The Growth of Renewable Energy Sources and Review of Microgrids in Indian Perspective

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Abstract— **As a consequence of the excessive release of harmful gases (chlorofluorocarbons) by industries, thermal power plants, and vehicles, global warming has become a pressing issue. To mitigate the impact of global warming on our planet, there is a global shift towards green energy. Green energy refers to the energy generated from sources such as solar, wind, small hydro, biomass, etc. However, these sources are intermittent and unpredictable, making it challenging for the existing systems to provide a continuous power supply. To address this issue, extensive research has been conducted on renewable energy resources, leading to the development of hybrid microgrid system configurations. This paper aims to provide a comprehensive review of microgrids in India, highlighting their functional benefits, current renewable energy statistics globally and in India, climatic challenges, as well as the targets set by the world and India for harnessing renewable energy potential.**

Keywords— Review of microgrid system, achievements of renewable power, climatic challenges, functional benefits of the microgrid.

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1. INTRODUCTION

Sustainable living holds great significance for every individual on Earth. It is within our capacity as human beings to minimize our personal impact on the environment. As an Electrical Engineer, I am particularly inclined towards promoting green power. Green power refers to the generation of electricity through Renewable Energy (RE) Systems such as wind, solar, biomass, small hydro, ocean, and coal energy, among others. The advancement of these decentralized energy systems plays a crucial role in reducing carbon emissions, enhancing power quality, and improving reliability [1]. However, it is important to note that renewable resources like solar, wind, tidal, and ocean wave energy are intermittent in nature. This limitation has led to the development of hybrid renewable energy systems, which incorporate storage systems to enhance overall performance. This paper focuses on the concept of Microgrid, an energy system that combines multiple forms of energy generation and/or storage, or utilizes different types of fuel power generators with small power ratings. Microgrids have proven to be particularly beneficial for off-grid electrification. Over the past few decades, extensive research has been conducted worldwide in the field of renewable energy, encompassing feasibility studies, simulation models, control mechanisms, and experimental setups [2-15]. It is worth noting that 83.30% of people reside in rural areas [3], and in India alone, 244 million individuals live without access to electricity, as highlighted by the International Energy Agency's World Energy Outlook 2016.

India is renowned as a rapidly progressing nation with a substantial population. The provision of electricity plays a pivotal role in promoting various aspects such as healthcare, literacy rates, agriculture, and population management. To ensure the electrification of these regions, it is imperative to focus on power generation and distribution. However, the Indian power sector currently grapples with a significant challenge, as it experiences a considerable 26% loss of power during the transmission and distribution process [11].

Providing access to electricity in rural areas is crucial for the rapid development of countries. As of 2012, approximately a quarter of the population in developing nations lacked access to electricity, which translates to around 1.3 billion individuals worldwide. In Asia alone, this accounts for approximately 36% of the total population. However, it is projected that this figure will decrease to 16% by 2030. In India, only 74% of rural areas currently have access to electricity. Electrifying the remaining regions requires significant investments in energy generation, transmission, and distribution to remote areas. In recent years, there has been a global shift towards green energy sources. India, in particular, is well-suited for harnessing solar, wind, and small hydropower. In fact, around 40% of India's land area is suitable for wind energy generation..

In 2014, the Indian government introduced fresh initiatives aimed at producing 175GW of power from renewable sources by 2022. Furthermore, India has pledged to achieve a 40% share of non-fossil fuel electricity by 2030. To accomplish this, approximately 200GW of renewable capacity and 51GW of nuclear capacity will be incorporated by 2030. The specific targets are outlined in the table below:

TABLE I: TARGETS OF INDIAN RENEWABLE ENERGY SYSTEMS

S. No	source	Power in GW
1	Solar energy	100
2	Wind energy	60
3	Biomass	10
4	Small hydropower	5
5	Total power	175GW

* Source SECI

In order to reach the desired goal, an extra investment of $189 billion and increased effort are necessary. The Indian Government should take the lead in collaborating with state governments to implement programs aimed at generating renewable electrical energy in remote rural areas [15].

2. RENEWABLE ENERGY STATUS

A) Renewable Energy Status in World

World climatic conditions:

The United Nations Framework Convention on Climate Change (UNFCCC) aims to address the effects of the increasing greenhouse gas emissions, as highlighted in the Intergovernmental Panel on Climate Change (IPCC) Report. According to the report, these emissions are projected to increase by 25% to 90% by 2030 compared to the levels in 2000. Consequently, the Earth's temperature has already risen by 3 degrees Celsius, and it is expected to further increase by 1 to 2.5 degrees Celsius. The UNFCCC is working towards finding solutions to mitigate these effects.

Framework Convention on Climate Change made one framework for each country to make significant progress to
[8-9]:

- Set targets for the world to reduce our greenhouse gas emissions fast enough to limit global warming to the safe level of 1.5 degrees.
- Invest in 100% clean energy, particularly using local grids so it reaches those in poverty beyond the reach of national electricity grids.
- Support more sustainable, low emission agriculture, to stop communities from going hungry and help them cope better with more floods and droughts caused by climate change.

Renewable Energy:

Renewable energy plays a crucial role in the continuous transformation of the world's energy sector. A significant number of countries, approximately 175, have set their targets for green energy [3-4], [14]. Moreover, nearly 150 nations have implemented new policies to support investments in various renewable technologies. Figure 1 illustrates the global power capacity additions from both renewable and non-renewable sources between 2001 and 2015..

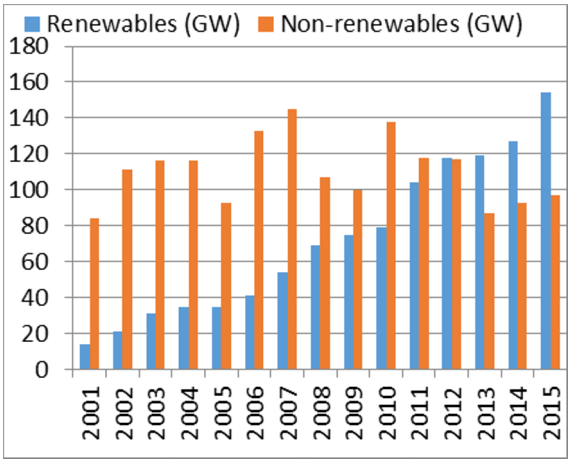

Figure 1: RE and Non-RE installation growth from2001-15.

Due to the rapid advancement of renewable energy systems, a wide array of advantages will be realized, including environmental, employment, and social benefits. Asia, particularly China's solar industry, accounts for 60% of renewable energy employment. The top five countries in terms of power generated through solar PV are Germany (38250MW), China (28330MW), Japan (23409MW), Italy (18622MW), and the US (18317MW). Across the globe, a total of 24100TWh of electrical energy is generated, with 76.5% (18436.5TWh) coming from non-renewable sources and 23.5% (5663.5TWh) from renewable energy systems. As of 2015, the global electricity generation stands at 24100 TWh, with 76.5% being non-renewable and 23.5% being renewable. Figure 2 illustrates the power generation from different types of renewable energy systems. The cumulative capacity of hydropower is projected to increase by an additional 119 GW by 2022. By 2050, hydropower has the potential to double its contribution, reaching a global capacity of 2,000 GW and generating over 7,000 TWh..

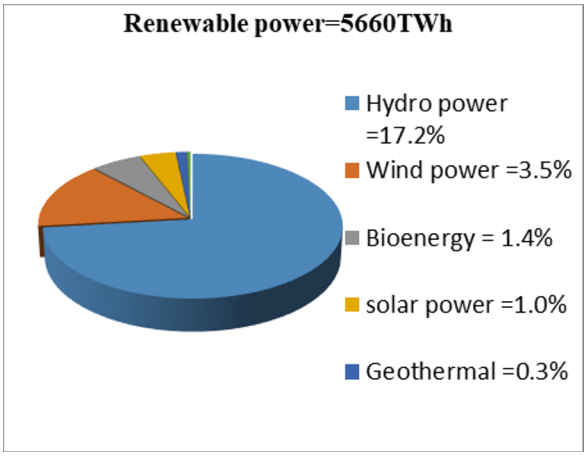

Figure.2: Power generation with RE across the world in percentages.

This achievement, driven primarily by the quest for clean electricity, could prevent annual emissions of up to 3 billion tonnes of CO2 from fossil-fuel plants.

World Renewable power capacity and annual growth rate 2001-2015 shown in figure 3.

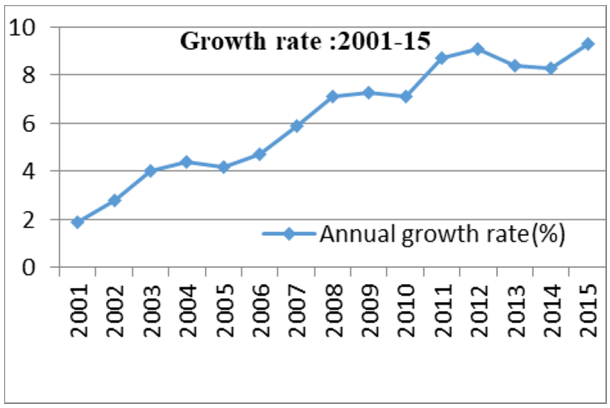

Figure.3: The annual Growth rate of RE across the world from 2001-2015.

B) Renewable Energy Status in India

India possesses a diverse climate, characterized by multiple seasons and a tropical environment. It boasts an extensive coastline spanning approximately 7516.6 kilometers, along with 2094 kilometers of Island Territories, making it highly suitable for the generation of renewable energy. A climate that maintains a consistent temperature of 18 degrees Celsius (64 degrees Fahrenheit) throughout the year is referred to as an in-exsiccated or tropical climate. India has a substantial energy potential of around 900 gigawatts (GW) from commercially viable sources, including wind power (100 GW at a minimum height of 80 meters), small hydropower (20 GW), bioenergy (25 GW), and solar power (750 GW), utilizing 3% of the available wasteland from the mainland, which spans 5422.6 kilometers. The Ministry of New and Renewable Energy (MNRE) serves as the central governing body responsible for all matters related to new renewable energy. It actively promotes the implementation of MNRE-initiated programs, encompassing renewable power, energy access for rural and urban areas, lighting, cooking, water heating, motive power, electrification, as well as industrial and commercial applications.

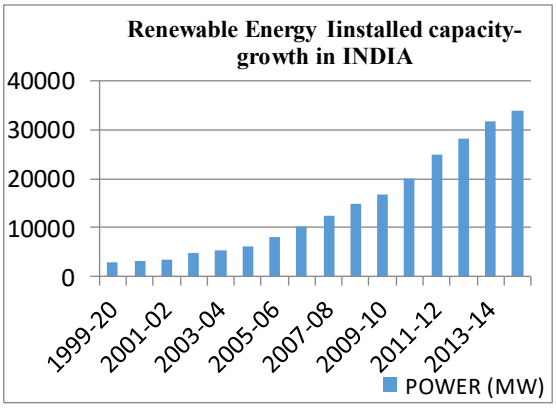

Figure.4: RE system Installation growth in India from 1999-2014.

The current (June 2018) installed capacity of Indian conventional and non-conventional energy systems shown in below table.

TABLE II: INSTALLED CAPACITY OF INDIAN ENERGY SYSTEMS [2]

S.NO	Type of Sources	% of Installed capacity	Total percentage (%) & Power in MW
1	Wind Solar Small Hydro Bio-mass Waste to energy	9.9 6.7 1.29 2.51 0.04	20.4% = 70,648.61MW
2	Diesel Nuclear Hydro Gas Coal	0.24 1.95 13.1 7.2 57	79.6% = 2,74,846.01MW

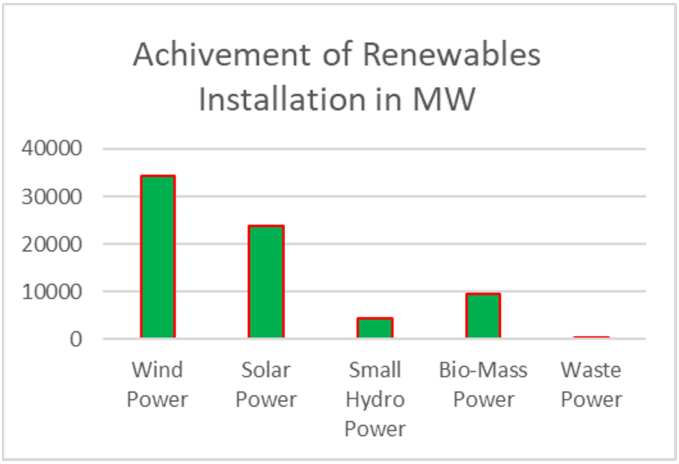

Figure.5: RE system Installation achievement in India up to July 2018.

The Government of India has implemented several schemes to promote village and rural electrification, such as the Jawaharlal Nehru National Solar Mission, Deendayal Upadhyaya Gram Jyoti Yojana (DUGJY), and Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY). These initiatives have resulted in approximately 1.1 million households utilizing solar energy to fulfill their daily energy requirements. In India, the solar power capacity has reached 6500MW, with an average cost of approximately 73USD/MWh. The installation capacity for renewable energy has been consistently increasing each year to meet the predetermined targets set for 2022. The growth rate since 1999 is depicted in figure 4, while the progress of renewable energy installation up until July 2018 is illustrated in figure 5 [1]..

India has taken the initiative to reduce the intensity of greenhouse gas emissions in its GDP by 20 to 25 percent from 2005 levels by the year 2020. This commitment was voluntarily made by India during the 20th conference of the parties to the United Nations Framework Convention on Climate Change (UNFCCC) held in Lima, Peru..

3. MINIGRID INITIATIVES AND ITS FUNCTIONAL BENEFITS

A) Minigrid Initiatives In India

The Indian Government is actively promoting the establishment of microgrids by private and state government energy development agencies in order to achieve their ambitious targets by 2022. Financial assistance in the form of grants and subsidies is provided to support these initiatives [10], [12-13]. Here are a few examples of existing microgrids:.

a) *Rice-husk power-based microgrids in Bihar:*
In the state of Bihar, there are currently 80 microgrids powered by rice husks, with a total capacity of 32 kW. These microgrids provide a daily power supply of 30 watts to approximately 48 villages, benefiting around 32,000 families. The cost for this power supply is Rs. 100 per month..

b) *Dhanai solar city*: A solar-powered microgrid with a capacity of 100 kW has been implemented to provide electricity to approximately 350 households at a rate of 12-14 rupees per kW per month..

c) *Decentralized energy systems of India (DESI) power*: In the states of Bihar and Madhya Pradesh, solar and biomass plants with a capacity of 260 kW provide electricity to 450 households in the villages at a unit cost of approximately 5 rupees.

d) *Solar electricity company (SELCO) foundation*: SELCO, a non-profit and public charitable trust headquartered in Bangalore, has successfully implemented solar-powered mini-grids in several rural communities across India.

e) *Biomass power plant in Karnataka:* The 500KW biomass power plant, located in the vicinity of Kabbigere village, Thovinakere gram panchayat in Karnataka state, is currently providing electricity to a cluster of five villages, each comprising a minimum of 80 households.

f) *Uttar Pradesh New and Renewable Energy Development Agency (UPNEDA)*: The organization, Mero GAO Power (MGP), has successfully implemented solar-based microgrids in 27 districts of Uttar Pradesh, India. These microgrids provide electricity to households and commercial establishments in remote locations. The pricing structure includes a fixed charge of Rs. 50 along with monthly energy charges. MGP is responsible for the construction, ownership, and operation of these microgrids, which cater to the lighting, heating, and charging needs of villages in off-grid areas. With a customer base of over 20,000 households and a population of 1 lakh people, MGP has established a robust and impactful business model..

g) *Sikkim Renewable energy development agency:* Sikkim possesses abundant hydro resources, making it one of the states with vast hydro assets. In the southern, northern, and western regions of Sikkim, there are microgrids such as the 10 kW Karek micro-hydro, 20 kW Ghor micro-hydro, 7 kW Banjhakri micro-hydro, and 25 kW Biri Khola micro-hydro, which have been installed and funded by MNRE. These microgrids are owned by a state agency and provide electricity to 92 households, government schools, and commercial loads at affordable tariffs..

h) *Chhattisgarh Renewable energy development agency (CREDA):* In India, the state of Chhattisgarh has achieved success in electrifying approximately 30,000 households through the implementation of 500 kW Solar PV off-grids. These households are charged a fixed rate per home, making this project a notable accomplishment.

i) *West Bengal Renewable energy development agency (WBREDA):* Solar, Wind, and Biomass-powered microgrid initiatives have been effectively implemented within the capacity range of 25 kW to 500 kW, providing electricity to around 22 villages at an affordable rate. Additionally, the organization has constructed hybrid microgrids that cater to more than 2000 customers residing in remote regions, encompassing villages located in the Sundarbans and Bengal Tiger reserve.

j) *A Solar Smart Microgrid project in Rajasthan:* In March 2012, a microgrid powered by a 40 kW solar PV system was established in Khareda Lakshmipura, Rajasthan. This microgrid successfully brought electricity to remote villages, providing power for essential needs such as lighting, fans, and mobile charging. Additionally, a wireless monitoring system was implemented, with a monthly charge ranging from Rs. 75-100.

k) *Orissa Renewable energy development agency (OREDA):*
The state Orissa is having different types of tribal The lives of the community residing in remote forest lands have been significantly impacted. The initial funding for the establishment of the first microgrid in Nuapada District was provided by the United Nations Development Programme (UNDP). Subsequently, the MNRE and OREDA contributed funds in a 9:1 ratio. As a result, a total of 1100 villages have been electrified, with 60 villages having individual solar homes for electricity. Additionally, small rating microgrids ranging from 2 to 4.5 kW,

equipped with battery backup, have been installed, with a minimum monthly charge of Rs. 10 - 30.

B) FUNCTIONAL BENEFITS OF MICROGRID**:**

Microgrids possess numerous discernible and measurable benefits that define their operational methods and capabilities. They serve as an empowering technology for meeting the planning and operational requirements of modern dynamic distribution systems, offering intelligent features at both the aggregate DER and distribution system levels [6].

- Addition and installation of DERs near the load.
- Diminishing the total power changes on the dispersal grid.
- With enriched reliability and operating efficiency, irrespective of grid-connected or isolated distribution systems are reconfigured.
- Empowering market cooperation of DERs introduced inside the microgrid.
- Enabling customers and end consumers

Quantifiable benefits can be employed in the development of a business case for establishing microgrids. A commercial occasion can be founded on one or multiple of the subsequent benefits:

- Improving the dependability of the power supply to end consumers
- Corresponding power quality to end consumers desires
- Giving auxiliary services to the grid, voltage, and frequency including voltage and frequency related services
- Bringing down the carbon impression
- Improving grid stability

Improving energy security and flexibility of the distribution grid utilizing local energy resources.

4. CONCLUSION

This document presents the data on greenhouse gas emissions and their impact on global climate conditions. Additionally, it highlights the objectives and strategies to alleviate the adverse effects of greenhouse gas emissions through the use of renewable energy sources (RES). In India, solar microgrids have been implemented for rural electrification at affordable rates. The Indian government has launched various initiatives in line with the IPCC and UNFCCC to achieve the country's 2022 targets through the deployment of 175GW of renewable energy. Notably, there has been a significant increase in renewable energy installations worldwide and in India over the past decade

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