribution automation (DA), advanced metering infrastructure (AMI) such as prepaid meters and the like. However, the communication network is limited to high voltage transmission equipment and feeble parts of the present power network need to be strengthened to have better smart grid architecture. India is planning to have a full phase smart grid by 2025, for which devices like (FACT) flexible AC transmission controllers and phasor measurements units (PMUs) are being installed. Around 14 pilot projects are being implemented by the Government of India under the Restructured Accelerated Power Development and Reforms Programme (R-APDRP) and the US-India Partnership to Advance Clean Energy-Development (PACE-D) programmes (apdrp.gov.in). Data management technologies and automatic screening of data, collected through remote terminal units (RTUs) is the worldwide challenge to make the network smart and to take quick decisions (ISGTF 2013).

Yet, the smart grid vision needs contributions from industry, academic and research institutions. The architecture of a smart grid needs to be adapted considering the load dynamics and resource availability, as also future demand. The Indian power sector still suffers from huge unmet demand due to lack of peak load management and high AT&C losses. A Smart grid could reduce network losses and narrow the energy-demand gap.

However, replicating the smart grid architecture may not be the solution for all problems that plague the Indian power sector. For this, we need radical government policies focusing on RE, revolutionary improvements in end-use technologies and changes in resource utilisation practices. Besides, there is a dire need to re-structure the energy portfolio to do away with the environmental problems that have resulted from the uncontrolled consumption of fossil fuel resources.

Endnote

India's southern region can easily use the ample solar insolation it receives for more than 300 days in a year to generate solar energy in a decentralised mode, and thus tide over its severe energy and peak power crisis.

For this, micro grids need to be promoted to meet community-level demand through locally available energy resources. Wastelands in the interior taluks are best suited for grid connected hybrid energy generation, while, micro grids and rooftop generation can be promoted in metropolitan and biodiversity rich Western Ghats taluks. The exploitation of RE sources need to be promoted through appropriate policy intervention and grid integration. The share of energy sources can be decided depending on the variability of insolation and the geographical location. Aggressive tapping of renewable sources meanwhile, can also help mitigate GHG emissions and reduce dependence on fossil fuels. GY

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