INVESTIGATE THE MAJOR CHALLENGES IN INTEGRATION OF WIND & SOLAR POWER SYSTEMS

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Abstract:

Electricity is a crucial facet of any country's prosperity. India had an installed power generation capacity of 370 GW as of March 30, 2020, which is about 168 times the installed capacity in 1947 (1362 MW).Electricity generation growth has been steadily increasing day by day, and in the year 2018-19 the generation was about 356,100 MW with a growth of 4% over the previous year. However, the demand has been consistently outstripping the supply even as power availability has increased due to significant investments on the supply side. India faces the challenge of poor reliability and a poor quality of electricity, leading to frequent load shedding situations in one part of the country or the other.
India has large untapped resources of wind and solar energy, which if utilized properly, can fulfil the energy requirements of the country to a large extent. This thesis presents the journey of the Indian power sector through time, analyses various demand and supply scenarios, which are mutually exclusive, and also assesses various issues facing the Indian Power System. This work proposes that integration of enhanced electrical capacity realized through a large-scale integration of renewable energy resources, such as wind and solar energy, in the Indian electrical grid can lead to a smarter grid platform. This platform will ensure increased efficiency, reliability, and security, as well as reducing the environmental impact of supplying the electrical power needs of the modern society. The result is an enhanced electricity management environment and a dynamic programmable renewable source mobilization in India leading to energy independence and an electrical grid that is much more reliable, secure, efficient, and greener.

Keywords: Integration of power sources, wind, solar energy.

1. Introduction:

India is the world's third largest producer and third largest consumer of electricity. The national electric grid in India has an installed capacity of 368.79 GW as of 31 December 2019.Renewable power plants, which also include large hydroelectric plants, constitute 34.86% of India's total installed capacity. During the 2018-19 fiscal year, the gross electricity generated by utilities in India was 1,372 TWh and the total electricity generation (utilities and non-utilities) in the country was 1,547 TWh. The gross electricity consumption in 2018-19 was 1,181 kWh per capita. In 2015-16, electric energy consumption in agriculture was recorded as being the highest (17.89%) worldwide. The per capita electricity consumption is low compared to most other countries despite India having a low electricity tariff.

India's electricity sector is dominated by fossil fuels, in particular coal, which during the 2018-19 fiscal year produced about three-quarters of the country's electricity. The government is making efforts to increase investment in renewable energy. The government's National Electricity Plan of 2018 states that the country does not need more non-renewable power plants in the utility sector until 2027, with the commissioning of 50,025 MW coal-based power plants under construction and addition of 275,000 MW total renewable power capacity after the retirement of nearly 48,000 MW old coal-fired plants.

1.1 Installed capacity by source in India as on 31 March 2020

Installed Capacity as on	Thermal (MW)				Nuclear (MW)	Renewable (MW)			Total (MW)	% Growth (on yearly basis)
	Coal	Gas	Diesel	Sub-Total Thermal		Hydro	Other Renewable	Sub-Total Renewable		
31-Mar-2019[3]	200,704	24,937	637	226,279	6,780	45,399	77,641	123,040	356,100	3.52%
31-Mar-2018	197,171	24,897	838	222,906	6,780	45,293	69,022	114,315	344,002	5.25%
31-Mar-2017	192,163	25,329	838	218,330	6,780	44,478	57,260	101,138	326,841	10.31%
31-Mar-2012	112,022	18,381	1,200	131,603	4,780	38,990	24,503	63,493	199,877	9.00%
31-Mar-2007	71,121	13,692	1,202	86,015	3,900	34,654	7,760	42,414	132,329	5.19%
31-Mar-2002	62,131	11,163	1,135	74,429	2,720	26,269	1,628	27,897	105,046	4.49%
31-Mar-1997	54,154	6,562	294	61,010	2,225	21,658	902	22,560	85,795	4.94%
31-Mar-1990	41,236	2,343	165	43,764	1,565	18,307	-	18,307	63,636	9.89%
31-Mar-1985	26,311	542	177	27,030	1,095	14,460	-	14,460	42,585	9.94%
31-Mar-1979	14,875	168	164	15,207	640	10,833	-	10,833	26,680	12.02%
31-Mar-1974	8,652	165	241	9,058	640	6,966	-	6,966	16,664	10.58%
31-Mar-1966	4,417	137	352	4,903	-	4,124	-	4,124	9,027	18.80%
31-Mar-1961	2,436	-	300	2,736	-	1,917	-	1,917	4,653	12.25%
31-Mar-1956	1,597	-	228	1,825	-	1,061	-	1,061	2,886	13.04%
31-Dec-1950	1,004	-	149	1,153	-	560	-	560	1,713	8.59%
31-Dec-1947	756	-	98	854	-	508	-	508	1,362	-

Table 1 Growth of Installed capacity in India

At present the traditional power generation industry is at a juncture where issues like capacity additions, enhanced reliability of power supply and quality, need to be addressed quickly. These issues are paving the way for more investments and easier regulatory norms for absorption of more renewable energy in the Indian National Grid. India's power generation sector consists mainly of coal-based thermal plants.

Since most renewable energy sources are intermittent in nature, it is a important task to integrate a significant portion of renewable energy resources into the power grid infrastructure mainly the electricity flow takes place in one direction from the centralized plants to consumers. When compared to large power plants, a renewable energy plant is having less capacity. But as emerging resources renewable energy should be taken into account. By achieving the integration as shown in Fig.1 we can improve monitoring techniques, protection, optimization and the operation. And also two-way flow of electricity can be employed.

2. Wind Energy Data:

Wind power is one of the fastest-growing renewable energy technologies. Usage is on the rise worldwide, in part because costs are falling. Global installed wind-generation capacity onshore and offshore has increased by a factor of almost 75 in the past two decades, jumping from 7.5 gigawatts (GW) in 1997 to some 564 GW by 2018, according to IRENA's (International Renewable Energy Agency.) latest data. Production of wind electricity doubled between 2009 and 2013, and in 2016 wind energy accounted for 16% of the electricity generated by renewables. Many parts of the world have strong wind speeds, but the best locations for generating wind power are sometimes remote ones. Offshore wind power offers tremendous potential.

Wind is used to produce electricity using the kinetic energy created by air in motion. This is transformed into electrical energy using wind turbines or wind energy conversion systems. Wind first hits a turbine's blades, causing them to rotate and turn the turbine connected to them. That changes the kinetic energy to rotational energy, by moving a shaft which is connected to a generator, and thereby producing electrical energy through electromagnetism.
The amount of power that can be harvested from wind depends on the size of the turbine and the length of its blades. The output is proportional to the dimensions of the rotor and to the cube of the wind speed. Theoretically, when wind speed doubles, wind power potential increases by a factor of eight.Wind-turbine capacity has increased over time. In 1985, typical turbines had a rated capacity of 0.05 megawatts (MW) and a rotor diameter of 15 metres. Today's new wind power projects have turbine capacities of about 2 MW onshore and 3–5 MW offshore.

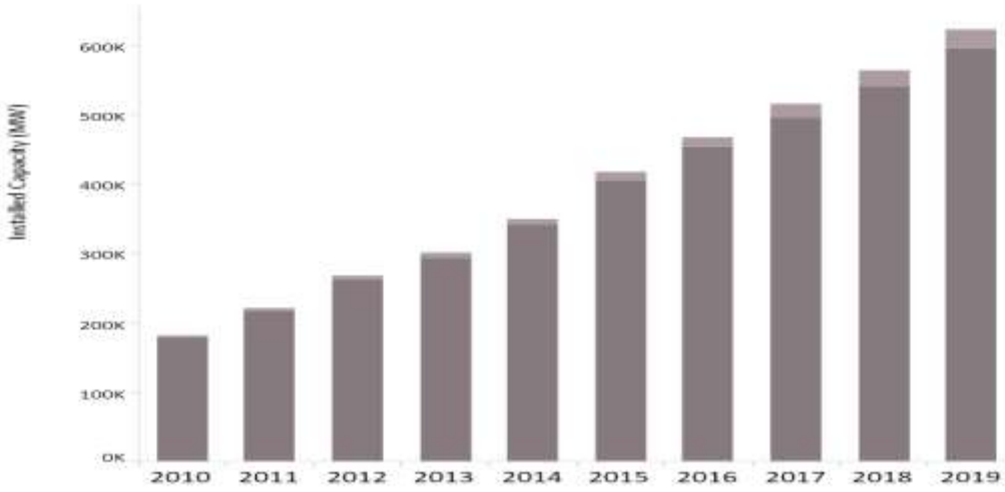

Fig. 1 Total Installed capacity of wind energy

3. Solar Energy Data:

Energy can be harnessed directly from the sun, even in cloudy weather. Solar energy is used worldwide and is increasingly popular for generating electricity or heating and desalinating water. Solar power is generated in two main ways:

Photovoltaics (PV), also called solar cells, are electronic devices that convert sunlight directly into electricity. The modern solar cell is likely an image most people would recognise – they are in the panels installed on houses and in calculators. They were invented in 1954 at Bell Telephone Laboratories in the United States. Today, PV is one of the fastest-growing renewable energy technologies, and is ready to play a major role in the future global electricity generation mix.Solar PV installations can be combined to provide electricity on a commercial scale, or arranged in smaller configurations for mini-grids or personal use. Using solar PV to power mini-grids is an excellent way to bring electricity access to people who do not live near power transmission lines, particularly in developing countries with excellent solar energy resources.The cost of manufacturing solar panels has plummeted dramatically in the last decade, making them not only affordable but often the cheapest form of electricity. Solar panels have a lifespan of roughly 30 years, and come in variety of shades depending on the type of material used in manufacturing.

Concentrated solar power (CSP), uses mirrors to concentrate solar rays. These rays heat fluid, which creates steam to drive a turbine and generate electricity. CSP is used to generate electricity in large-scale power plants.

A CSP power plant usually features a field of mirrors that redirect rays to a tall thin tower. One of the main advantages of a CSP power plant over a solar PV power plant is that it can be equipped with molten salts in which heat can be stored, allowing electricity to be generated after the sun has set.

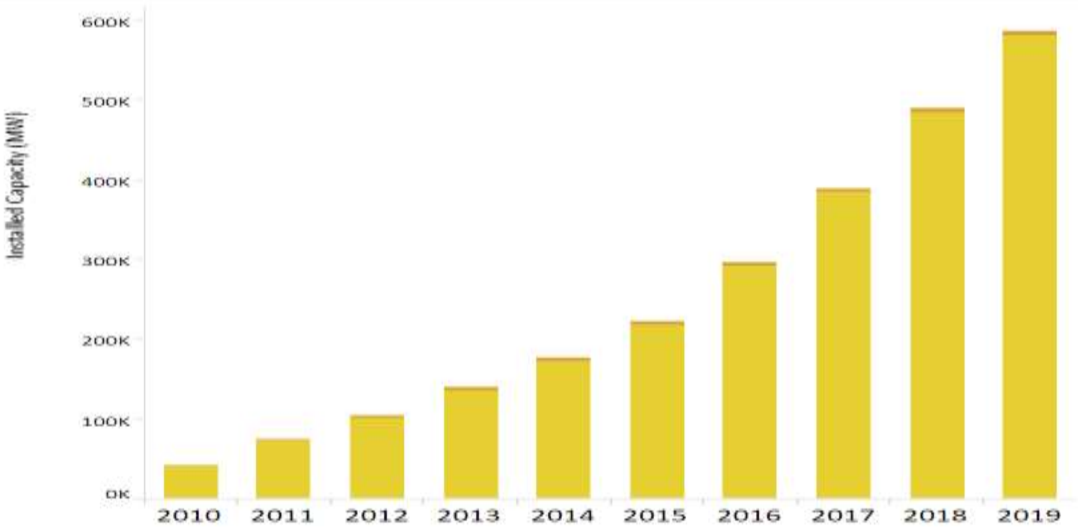

Fig. 2 Total Installed capacity of solar energy

4. Renewable Integration:

The integrated RE is the process of power transfer "watt" from renewable energy sources to the utility system grid, so the network is fed by a source of RE. Figure.1 describes in general the shape of the integration of RE technologies into the grid. The AC grid could have two input of power generation: conventional/ unconventional power plants and RE plants "wind, solar, etc." The output of power from RE has to be an AC power in order to meet integration conditions where allow power to transfer to the substation A, which might be a distribution substation. After that, the power can move to transmission lines, which could be high or low voltage, or directly to distribution system, which usually is low or medium voltage.

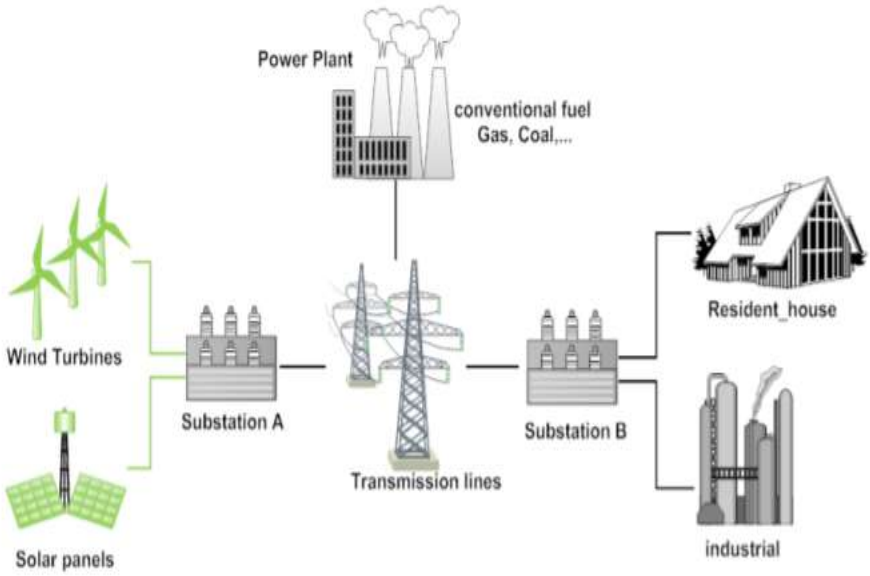

Fig. 3 The general structure of integrating renewable energy into AC Grid

5. Purpose of renewable Integration:

Renewable Energy Integration focuses on incorporating renewable energy, distributed generation, energy storage, thermally activated technologies, and demand response into the electric distribution and transmission system. A systems approach is being used to conduct integration development and demonstrations to address technical, economic, regulatory, and institutional barriers for using renewable and distributed systems. In addition to fully addressing operational issues, the integration also establishes viable business models for incorporating these technologies into capacity planning, grid operations, and demand-side management.

The goal of Renewable energy integration is to advance system design, planning, and operation of the electric grid to:

- reduce carbon emissions and emissions of other air pollutants through increased use of renewable energy and other clean distributed generation
- increase asset use through integration of distributed systems and customer loads to reduce peak load and thus lower the costs of electricity
- support achievement of renewable portfolio standards for renewable energy and energy efficiency
- enhance reliability, security, and resiliency from micro grid applications in critical infrastructure protection and highly constrained areas of the electric grid
- support reductions in oil use by enabling plug-in electric vehicle (PHEV) operations with the grid.

6. Challenges in Integration of wind & solar power systems:

6.1 Variability:

This is the biggest and most vexing.Power plants that run on fuel (along with some hydro and geothermal plants) can be ramped up and down on command. They are, in the jargon, "dispatchable." But VRE plants produce power only when the wind is blowing or the sun is shining. Grid operators don't control VRE, they accommodate it, which requires some agility.

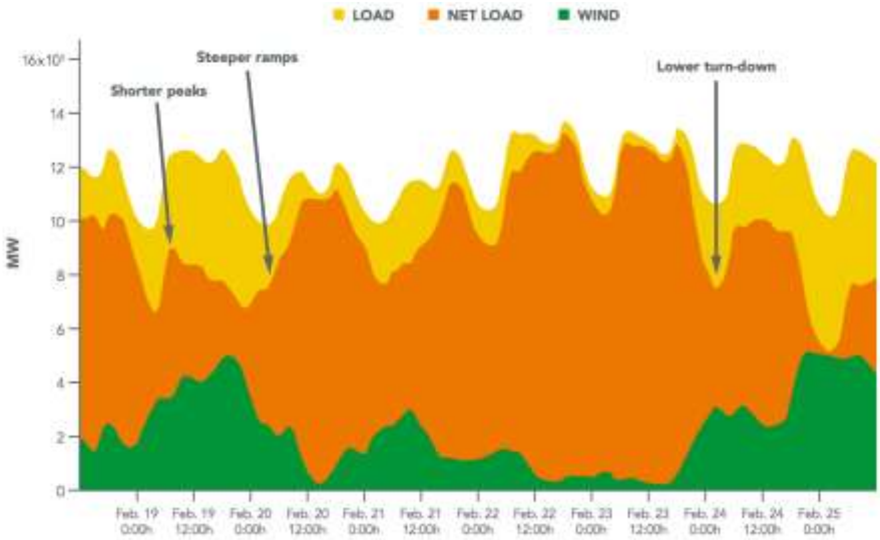

Fig. 4 wind power as an illustration

This shows one week of electricity supply and demand (details and location not particularly important). The green at the bottom is power coming in from wind. The yellow at the top is total demand. The orange in the middle is the gap between the two, the amount that has to be supplied by conventional power plants.Another way of looking at it: from the perspective of the grid operator, who has control over a set amount of dispatchable power, VRE energy supply is functionally equivalent to reduction in demandlarge, rapidly rising and falling fluctuations in demand for dispatchable power.
On the chart above, "shorter peaks" refers to times when conventional plants are supplying the day's "peak load," which is when power is most valuable. VRE reduces or "shaves" the peak, thus screwing with the economics of conventional plants. "Steeper ramps" refers to times when conventional plants have to increase or decrease their output quickly in response to fluctuations in VRE often more quickly than they are designed or regulated for. And "lower turn-down" means that in times of high VRE supply, conventional plants will have to run at the lowest output they are capable of, i.e., "minimum load."All these effects of variability pose challenges to the rules and economics that govern existing power infrastructure.

Most of green energy sources rely on uncontrolled recourses. On other words, producing power from RE comes from nature resources such as sunshine, wind, or ocean waves. This kind of sources leads us to know that power generation from RE is intermittent and inconstant. As a result, it is a challenge mission to share power from RE technologies into Ac grid. There are many problems of this incorporation and figure 2 shows the mainly issues that will be discussed as follow: power quality, cost, availability of power, location of RE resource, change in power, speed of change in power, and power forecast.

Figure 5: The most challenges of RE-Grid integration

6.2 Power Quality Issues

Power quality is an important major in power system to ensure stability and high efficiency of the grid system, so ideal PQ leads the system to work well with high reliability and less cost. In contrast, poor PQ can have major harmful effects on the power grid as well as industrial processes, high cost, and equipments failure. Many studies say that power quality troubles cost U.S. around $15 billion per year, according to Schneider Electric. PQ problems include frequency disorder, voltage/current harmonics, low power factor, voltage fluctuation and transmission lines transits. Since the power output from RE technologies are fluctuation, most of PQ issues are present either it is on-grid or off-grid. Therefore, when the integrating is designed, these concerns are going to affect the grid badly. For example, if power factor of the system goes very low, equipments will get damage. In addition, in solar energy, voltage and frequency are not constant due to amount of irradiance, so this cause voltage deviation and frequency deviation, and these two deviations are major challenges in the integrating RE into the grid.

6.3 Availability of Power

One of the biggest concerns in RE-Grid integration is the power generation depends on natural resources that are uncontrollable by human. In PV energy, as shown in figure 5, producing electricity stand up on when sunshine is available and off at night, and also wind energy depends on the availability of wind, so if the speed of wind is zero or very low, the turbine will not turn, and this result in zero power flow to the grid. The instability of producing energy in RE technologies is making the integration more complex, and it causes detrimental aspects for system operation such as harmonics in the converters unless solutions has found such as storage systems such as batteries that allow to have constant frequency and voltage.

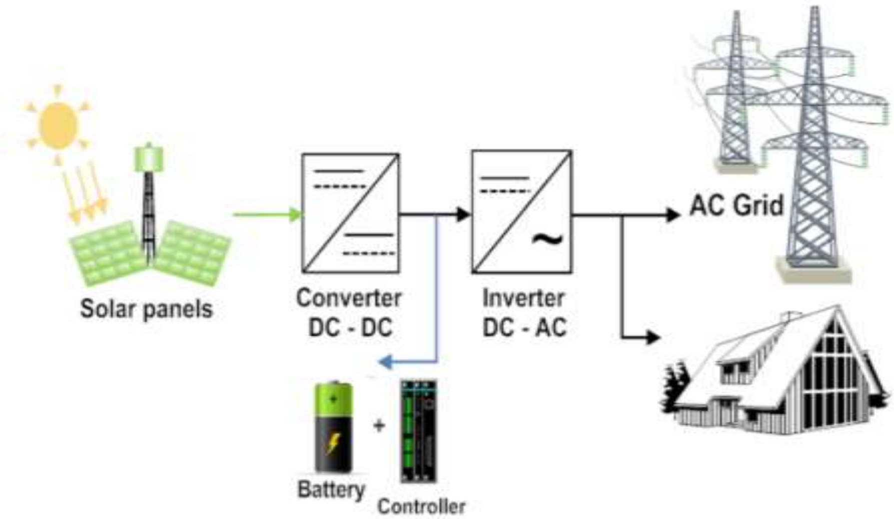

Fig. 6 General structure of PV energy.

6.4 Speed of Variation

From figure 4, we can easily notice that the fluctuations are changing in a small period of time. The minimum power around 450 MW is changing to 4,450 MW in just 24 hours. Therefore, the fluctuation speed could appear in hour-to-hour, minutes to minutes, or even second to seconds. In slow change, power output may be expected, but on other hand, high speed of variations is another challenge that might face the RE-Grid integration in the large scale, especially.

6.5 Forecasting

Generally, Forecasting in power systems is a major subject of power management system for grid system planning to ensure the stability and high reliability. Because most of RE technologies depend on weather and environmental factors, the prediction in power generation is hard in term of accuracy. Accuracy is usually obtained in case of load forecast in power system distribution, and it results in high quality of operation due to the constant producing of power and it is to ensure the future load demand. In RE technologies, forecasting studies are required in power generation, and if the main source of power is not constant and uncontrollable, RE-Grid integration become more difficult. In addition, each technology of RE has its own characteristics, so forecast studies and research will be different. Furthermore, there are several forecast methods for each of the technologies such as short and long term forecasts. The short term, usually in hours, is not considering problematic in the integration, but the long term is an issue due to its less accuracy and this cloud affect the operation of the grid.

6.6 Location of RE Plants

Most of RE plants that share their energy with the grid are large scale of capacity, so usually the area of such one plant is considerable. Sometimes, we are forced of the RE sources locations due to several factors that each technology has own reasons of choosing the location. Picking a place to operate one of RE technology involves on many elements that make RE-Grid integration under challenges. First, some RE source are not available in each region. Second, distance between RE source and the grid is a major aspect in term of cost and efficiency. Also, RE sources depend on weather, climate, and geographical location. For example, solar energy in state of Arizona or Texas is more efficient than in Michigan due to the high percent of sun radiation time per day in Arizona and Texas. As a result, the integration will be more flexible in these states than Michigan. Also, tidal and ocean wave energy are another example that points selecting location of RE and integrating into AC grid is uncontrolled.

6.7 Cost issue

Economic estimation is a prime part in RE Grid integration planning since we have to keep the rate of cost low as possible. The two main aims of the RE incorporation are to save our environment and reduce the cost of generation power in both RE and conventional plants. We can properly observe that facing these difficulties will result in some economic issue. Power generation forecast requires numerous prediction studies and simulations, and this depends on the accuracy of power generation. Also, location play a role in the total cost since most of large RE plants are located far away from cities and substations of the grid, so they require transfer power by extension transmission lines that depend on voltage level. Therefore, energy storage strategy is a solution of variation, and availability power especially in large capacity of RE plants requires massive storage system to storage energy before integrating process. However, the storage system has high cost, and it is really a challenge in term of producing high of megawatt.

7. Solutions for integrating solar and wind into the grid

Improved planning and coordination: This is the first step, making sure that VRE is matched up with appropriately flexible dispatchable plants and transmission access so that energy can be shared more fluidly within and between grid regions. Flexible rules and markets: Most grids are physically capable of more flexibility than they exhibit. Changes to the rules and markets that govern how plants are scheduled and dispatched, how reliability is assured, and how customers are billed, says NREL, "can allow access to significant existing flexibility, often at lower economic costs than options requiring new sources of physical flexibility."

This is the low-hanging fruit of grid flexibility. Recent research from the Regulatory Assistance Project offers an overview of the changes needed in "market rules, market design, and market operations." A new Department of Energy study describes utility best practices in "time-of-use pricing," which varies the price of electricity throughout the day to encourage demand shifting. In New York, utility regulations are being fundamentally rewritten to optimize the management of distributed energy resources (DERs). There's a ton of this stuff underway.

Flexible demand and storage: To some extent, demand can be managed like supply. "Demand response" programs aggregate customers willing to let their load be ramped up and down or shifted in time. The result is equivalent, from the grid operator's perspective, to dispatchable supply. There's a whole range of demand-management tools available and more coming online all the time.

Similarly, energy storage, by absorbing excess VRE at times when it's cheap and sharing it when it's more valuable, can help even out VRE's variable supply. It can even make VRE dispatchable, within limits. (For example, some concentrated solar plants have molten-salt storage, which makes their power available 24 hours a day.)

Flexible conventional generation: Though older coal and nuclear plants are fairly inflexible, with extended shut-down, cool-off, and ramp-up times, lots of newer and retrofitted conventional plants are nimbler and can be made more so by a combination of technology and improved practices. Grid planners can favour more flexible non-VRE options like natural gas and small-scale combined heat and power (CHP) plants. Cycling conventional plants up and down more often does come with a cost, but the cost is typically smaller than the fuel savings from increased VRE. Flexible VRE: New technology enables wind turbines to "provide the full spectrum of balancing services (synthetic inertial control, primary frequency control, and automatic generation control)," and both wind turbines and solar panels can now offer voltage control.

8. THE BENEFITS

Impact of RE-Grid integration has been approved, so the positive aspect of RE Grid integration can be classified mainly as follow: environmental, social, and economic positives. First, RE technologies has zero fossil fuel emission, so the integration will help fossil fuel power generation plants to reduce emission of CO2 in way of less generating power. In 2013, the total power generation from RE in China is 1,108 billion Kwh, so by sharing this producing with grid, the incorporation results in reducing the power generation from fossil fuel plants. In addition, it will help to increase to save our natural recourse by reducing extraction of fuels.

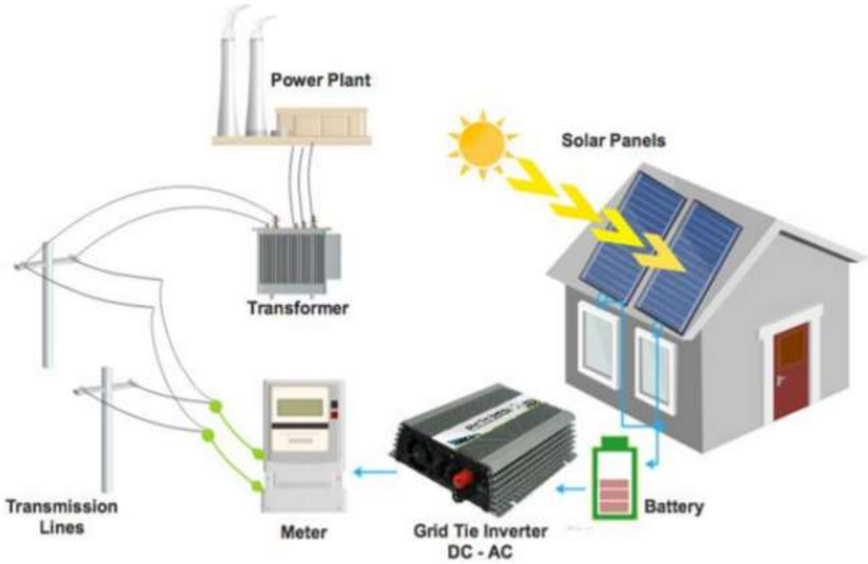

Fig. 7 General integrating process using GRI

Second, our societies and plant will become more clean and health due to the low reducing CO2. Also, the integration improves the reliability of power grid failure since it uses storage system. On other words, recently, we see many people who insulate their own energy source such as solar energy, so they gain many benefits such sale the extra energy to the utility, and they have their own electricity, so if the grid fails in power, they can use their independent source. Figure 5 shows the main picture of using solar energy using grid tie inverter GTI to integrate into the grid in homes. According to Union of Concerned Scientists, there were 400,000 houses in the U.S. that used solar panels in 2013 and by 2020 will be between 900,000 to 3.8 million houses using solar energy.

9. Methodology - capturing major integration challenges:

An intuitively appealing technique for representing the load matching properties of VRE and the induced challenges is provided by load duration curves (LDCs) and residual load duration curves (RLDCs). These curves are mostly used for illustrative purposes and sometimes indirectly used as a model input. We present here for the first time the application of RLDCs as a direct quantitative tool for analysing systems with arbitrary levels of penetration of both wind and solar PV, and demonstrate the intuitive clarity of this approach to thinking about VRE challenges. We start by explaining the concept of RLDCs. As a first preparatory step, we introduce the well-known concept of a load duration curve LDC, which is derived by sorting the load curve i.e. the time series of power demand for one year or longer fromhighest to lowest values.

10. Conclusion:

India is a vast country and home to a plethora of cultures, ideas, religions and a conscientious economic sphere. Banking on its aspirations to become a superpower in the near future, India is on track to increasing its economic pace. The huge growth in the economy is putting an acute stress on the energy sector. Even with vast resources of certain conventional fuels, such as coal, the abrupt shift from a producer controlled to a vertical utility controlled infrastructure to bridge the supply and demand gap has put a tremendous amount of pressure on the producers. Many times, the producers succumb to this frenzy which results in an unreliable electrical infra-structure in the country. Besides that, the traditional electrical grid of the country is deemed inefficient and not at the level necessary to provide services to the growing economy of the country, which is showing in various reliability reports about India.Climate change mitigation policies will certainly requiredramatically increased levels of electricity produced from variable renewable sources, as described at the beginning of this paper. Although the focus of this work is on the challenges to integration of VRE in the existing system, the potentially large negative externalities of anthropogenic climate change, together with the known negative externalities of current energy systems indicate that an energy system transformation will be necessary over the next few decades. The acceptance and success of this transformation will be enhanced if foreseeable consequences are examined carefully and early in the process such that options for avoiding problems can be developed in parallel with the ramp-up of VRE deployment.

To achieve the 'electricity for all' by 2027 goal, there is but a need to tap into all the possible renewable energy sources, and optimizing energy use. This can be done by the introduction of a smart grid in the country, which has already been deployed in certain cities and Pradesh's. A smart grid approach will upgrade the electrical infrastructure of the country to a modern, well connected, efficient and reliable system that provides a platform for the economic and overall development of the country.

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