RENEWABLE ENERGY: EMERGING TRENDS, POTENTIAL IN INDIA AND ITS IMPROVEMENT

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ABSTRACT

India is faced with the major challenges of providing energy access to all its citizens, heavy dependence on fuel imports for energy security, and complying with international protocols on climate change mitigation, although the economic and social development is the foremost priority. The increase in energy demand due to growing population and industrialization in the face of depleting fossil fuel resources has stimulated the country's efforts in adopting power generation from renewable energy sources. Starting with small percentage of the country's total installed capacity, the share of renewable power generation has reached many heights as of now . In the aspect of total installed renewable power generation, India occupies the fifth position in the world today. While the governmental policies have steadily encouraged the adoption of renewable power generation, there is need and potential for more vigorous engagement in pursuit of achieving power for all citizens along with economic development. This article presents a brief review of emergence and growth of renewable power generation in India, wind and solar sectors in particular.

Keywords Geothermal Energy, Hybrid energy System, Ministry of New and Renewable Energy, Reliability, Unit Optimization.

I. INTRODUCTION

Electricity is the key factor for industrialization, urbanization, economic growth and improvement of quality of life in society. India is the world's fifth prevalent in the electricity sector. India's energy consumption has been increasing at a relatively fast rate due to population growth and economicdevelopment. Rapid urbanization and improving standards of living for millions of Indian households, the demand is likely to grow significantly. According to International Energy Agency (IEA), India will bethe second largest contributor to the hike in the global energy demand by 2035 [1]. In order to sustain the production, industries have opted for inefficient diesel-fuelled backup power. India's energy planning, which is based on the twin objectives of high economic growth and providing electricity to all, is failing to meet either. The

utility electricity sector in India had an installed capacity of 288 GW as of 31 January 2016 [2][3].Renewable Power plants constituted 28% of total installed capacity and Non-Renewable Power Plants constituted the remaining 72%. The

gross electricity generated by utilities is 1,106 TWh(1,106,000 GWh) and 166 TWh by captive power plants during the 2014–15 fiscal [4]. The gross electricity generation includes auxiliary power consumption of power generation plants. India became the world's third largest producer of electricity in the year 2013 with 4.8% global share in electricity generation surpassing Japan and Russia [5]. During the year 2014-15, the per capita electricity generation in India was 1,010 kWh with total electricity consumption (utilities and non-utilities) of 938.823 billion or 746 kWh per capita electricity consumption[6].Electric energy consumption in agriculture was recorded highest (18.45%) in 2014-15 among all countries[7]. The per capita electricity consumption is lower compared to many countries despite cheaper electricity tariffin India.There is growing energy inequity between rural and urban areas and also between the developed and developing states. There are millions who are yet to be benefited from electricity in rural India. The scarcity of electricity in rural areas in comparison to urban areas seems to be biased.The world's conventional energy sources based on oil, coal, and natural gas have limited reserves and are expected to end in nearby future. The world's identified coalreserve is expected to last 225 years at the current usage rate and only 65 years if the usage rises 2 percent per year [8].Thus, depleting nature of conventional energy had forced planners to look for never ending and non-polluting new renewable energy sources those continuously replenished by natural processes. Energy present in wind, sunlight, falling water, sea waves, geothermal heat, or biomass is converted into a form which can be used such as heat or electricity by a renewable energy system. However, only 15 to 20 percent of world's total energy demand is met by this renewable energy. India is world's 6th largest energy consumer, accounting for 3.4% of global energy consumption.in delivery through the centralized system. While the urban-rural difference in energy supply could be reduced through renewableenergy, it is more complex to overcome the widening gap between developed and not so developed states [9].However,the common problem of solar and wind energy systems the dependence on weather and climatic changes and the unpredictable nature.Due to this nature,there is always a mismatch between the generated energy and the load demand. This will make the system less reliable and arises need for storage or other source in the system. But, the optimal mix of two or more sources can overcome the drawbacks completely or partially due to the complementary nature of these sources. This optimal mix of the resources emerges as new field of study can be called as the hybrid energy system. In generalahybridrenewableenergysystem(HRES)canbe defined asanenergysystem,whichconsistsoftwoormore renewablesources,such thatthepowergenerated ismorereliable and costeffective.Itcanbeconnectedtogridorworkinisolation and itmayormaynothavethestoragecapabilityora conventional sourceinit.

II. THE PRESENT POWER SCENARIO IN INDIA

In order to address the lack of adequate electricity availability to all the people in the country by the platinum jubilee (2022) year of India's independence, Government of India under NarendraModi as Prime Minister has launched a scheme called "Power for All". This scheme will ensure that there is 24/7 continuous electricity supply provided to all households, industries and commercial establishments by creating and improving necessary infrastructure. Its a joint collaboration of centre with states to share funding and create overall economic growth. Currently nine states have joined the scheme. India has transitioned from being the world’s seventh-largest energy consumer in 2000 to fourth-largest one within a decade. The country has the fifth-largest power generation portfolio worldwide [5]. India’s energy basket has a mix of all the resources available including renewables. The dominance of coal in the energy mix is likely to continue in near future. At present India's coal dependence is borne out from the fact that ~58 % of the total installed electricity generation capacity is coal based. Out of total thermal installed capacity 86% capacity is coal based [6]. Other renewables such as wind, geothermal, solar, and hydroelectricity represent a 2 percent share of the Indian fuel mix. Nuclear holds a 2% percent share [7]. Total installed capacity in the country stands at ~234 GW of which (i) Thermal power accounts for 61 % (ii) Renewable energy accounts for 13% [6].

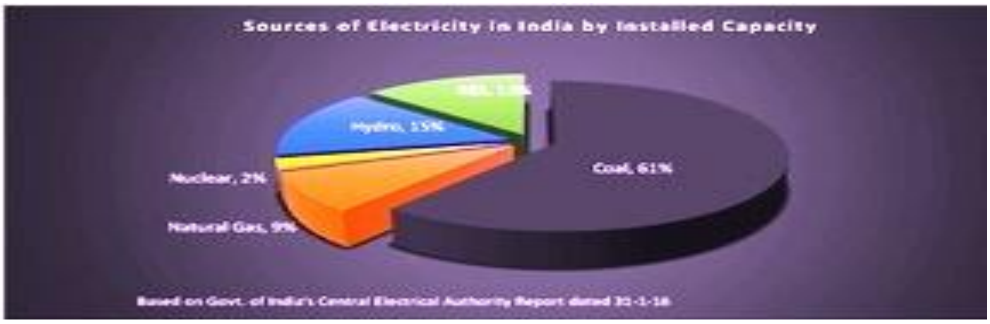

Fig. 1 Sources of Electricity

2.1 Installed capacity

The total installed power generation capacity is sum of utility capacity, captive power capacity and other non-utilities.

Table 1 Installed Capacity (Up to 31.03.2015)

Installed Capacity as on	Thermal (MW)				Nuclear (MW)	Renewable (MW)			Total (MW)	% Growth (on yearly basis)
	Coal	Gas	Diesel	Sub-Total Thermal		Hydel	Other Renewable	Sub-Total Renewable		
31-Dec-1947	756	-	98	854	-	508	-	508	1,362	-
31-Dec-1950	1,004	-	149	1,153	-	560	-	560	1,713	8.59%
31-Mar-1956	1,597	-	228	1,825	-	1,061	-	1,061	2,886	13.04%
31-Mar-1961	2,436	-	300	2,736	-	1,917	-	1,917	4,653	12.25%
31-Mar-1966	4,417	137	352	4,903	-	4,124	-	4,124	9,027	18.80%
31-Mar-1974	8,652	165	241	9,058	640	6,966	-	6,966	16,664	10.58%
31-Mar-1979	14,875	168	164	15,207	640	10,833	-	10,833	26,680	12.02%
31-Mar-1985	26,311	542	177	27,030	1,095	14,460	-	14,460	42,585	9.94%
31-Mar-1990	41,236	2,343	165	43,764	1,565	18,307	-	18,307	63,636	9.89%
31-Mar-1997	54,154	6,562	294	61,010	2,225	21,658	902	22,560	85,795	4.94%
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-2007	71,121	13,692	1,202	86,015	3,900	34,654	7,760	42,414	132,329	5.19%
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-2014	145,273	21,782	1,200	168,255	4,780	40,532	31,692	72,224	245,259	10.77%
31 March 2015[3]	169,118	23,062	1,200	188,898	5,780	41,267	@35,777	77,044	271,722	10.8%

@*The break up of other renewable sources is small hydro (4,055.36 MW), wind power (23,444.00 MW), biomass power/Cogeneration (1,410.20 MW), Bagasse cogeneration (3,008.35 MW), waste-to-power (115.08 MW) and solar power*(3,743.97 MW)[10].

The planned additional thermal power generation capacity excluding renewable power during the last two years of the 12th plan period (up to March 2017) is nearly 84,000 MW.[11]

2.2 Captive power

The installed captive power generation capacity (above 1 MW capacity) in the industries is 47,082 as on 31 March 2015[3]. Another 75,000 MW capacity diesel power generation sets (excluding sets of size above 1 MW and below 100 KVA) are also installed in the country.[12][13] In addition, there are innumerable DG sets of capacity less than 100 KVA to cater to emergency power needs during the power outages in all sectors such as industrial, commercial, domestic and agriculture[14].

III. ELECTRICITY DEMAND IN INDIA

During the fiscal year 2014-15, the electricity generated in utility sector is 1,030.785 billion KWh with a short fall of requirement by 38.138 billion KWh (-3.6%) against the 5.1% deficit anticipated. The peak load met was 141,180 MW with a short fall of requirement by 7,006 MW (-4.7%) against the 2.0% deficit anticipated. In a May 2015 report, India's Central Electricity Authority anticipated, for the 2015–16 fiscal year, a base load energy deficit and peaking shortage to be 2.1% and 2.6% respectively[15]. Southern and North Eastern regions are anticipated to face energy shortage up to 11.3%. The marginal deficit figures clearly reflect that India would become electricity surplus during the 12th five-year plan period[16][17]. By the end of calendar year 2015, India has become power surplus country despite lower power tariffs [7][8].

Table 2 Demand and Supply in India

Region	Energy			Peak Power		
	Requirement (MU)	Availability (MU)	Surplus(+)/Deficit(-)	Demand (MW)	Supply (MW)	Surplus(+)/Deficit(-)
Northern	355,794	354,540	-0.4%	54,329	54,137	-0.4%
Western	353,068	364,826	+3.3%	48,479	50,254	+3.7%
Southern	313,248	277,979	-11.3%	43,630	35,011	-19.8%
Eastern	124,610	127,066	+2.0%	18,507	19,358	+4.6%
North-Eastern	15,703	13,934	-11.3%	2,650	2,544	-4.0%
All India	***1,162,423***	***1,138,346***	***-2.1%***	***156,862***	***152,754***	***-2.6 %***

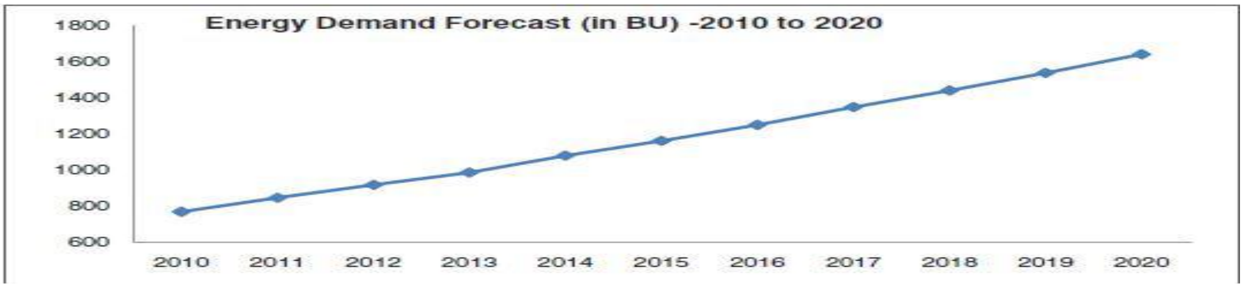

Fig. 2 Energy Demand Forecasting

If current average transmission and distribution average losses remain same (32%), India needs to add about 135 GW of power generation capacity, before 2017, to satisfy the projected demand after losses. McKinsey claims[18] that India's demand for electricity may cross 300 GW, earlier than most estimates. A demand of 300 GW will require about 400 GW of installed capacity, McKinsey notes. The extra capacity is necessary to account for plant availability, infrastructure maintenance, spinning reserve and losses.

IV. NON- CONVENTIONAL SOURCES OF ENERGY

Renewable energy in India is a sector that is still in its infancy. India's electricity sector is amongst the world's most active players in renewable energy utilization, especially windenergy[19].As of 31 Dec 2015, India had grid connected installed capacity of about 38.82 GW non-conventional renewable technologies-based electricity capacity, about 13.32% of its total.[20][21] For context, the total installed capacity for electricity in Switzerland was about 18 GW in 2009. As of August 2011, India had deployed renewal energy to provide electricity in 8846 remote villages, installed 4.4 million family biogas plants, 1800 microhydel units and 4.7 million square metres of solar water heating capacity. India plans to add about 30 GW of installed electricity generation capacity based on renewal energy technologies, by 2017.

Table 3 Capacity of various sources of Power

Type	Technology	Capacity (in MW)
Grid Connected Power		
	Wind	25088.19
	Small Hydel Power Projects	4176.90
	Biomass Power & Gasification and Bagasse Cogeneration	4550.55
	Solar	4878.87
	Waste to Power	127.08
Total - Grid Connected Power		***38821.59***
Off-Grid/Captive Power		
	Biomass (non-bagasse) Cogeneration	602.37
	SPV Systems (>1 kW)	289.01
	Waste to Power	146.51
	Biomass Gasifiers	188.87
	Water Mills/Micro Hydel	17.21
	Aerogenerator/Hybrid Systems	2.67
Total - Off-Grid/Captive Power		***1236.64***

V. SOURCES OF RENEWABLE ENERGY

5.1 Solar Energy

India is endowed with vast solar energy. The solar radiation of about 5,000 trillion kWh per year is incident over its land mass with average daily solar power potential of 0.25 kWh per m^2 of used land area with the available commercially proven technologies.[22] As of 31st Dec 2015, the installed capacity is 4878 MW [23]. India expects to install an additional 10,000 MW by 2017, and a total of 100,000 MW by 2022 [24][25]. Installation of solar power plants require nearly 2.4 hectares (6 acres) land per MW capacity which is similar to coal-fired power plants when life cycle coal mining, consumptive water storage & ash disposal areas are also accounted and hydro power plants when submergence area of water reservoir is also accounted. 1.33 million MW capacity solar plants can be installed in India on its 1% land (32,000 square km).

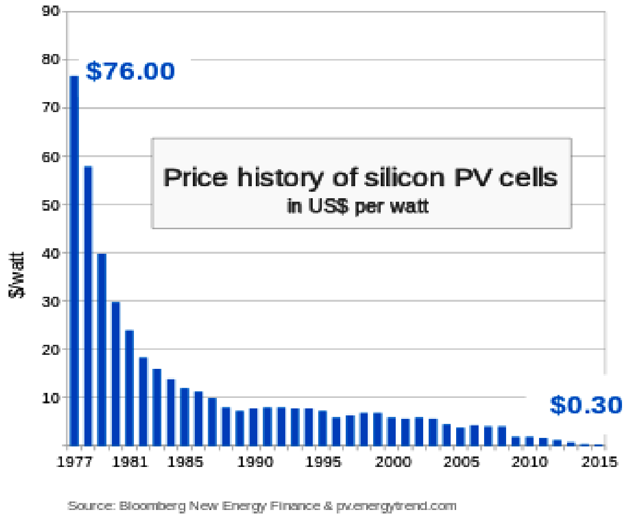

Table 4 Price history of solar PV cell

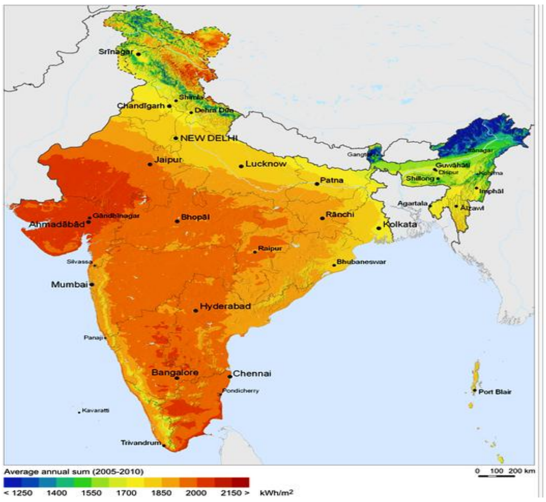

Fig.3 Intensity of Sun

5.2 Wind Energy

During recent years, theamount of energy produced by wind-driven turbines has increased rapidly due to considerable advancement in turbinetechnologies, making wind power economically compatible with conventional sources of energy. Wind energy makes up the major about 68 per cent [26] of the total renewable energy capacity installed in India.

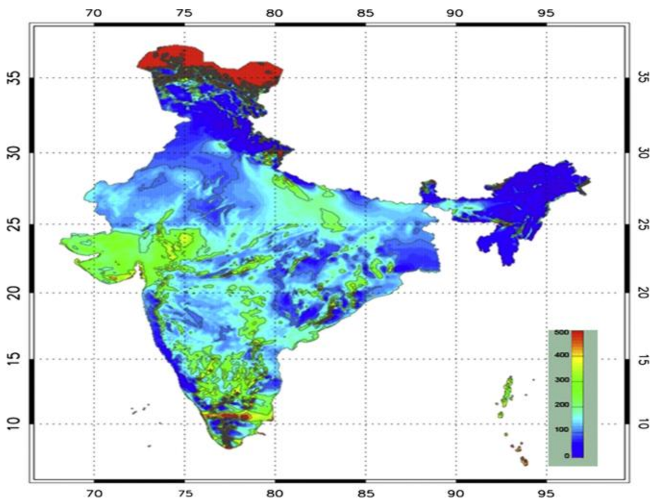

Fig. 4 Wind Power Density in India

5.3 Small Hydro Power

Hydro projects in India, which are under 25 MW in capacity, are classified as "small hydropower". The total installed capacity of SHP projects in India was 3,632 MW in March 2013. This is spread over 950 projects; hence, the average SHP project capacity is 3.8 MW.

5.4 Geo Thermal Energy

The Geothermal energy of the Earth's crust originates from the original formation of the planet (20%) and from radioactivedecay of minerals (80%). Geothermal energy comes fromthe natural heat of the Earth primarily due to the decay of the naturally radioactive isotopes of uranium, thorium andpotassium. Because of the internal heat, the Earth's surface heat flow averages 82 mW/m2 which amounts to a totalheat of about 42 million megawatts [27].

According to its property, geothermal energy can be divided into four types: hydrothermal field, geo pressured geothermal

resource, hot dry rock deposit and magma resource [28].The most promising geothermal fields in India are:

(i) NW Himalayas: Puga-Chumathang (Ladakh district, J&K) where a 1MWe plant is planned and Parbati Valley

with the Manikaran field in Himachal Pradesh where in 1992 a 5kWe geothermal binary cycle plant wassuccessfully run.

(ii) Central India: Tattapani region (Madhya Pradesh) where the installation of a 20MWe binary plant has been planned.[29]

5.5 Biomass

Biomass is a renewable energy resource derived from the carbonaceous waste of various human and natural activities.

It is derived from numerous sources, including the by-products from the timber industry, firewood, agricultural residuessuch as bagasse, crop straw, animal dung and wastes generated from agro-based industries. In India, a total of 4,449 MW has been installed under bio energy, both in grid connected and off-grid capacities.[30]

5.6 Ocean Thermal Energy Conversion

OTEC, Ocean Thermal Energy Conversion is an energy technology that converts solar radiation to electric power. Unlike wind and solar, the Plant Load Factor (PLF) of these plants may be around 80 percent. India has built a 1MW floating OTEC pilot plant near Tamil Nadu [31]. A pilot plant of capacity 14 MW is proposed to be set up in the State [32].

VI. EMERGING TRENDS IN RENEWABLE ENERGY

From 230MW in 2002-03 to over 17000MW in 2010-11, India's renewable energy sector has grown to over 40 times in the last decade [33]. India ranks fifth in the world in terms of installed wind capacity. India's National Action Plan on Climate Change(NAPCC) aims to achieve 15% share of renewable energy in the total installed capacity. The wind energy sector in India has shown a compounded growth of 50% over the last decade. Indian wind energy equipment exports stood at $975 million for the fiscal year 2009-10. Solar is the most abundant renewable energy. India has taken up the ambitious solar mission which aims to add 20000MW by 2022 in India's installed capacity. India currently has 1000MW of solar modules manufacturing capacity and 600MW of solar cell manufacturing capacity. In 1980 the Department of Non-Conventional Energy Sources was formalized [33]. Policies in India are increasingly focusing on Market Based Mechanisms to promote renewable energy. Government is following mechanisms like Performance Linked Incentives and Renewable Energy Purchase Obligations, etc

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Fig.5 Market mechanism

VII. IMPROVEMENTS IN RENEWABLE ENERGY

In all the available renewable energy sources wind energy and solar energy are the most preferred because of their omnipresent nature. In recent years a lot of research work is going on in the field of renewable energy and a lot of research papers are coming out. One improvement that has taken place in the field of renewable energy is the introduction of Hybrid Renewable Energy (HRES) [34].In general a Hybrid Renewable Energy System(HRES)can be defined as an energy system, which consists of two or more renewable sources , such that the power generated is more reliable and cost effective. It can be connected to grid or work in isolation and it may or may not have the storage capability or a conventional source in it. Typically the size of the HRES varies from few kW to hundreds of kW depending on the load it is serving . The HRES , with the capacity less than 5kW can be treated as the small systems, this kind of systems are generally used to serve the loads of a remotely located home or at electronic communication relay systems . Then the systems with the capacity more than 5kW and less than 100kW can be treated as the medium systems , these are used to power remotely located community which contains several homes and other required amenities . The medium systems in most cases work in stand-alone mode and sometimes may be connected to utility grid, if it is nearby. The other type of the system, which is capable to power a region, with the capability of more than 100kW can be called as the large system . These systems are generally connected to grid, to enable the power exchange between the grid and the system in case of surplus or deficiency [34].

VIII. RESEARCH ON HYBRID ENERGY SYSTEMS

For any hybrid system sizing of various systems is very much necessary to ensure the reliability of the supply while keeping the cost of the system low. The next section of this work includes the various size optimization techniques which are available in the literature and may be employed. For the proper operation of system a controller is required and converters play an important role in improving the power quality by reducing the effect of harmonics. Different controllers and converters for this purpose are discussed. Any system which is designed needs to be assessed for checking the proper functioning. As the sources are not predictable the system should work in the environment for which it may not be prepared to.

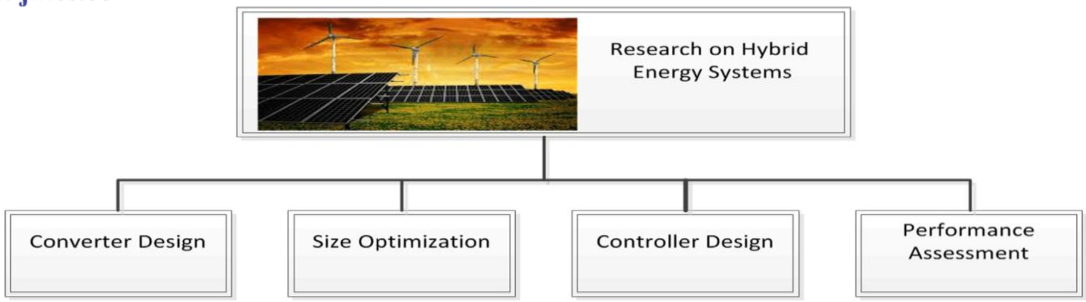

Fig.6 Research on Hybrid energy system

IX. UNIT SIZING OF PV/WIND HRES

A hybrid PV/wind system consists of a wind energy system, solar energy system , controllers , battery and an inverter for either connecting to the load or to integrate the system with a utility grid as shown in figure. Here, the solar and wind sources are the main energy sources, and the battery gets charged when the generated power is in surplus. And when the power demand is more than the actual generation the battery discharges and provides support for meeting the load demand. The performance of hybrid systems is mainly dependent on the performance of its individual components. For analyzing the system performance these components need to be modeled individually. The accuracy of individual component's model decides the accuracy of the entire system. Along with the models of the components, an understanding of local weather patterns and load patterns are very much important in optimal sizing of hybrid system.

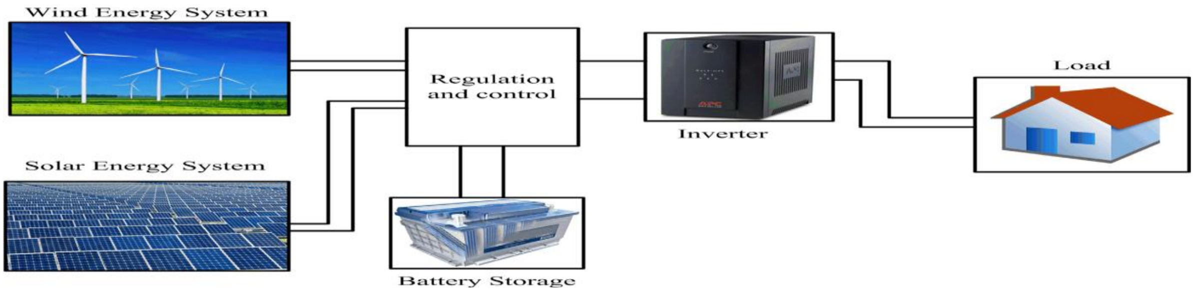

Fig. 7 Unit Sizing of HRES

X. MODELING OF HYBRID RENEWABLE ENERGY SYSTEM COMPONENTS

Various modeling techniques are developed by researchers to model components of HRES. Performance of individual component is either modeled by deterministic orprobabilistic approaches. General methodology for modeling HRES components likePV, wind, diesel generator, and battery is described below:

10.1 Modeling of Photovoltaic system

The input energy to PV system is solar radiation and total solar radiation on an inclinedsurface is estimated as [35]:

$$I_T = I_b R_b + I_d R_d + (I_b + I_d) R_r, \quad \text{...........(1)}$$

whereI_b and I_d are direct normal and diffuse solar radiations, R_d and R_r are the tilt factorsfor the diffuse and reflected part of the solar radiations.The total solar radiation thus estimated depends on position of sun in the sky, whichvaries from month to month. Hourly power output from PV system with an area Apv (m^2)on an average day of jth month, when total solar radiation of IT (kW h/m^2) is incident on [35]:

PV surface, is given by :

$$P_{Sj} = I_{Tj}\eta A_{PV}, \quad ....(2)$$

where system efficiency Z is given by [3]:

$$\eta = \eta_m \eta_{pc} P_f \quad ....(3)$$

and, the module efficiency Zmis given by [3]:

$$\eta_m = \eta_r[1 - \beta(T_c - T_r)], \quad ....(4)$$

whereZr is the module reference efficiency, Zpc is the power conditioning efficiency, Pf is thepacking factor, b is the array efficiency temperature coefficient, Tr is the reference temperature for the cell efficiency and Tc is the monthly average cell temperatureandcan also be calculated.

10.2 Modeling of Wind Turbine System

Power output of wind turbine generator at a specific site depends on wind speed at hubheight and speed characteristics of the turbine. Wind speed at hub height can be calculatedby using power-law equation [35]:

$$V_z = V_i \left[\frac{Z}{Z_i}\right]^x, \quad ....(5)$$

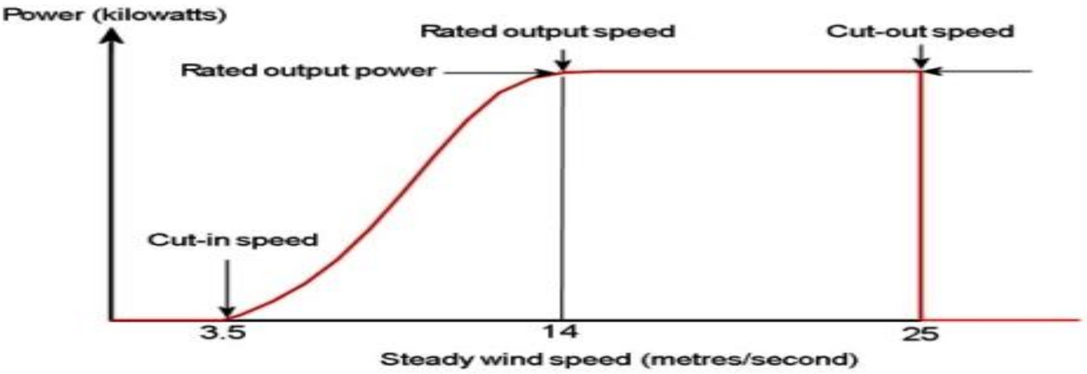

Fig. 8 Typical wind power characteristics Versus Speed

XI. RELIABILITY ANALYSIS

Due to the unpredictable nature of the power produced by a PV and wind energy system an analysis for the reliability plays a vital role for a hybrid system design. There are various methods for carrying out the reliability analysis; the loss of power supply probability(LPSP) is one of the widely used methodologies for this purpose. LPSP can be defined as the probability that loss of power supply occurs. Which means the combined hybrid system is unable to supply the power to the load. The mathematical form of the LPSP is given by [34]:

$$\text{LPSP} = \frac{\sum_{n=1}^{Tn} \text{time}(\text{if} P_{\text{supplied}} < P_{\text{demand}})}{T_h} \quad ....(6)$$

The system cost analysis also plays an important role in analyzing a hybrid system. There are several ways of performing system cost analysis; Levelized cost of energy (LCE),sometimes referred to as Levelised unit electricity cost, can be defined as, the ratio of total annualized system cost to the annualized energy generated by the system, given by [34]:

$$\text{LCE} = \frac{C_{A\_\text{total}}}{E_{\text{total}}} \qquad ....(7)$$

Several authors have used LCE for the cost analysis. Another important parameter used by the researchers is the annualized life cycle cost as presented , given by [34]:

$$\text{ALCC} = \text{CRF} * \text{LCC} \qquad ....(8)$$

where LCC is the life cycle cost, which is the total cost of equipment purchase and maintenance over its useful life by considering the influence of cost increment on the annual maintenance and running costs and CRF is called as the capital recovery factor given by [34]:

$$\text{CRF} = \frac{d(1+d)^t}{[(1+d)^t - 1]} \qquad ....(9)$$

where d is the discount rate and t is the life time of the project.

XII. CONCLUSION

The global energy consumption is rising rapidly. It is likely that environmental considerations will constrain the access to fossil fuels in the future. As a result, a part of the increasing energy demand is likely to be met by renewable energy sources i.e. solar power and wind power. In past we have been dependent on the perishable sources of energy but now we all need to take a step towards the production of energy from the non - conventional sources of energy like wind and solar energy. In India, The Ministry of Nonconventional Energy Sources, Government of India is attempting to electrify as many villages as possible with the solar photovoltaic system. The economically exploitable potential of the solar power technology of India is quite high.. Various research are been taking place day to day in this field like the HRES. Hybrid renewable sources have been widely appreciated all around the globe as the sustainable source for the future energy needs. Keeping this in mind, an extensive literature review on the stand-alone and grid connected PV/wind/battery hybrid energy system has been presented in this work. HRESs are mainly recognized for remote area power applications and are now a days cost-effective where extension of grid supply is expensive. Although, the cost and technological development of HRES in recent years has been encouraging, they remain an expensive source of power. HRES provides prospects of incorporating in power generation capacity to improve power quality, due to the dispersed generation. This integration results in increasing power value of conventional generation and also provides market for penetration of renewable energy systems. In order to introduce HRES in existing power supply network, in depth study is to be carried out to check feasibility and technical competitiveness. Penetration levels on network basis, is the future of hybrid power system in power generation capacity of the country, as outlined in this paper. Paper also, present future development, which will allow a further expansion of markets, both in developed and developing countries.

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