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Praktičnost pasovne obnovljive energije v Indiji

KARTHIK SUBRAMANYA BHAT & UDO BACHHIESL

Povzetek Indija se, tako kot mnogo drugih držav po svetu, kjer postaja eden pomembnejših dejavnikov energetska tranzicija s čim manj škode za gospodarstvo. Indijski energetski sektor je zelo ogljično intenziven, saj zagotavljajo 70% celotne proizvedene električne energije v termoelektrarnah na premog. Obnovljivi viri zavzemajo okoli 15% celotne energije. Dostopnost energetov, skupaj s številnimi drugimi dejavniki, predstavlja glavno oviro za prehod v uporabo čiste energije. Zaradi majhnih sezonskih nihanj v porabi električne energije za pokrivanje pasovne energije skrbijo s poceni energijo iz premogovnih termoelektrarn, medtem ko za pokrivanje konic skrbijo plinske elektrarne. Mit, da z obnovljivimi viri ni mogoče zadostiti potrebam po pasovni energiji, se je razširil in sprejel predvsem zaradi nestalne narave obnovljivih virov. V nekaterih študijah je prikazan optimističen prehod na 100% energije iz obnovljivih virov v prihodnjih desetletjih. V energetskem sektorju, ki v večini temelji na ogljiku, kot je to primer v Indiji, je pojem »pasovne energije« velika in močna ovira, saj zagotavljanje pasovne energije predstavlja pomemben dejavnik, ki neposredno vpliva na gospodarstvo države. V prispevku so prikazana razmišljanja, ali je v Indiji mogoče zagotavljati pasovno energijo iz obnovljivih virov, in izzivi, povezani s tem.

Ključne besede: • Indija • pasovna energija • obnovljivi viri • energetska tranzicija • ogljično intenziven •

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Practicality of Base Load Renewable Generation in India

KARTHIK SUBRAMANYA BHAT & UDO BACHHIESL

Abstract India, among several other countries globally, now faces a unique situation where managing the energy transition process without hurting the economic development becomes the highlight of its policies. The Indian power sector is highly carbon intensive, with coal based power providing 70% of the total electricity generated. Renewable energy occupies around 15% of the capacity mix. Energy access along with several other challenges, pose an obstacle to the needed transition to clean energy. As the seasonal load variations in India are not prominent, cheap coal based power supplies most of the load profile, while gas power plants are used for peak loads. The myth that renewable energy sources cannot meet baseload demand has become widely accepted and wide-spread, given their fluctuating nature. Several studies demonstrate an optimistic transition to 100% renewable sources might just be possible in the coming decades. In a carbon-rich power sector like India, the 'base load' mind set is a pretty big and powerful hurdle, as ensuring base load generation becomes a major issue with implications directly affecting the country's economy. In this study, an effort has been made to discuss whether base load renewable generation in India is feasible, and the challenges involved.

Keywords: • India • base load • renewable generation • energy transition • carbon intensive •

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1 Introduction

India is a country globally known for its diversity and size, on the other hand is also known for its energy related emissions. An overview of the primary energy usage deeply highlights the role of fossil fuels, mainly coal and oil. Moreover, the Indian fossil fuel balance shows that there is an import dependency of the country for both coal and oil, implying a direct relation to the country's economy. Most of the electricity in India comes from coal based power plants (up to 60% installed capacity), while renewables in the share are relatively less. Considering the steep increase in annual electricity demand growth and that a large part of the country's population lack electricity access, a large scale capacity expansion is necessary to ensure energy access. India plans to install 175 GW of solar PV and wind power by the year 2025, to achieve complete energy access and to significantly reduce its carbon footprint. Though the plans seem entirely over-optimistic, when and if achieved, it would solve much of the country's energy-related problems. However, having such a high penetration of renewable energy in the energy system leads to many significant problems, and a strategy for effective integration into the system becomes necessary.

'Base load' generation in India since a few decades has been done by coal based thermal power plants, given their reliability and cheap electricity generation prices. In the past, several possibilities for nuclear energy to take up the role of coal in the base load generation were considered, but were not realized as obstacles due to the non-participation in the Non-proliferation treaty and failed attempts to join the Nuclear Supply Group arose. However, the country now has the chance to shift the base load generation from coal based technology to renewable energy, considering the significant capacity expansion goals and available technical potential. Though the mind-set of the country's power sector seems to be inclined towards coal being never replaced by any technology in the near future, many initiatives like subsidy schemes, energy-savings initiatives and other energy efficiency improvement strategies have been proposed, in support of the much needed energy transition. These initiatives ensure lesser demand while in turn also assuring a possibility of large scale renewable electricity generation to take up the role.

2 Base load and base load power plants in India

Base load fundamentally means the load which can be expected throughout the 24 hours in a day, throughout the year. This would mean that the minimum electricity demand of the country over a year would form the base load. In a country with almost 330 million people without continuous access to electricity, base load satisfaction is given the utmost importance, next to only its economic development. India is predominantly focused on building such 'base load' power plants, to secure its minimum electricity requirements. It seems pretty reasonable that policy-makers in India usually have a lot of focus on 'base load' power, as the country's need for a source of 'reliable' power that is available throughout the year is uniquely high. With this special need to ensure sufficient energy supply, after the drastic economic reforms in the early 1990s, an almost continuous addition of coal based capacities has been observed in the country, with every consecutive year [1]. An illustration of the load variation in the year 2011, and the corresponding load duration curve is as shown in the accompanying Figure 8.1., where the base load is highlighted.

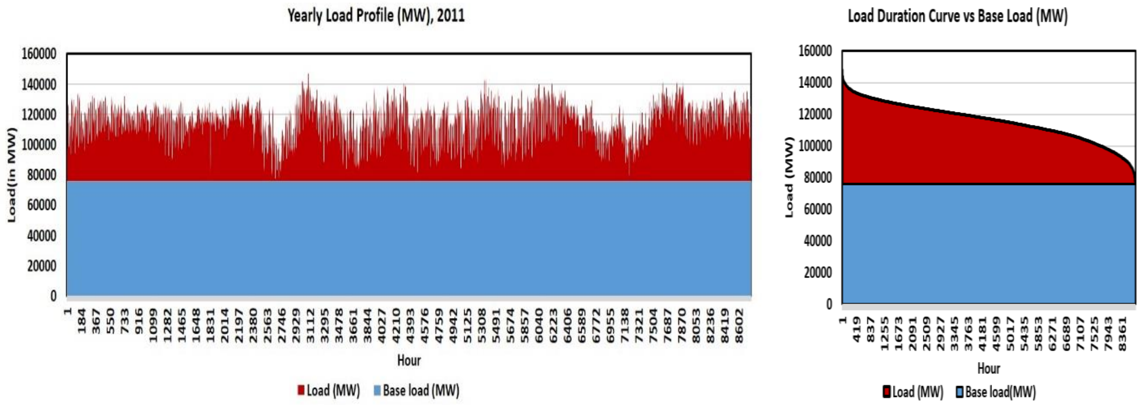

Figure 8.1. Electrical load profile in India for the year 2011

It can be observed that the electrical load in India has no such predominant seasonal variations throughout the year, the base load roughly accounting for around 52% of the yearly peak. This would mean that the base load constitutes for more than half of the total annual electricity demand. The intermediate and the peak loads are usually shared mostly by commercial and industrial sectors, while the industrial and domestic sectors which usually involve continuously operated processes, majorly occupy the base load region. It can also be observed here that the base load is a characteristic of electricity demand, rather than a necessity of the supply side [2].

The base load in India is traditionally covered by the so-called ‘base load’ power plants such as coal based or nuclear power plants which have higher availability factors and a steadier power output than many other power plant technology. Such power plants are usually characterized by high capital costs and lower variable costs. The intermediate load is usually covered by combined cycle gas plants, and the peak loads by gas and oil power plants. It is generally accepted that these ‘peak load’ power plants have lower capital costs, but comparably very high variable costs. By the end of the year 2016, India had an installed capacity of 186 GW of coal and 5.78 GW of nuclear thermal power plants. Also, a capacity of 24.5 GW gas and 994 MW of oil thermal power plants is expected to cover the intermediate and peak loads [3] (iv). Recent developments in the energy sector have shown a significant growth in the renewable energy, accounting up to 43 GW (excluding hydro power) of installed capacity. The added renewable capacity constitutes of mainly on-shore wind and solar PV capacities, and a small portion of biomass. A Figure 8.2. illustrates the fluctuating nature, with a comparison of the average load, wind and solar PV temporal variations over a year.

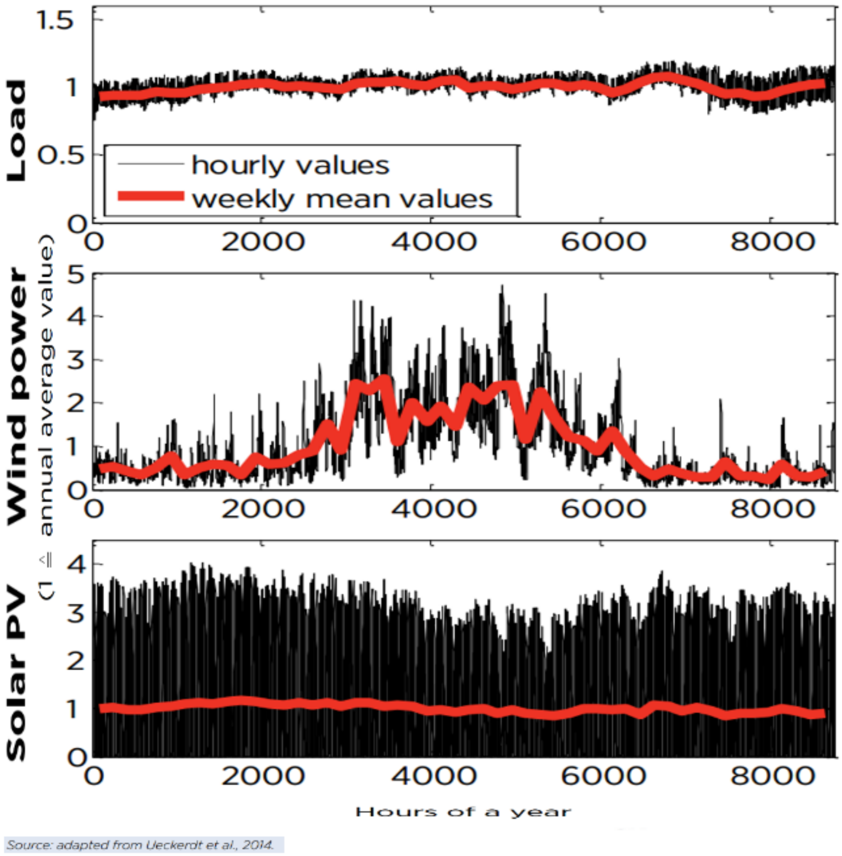

Figure 8.2. Comparison of average electrical load, wind and solar PV temporal variations in India [2][5]

For now, even with lesser flexibility, the role of the 'base load' power plants is significantly large, due to their constant output. But with a higher share of renewable energy in the future, the Indian power system would require a higher level of flexible interplay [4] between its components. Thus it cannot be completely guaranteed that any technology will run at a high utilization rate or even provide a constant output. Subsequently, the significant role of such base load power plants is more likely expected to decrease. Additionally, as electrical load is inherently variable, the fact that a heterogeneous mix of different generation technologies, by bringing in different degrees of variable costs would be a sensible option, and also be more cost effective with higher flexibility in output.

3 Challenges for renewable energy in the indian energy sector

India must not only change its focus on building base load power plants, but also change its objective in supplying all parts of the load i.e., from base load to peak load, in a cost effective and a much reliable way. When this mind-set is in play, renewable energy technology plays a big part in the realization of such an objective. The already large share of base load power plants, when further increased, might not only cause 'lock-ins', which are observed with power systems dominated by dependence on conventional plants, but could even endanger the required transition towards renewables[2]. Thus, several challenges for renewable energy exists, some of which are identified in this study.

a) Increasing demand and transmission losses: increases the base load value
b) Variable nature of renewables vs the 'base load' mind-set
c) Integration costs of large scale renewable energy

Many countries have similar challenges to the integration of renewable energy, and solutions can be derived from a general comparison of the global electricity sector.

a) Increasing demand and transmission losses

India is characterized by a huge electricity demand growth rate of 6.9% p.a.[1], and this situation elevates the risk of energy scarcity with every consecutive year. This abnormal electricity demand growth is due to the increase in population (consumers) and rapid industrialization. The Government of India (GoI), while only focusing on economic development created by the industry boom, takes up the task of building cheap gas and oil power plants with smaller capital costs but higher variable costs, as a temporary short-term solution. For long term planning, several coal power plants with higher capital costs and much-lower variable costs are proposed. Considering that coal power plants lack the flexibility to ramp at high rates to follow the variable intermediate and peak loads, the expensive gas or oil power plants are also run. This creates a situation where renewable power plants are utilized only to a minimum, and lose their relevance in the energy system.

A viable solution to this problem would be to improve the energy efficiency of the system by introducing several energy efficiency directives in all sectors. This would put a stop to the increasing of the demand, which would in turn, to some extent reduce the inclination of the power sector on coal capacity expansion. Base load is usually created from continuously operated processes, examples include industrial processes like smelting of aluminium, or other residential applications such as lighting, electronic equipment, refrigerators, freezers et cetera. By increasing the energy efficiency, pro-active maintenance and scheduled energy auditing of such processes, the base load value can also be inherently decreased.

Additionally, the efficiency of the distribution networks managed by the state owned distribution companies (DisCom) has been low, resulting in serious losses. In 2013, India's Transmission and Distribution (T&D) losses accounted to almost 23%, and the Aggregate Technical and Commercial losses (AT&C) almost 25.4% [6], must be identified as major problems. In simple terms, this loss rate would mean that the electricity generators would have to generate up to four units of electricity for every three units they sell to their retail and industrial customers. This creates a financially unfavourable situation (v)for the energy utilities due to severe lack of returns on the investment. A significant loss in transmission and distribution could only cause major problems in meeting the on-grid consumer demand, even with the availability of centrally generated power. The Figure 8.3. describes the demand projections and grid losses through the years.

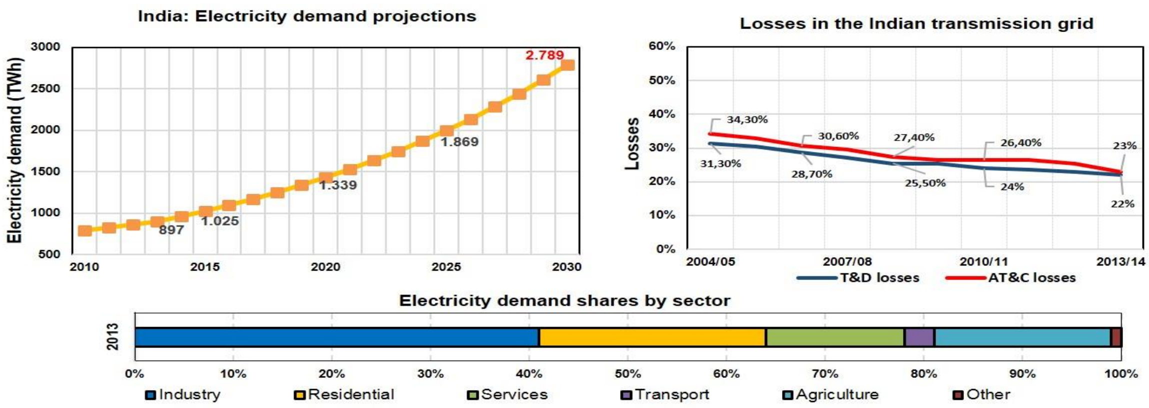

Figure 8.3. Electrical demand increase, grid losses, and the demand shares by sector in India

b) *Variable nature of renewable energy sources vs 'base load' mind-set*

Based on the nature of electricity generation output, two distinct categories of generation from renewable energy sources can be defined: 'variable' and 'dispatch-able'. While the generation from Variable Renewable Energy (VRE) sources cannot be significantly controlled given the highly intermittent nature, 'Dispatch-able' renewable power generators are able to control their generation output within a given specific range, similar to a conventional fossil fuel power plant. VRE sources include wind and solar irradiation. Reservoir hydropower plants, biomass power plants, and concentrated solar thermal power stations fall in to the dispatch-able category. The integration of dispatch-able renewable power plants normally does not pose any additional challenges to the power system [2]. In a country like India, where the concept of base load power is a significant factor, the VRE integration poses many challenges like geographical source dependency, over production, energy storage requirements and unreliability of power supply. Thus, a transformation towards renewables requires a rethinking of the concept of base load power plants in India

Comparing with the so called 'base load' power plants, power systems with a combination of VRE and dispatch-able renewable power plants could prove to be a feasible solution. VRE power plants could never cover base load power demands at all times. But this should not be considered as a disadvantage, since just covering the base load should not be the objective of the country. It must also be noted that the variability of VRE is the highest for an individual power plant, but when different VRE plants of the same type are combined across the country, the overall variability decreases considerably. Several countries have already proved that a mix of renewables can reduce the variability. In Germany, solar PV and off-shore wind power generation have been shown to complement each other due to opposite seasonal variations. Similarly, hydro power and wind energy complement each other in Brazil, where wind generation is at its peak during the dry season and hydro generation during the rainy season is at the maximum. The Figure 8.4. shows the nature of the average seasonal variation of the availability solar PV, off-shore wind and hydro power sources in India, in a year. The complementary nature is not easily observed, so a hybrid system including the conventional power plants have to be planned. Also, to avoid the stranding of the already available conventional fossil fuel power plant assets, a hybrid system has to be operated, to ensure both energy access and financial security of the private energy sector in India.

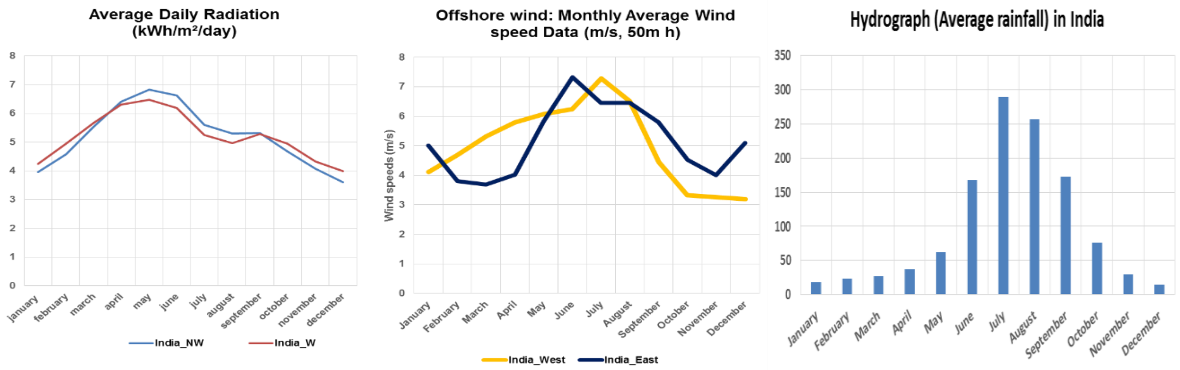

Figure 8.4. Seasonal variation of availability of solar PV, off-shore wind and hydro graph of India

Thus, as a solution, India must look at the options of a hybrid power system, with a generous mix of VRE, dispatch-able renewable energy and conventional power plants with high flexibility and relatively lower variable costs.

c) *Integration costs of large scale renewable energy*

Though India's interest in large scale renewable energy integration developed in the last few decades, the GoI has ambitious plans in this sector. After the Climate Change Conference in Paris 2015, the GoI revised its plans to increase its solar capacity fivefold from its initial target of 20 GW to an optimistic target of 100 GW by the year 2022. 75 GW of wind power has been planned to reach its renewable targets of 175 GW by 2022. Currently, around 7 % of the total electricity produced is from renewables (i)(ii). Wind energy in India is already considered competitive, as the Levelized Cost of Electricity (LCoE) from wind power was almost same or less than that from the fossil fuel. However, the LCoE from solar power was 11.79 % higher than imported coal in 2015 [7]. The cost is expected to decrease over time due to technological learning effects that drive the solar prices down while fossil fuels become more expensive. Solar power is projected to be cheaper than imported coal based power in 2019. The Figure 8.5. shows the calculated forecast for LCoE from imported coal, solar energy and wind energy in India.

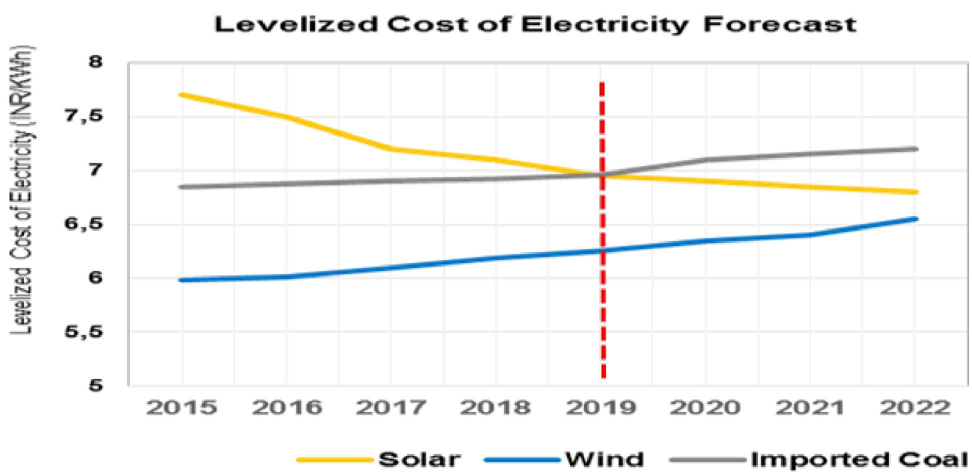

Figure 8.5. Levelized Cost of Electricity generation from coal, wind and Solar PV in India

A large scale integration of VRE power plants also inflicts so-called integration costs at the system level [9] [10]. These integration costs are just additional costs on the power system due to the integration of such power plants with uncertain and less predictable availability. Normally, VRE integration costs are low or even sometimes negative, when their share in the system is low [2]. This could mean that the integration would save costs on a system level. With higher shares of VRE integration, the concerned challenges technical obstacles due to fluctuation tend to decrease, but the integration costs are expected to increase. Due to the temporal variability of such sources, they cannot be relied upon during the peak load times. Thus, a considerable scale of renewable capacity would also need a considerable share of back up technologies like energy storage, and back-up conventional power plants. Unfortunately, energy storage is a relatively expensive option, which makes the integration less effective. The geographical dependency of VRE sources also create a need for investments in transmission and distribution networks, which also needs a lot of initial capital.

The level of integration costs of VRE is usually highly dependent on the characteristics of the power system involved. Thus, a solution for such an integration problem would be to make the Indian power sector to 'VRE friendly' by investing in flexible generation plants, strengthening the grid and flexible demand i.e., Demand Side Management (DSM). Also, the introduction of regulatory frameworks and innovative grid operation protocols could significantly reduce the integration costs by harnessing the potential for technical flexibility. To effectively reduce the system integration costs, it is necessary to shift from capital intensive base load power plants like coal power plants, to intermediate and peak load plants with higher flexibility and lower capital costs to complement the high VRE shares.

4 5-Point Check list as a solution

After the discussion and consideration of the challenges for renewable generation in the country, a unique five point check list is proposed in an effort to effectively strategize large scale renewable capacity expansion in India. These points in the checklist not only reflect the present situation of the country, but also provide an overview of the future of the electricity sector in India.

1. Energy Efficiency directives and Demand Side Management

Energy efficiency outside the power generation sector could effectively decrease the power demand by almost 20% [3] (vi), which means one unit in five could be shut down without any major repercussions. This would also act as a stop to the highly increasing demand growth rate, and would lessen the dependency on base load power plants. Demand Side Management would not only decrease the integration costs of the VRE power plants, but also encourage the consumer to play his part in the energy transition of the sector. Energy efficiency improvement should be given utmost priority, given the increasing nature of the country's overall electricity demand. India has already introduced energy efficiency directives for the domestic sector [11], and should focus on improvement of efficiency in the industrial and commercial sectors.

2. A more responsive power sector to improve transmission and distribution

The T&D and AT&C losses could not only severely hamper India's strategy to battle energy accessibility, but on a system level, add up to the increasing demand. Improvement and expansion of the transmission network should be considered also as a high-priority task, as a support to the large share of location specific VRE power plants in to the system. Meeting each of India's renewable energy integration challenges also depends on improving the efficiency of the transmission and distribution grids.

3. Investments in Peak and Intermediate load power plants

To significantly reduce the integration costs of VRE, and to provide flexibility to the generation side of the power system, the investments on Peak/Intermediate load power plants have to be encouraged. Such power plants need lesser capital than base load power plants like coal and thermal, and can be installed almost in any location, near the load centers. However, care must be taken to ensure cleaner operation of such power plants.

4. Distributed VRE generation, hand in hand with large scale renewable generation

Along with large scale VRE installations, small scale distributed VREs like urban rooftop PV, PV for agricultural use and wind installations in rural areas also have to be encouraged. Since the availability of solar irradiation almost everywhere in the country is evenly distributed, and that VRE technologies like Solar PV can be effectively integrated into urban infrastructure, the increase in awareness and encouragement towards such technologies have to be done, possibly by introducing lucrative support schemes

5. Promotion of energy efficient urbanization

Since almost half of India is considered yet to be built, an intelligent strategy for efficient urbanization has to be implemented. This not only helps decrease the increasing demand, but also helps effectively integrate VRE technology. Also, introduction of smart grids and electro-mobility [11] in developing areas could also be effective, as to support DSM initiatives and improved grid response when controlling the grid. Developing towns can be assigned Renewable Power Obligations (RPO) which would ensure that any new power plant built in this area would have to integrate a certain level of renewable power.

5 Conclusion

A brief study of the challenges involved with renewable integration in India provides us with an insight on whether the 'base load' renewable generation in the country is practical or not. Simply put in terms, the concept of 'base load' power plants have to be changed, for a transition in the Indian power sector. Also, for a sustainable renewable generation, India has to consider a hybrid system, renewables along with intermediate/peak load power plants, to be free of the base load mind set. Overall, it is definitely possible for India to replace its base load power plants with renewable energy, albeit with a diverse renewable portfolio (with both dispatch-able and VRE power plants). India's power system in the distant future would possibly be a combination of a high share of dispatch-able (hydro power and biomass), VRE (solar PV and Wind), and a significantly smaller share of combined cycle power plants

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Bookmarks

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