“INTEGRATION OF RENEWABLE ENERGY INTO THE INDIAN GRID”

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By

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CANDIDATE DECLARATION

I, ***KHUSHBOO RANI (Roll No. R21ET2PS0007)*** solemnly declare that the work embodied in this M.Tech Dissertation Part-II Title ‘’***INTEGRATION OF RENEWABLE ENERGY INTO THE INDIAN GRID***” is my own bonafied work carried out and I want to pursue this work in my final semester thesis.

I declare that to the best of my knowledge and belief matter embodied in this Thesis idea has not been submitted for the award of any other degree, diploma or certificate in this university or any other university in India or abroad.

I further declare that I have faithfully acknowledged, given credit to and referred to the authors/researchers wherever their works have been cited in the text and body of my work. I have not will fully lifted up para, text data, results from some others work reported in journals, books magazines, reports, dissertation, etc or available at websites or e- resources and included them in my work and cited as my own work.

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1 INTRODUCTION

1.1 BACKGROUND AND MOTIVATION

India is the third largest energy-consuming country in the world. It has become one of the largest sources of energy demand growth globally and has made significant progress towards its universal electrification target for residential users, with 100 million people gaining access in 2018 alone. Per capita electricity consumption across the 28 Indian states and eight union territories is still around a third of the world average, and is expected to continue increasing despite the government's intention to pursue strong energy efficiency standards, including LED lighting, efficient cooling and building standards. Total Indian electricity demand has begun to expand again following a significant decline in 2020 due to Covid-19. The pandemic has affected the financial viability of the electricity distribution companies (DISCOMs), which were already struggling with mounting debts and a liquidity crunch.

India faces three principal challenges: (1) how to expand reliable energy access and use while maintaining affordability for consumers and financial stability for the DISCOMs; (2) how, at the same time, to integrate increasing shares of renewable energy in a secure and reliable manner; and (3) how to reduce emissions to achieve ambitious social and climate objectives while meeting economic goals.

Renewable energy penetration is highly variable by state in India. The share of solar and wind in India's ten renewables-rich states (Tamil Nadu, Karnataka, Gujarat, Rajasthan, Andhra Pradesh, Maharashtra, Madhya Pradesh, Telangana, Punjab and Kerala) is significantly higher than the national average of 8.2%. Solar and wind account for around 29% of annual electricity generation in Karnataka, 20% in Rajasthan, 18% in Tamil Nadu and 14% in Gujarat (financial year [FY] 2020/21). India's renewables-rich states already have a higher share of variable renewable energy (VRE) than most countries internationally. As a result, many states are already facing system integration challenges.

Furthermore, in the coming decade the Indian power system is due to undergo an even more profound transformation. The government plans to increase renewable generating capacity from 175 GW in 2022 to 450 GW in 2030. Some state leaders have expressed concern that they will face excess VRE generation and the need to: (1) export significantly more power to other states; (2) allow renewables to displace some coal power plants locally; or (3) curtail more solar and wind to ensure system security. Recent trends underlying the main renewables integration challenges include the increasing variability of hourly demand, increasing ramping requirements due to the impact of solar on net demand, short-term frequency variations and local voltage issues.

While the Power System Operation Corporation (POSOCO), a wholly owned public sector undertaking under the Ministry of Power, highlighted that national-level inertia has declined slightly from the 2014 level at certain times, India does not yet face system inertia challenges. However, with future increases in solar and wind power, the renewables-rich states will experience periods when wind and solar make up the majority of generation, and it will then become imperative to monitor local system strength and inertia requirements. The report covers important international experience in managing systems with declining inertia levels.

1.2 OBJECTIVE

The primary objective for deploying renewable energy in India is to advance economic development, improve energy security, improve access to energy, and mitigate climate change. Sustainable development is possible by use of sustainable energy and by ensuring access to affordable, reliable, sustainable, and modern energy for citizens. Strong government support and the increasingly opportune economic situation have pushed India to be one of the top leaders in the world's most attractive renewable energy markets. The government has designed policies, programs, and a liberal environment to attract foreign investments to ramp up the country in the renewable energy market at a rapid rate. It is anticipated that the renewable energy sector can create a large number of domestic jobs over the following years. This paper aims to present significant achievements, prospects, projections, generation of electricity, as well as challenges and investment and employment opportunities due to the development of renewable energy in India. In this review, we have identified the various obstacles faced by the renewable sector. The recommendations based on the review outcomes will provide useful information for policymakers, innovators, project developers, investors, industries, associated stakeholders and departments, researchers, and scientists.

1.3 DELIMINATION OF RESEARCH

Furthermore, in the coming decade the Indian power system is due to undergo an even more profound transformation. The government plans to increase renewable generating capacity from 175 GW in 2022 to 450 GW in 2030. Some state leaders have expressed concern that they will face excess VRE generation and the need to: (1) export significantly more power to other states; (2) allow renewables to displace some coal power plants locally; or (3) curtail more solar and wind to ensure system security. Recent trends underlying the main renewables integration challenges include the increasing variability of hourly demand, increasing ramping requirements due to the impact of solar on net demand, short-term frequency variations and local voltage issues.

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1.3 BENEFITS OF RESEARCH

1) A Fuel Supply That Never Runs Out

As the name suggests, renewable energy is created from sources that naturally replenish themselves – such as sunlight, wind, water, biomass, and even geothermal (underground) heat.
Unlike the mining of coal, oil, and natural gas – which requires extensive networks of heavy machinery, processing stations, pipelines, and transportation – renewables convert natural resources directly into electricity. And while many fossil fuels are becoming harder and more expensive to source – resulting in the destruction of natural habitats and significant financial losses – renewable energy never runs out.

2 Zero Carbon Emissions

Perhaps the most significant benefit of renewable energy is that there are no greenhouse gasses or other pollutants created during the process. Whereas coal power plants create around 2.2 pounds of CO_2 for every kilowatt-hour of electricity – solar panels and wind turbines create none at all.
As we race to decarbonize our world and embrace energy sources that don't contribute to global warming, renewables are helping to provide us with emission-free energy, heat, cars, and even air travel.

3 **Cleaner Air and Water**

Burning fossil fuels to generate electricity does far more than warm the climate; it also contaminates the air we breathe and the water we drink.
Coal power stations, for example, release high volumes of carbon dioxide (CO_2) and nitrous oxide (N_2O) directly into the atmosphere – two of the most potent greenhouse gasses. But in addition, they also emit mercury, lead, sulfur dioxide, particulates, and dangerous metals – which can cause a host of health problems ranging from breathing difficulties to premature death. Fossil fuel electricity can also contaminate waterways, both from air pollution that falls to the ground during rain, and waste materials created during the production process.
On the other hand, renewable energy creates no pollution, waste, or contamination risks to air and water. And while the COVID-19 lockdowns gave us a glimpse of clear skies in major cities all over the world, renewable energy has the potential to make clean air the new normal.

4. A Cheaper Form of Electricity

With the rapid growth of renewable energy over the last ten years, solar and wind power are now the cheapest sources of electricity in many parts of the world. In the United Arab Emirates – an area well-known for its abundant land and sunny weather – a new sun farm recently secured the world's lowest price of solar energy at just 1.35c per kilowatt-hour.
The dramatic decline in solar and wind costs has even led to many fossil fuel multinationals – including the six major oil companies – to focus on renewable energy investment instead. And whereas green energy was once a "clean-but-expensive" alternative – it's now helping to reduce energy bills for people all over the world.

5. Renewable Energy Creates New Jobs

With an increasing focus on global warming and many governments setting ambitious carbon-reduction goals, one of the surprising renewable energy advantages is that it has quickly become a major source of new job growth. In America, renewables now employ three times as many people as fossil-fuels, and the Bureau of Statistics predicts that wind turbine technicians and solar panel installers will be some of the fastest-growing jobs over the next decade. And in addition to keeping millions of people in work over extended periods – many renewable energy jobs also pay above-average wages.

2.LITERATURE SURVEY

2.1 LITERATURE REVIEW

Wind power, solar power and water power are technologies that can be used as the main sources of renewable energy so that the target of decarbonisation in the energy sector can be achieved. However, when compared with conventional power plants, they have a significant difference. The share of renewable energy has made a difference and posed various challenges, especially in the power generation system. The reliability of the power system can achieve the decarbonization target but this objective often collides with several challenges and failures, such that they make achievement of the target very vulnerable, Even so, the challenges and technological solutions are still very rarely discussed in the literature. This study carried out specific investigations on various technological solutions and challenges, especially in the power system domain. The results of the review of the solution matrix and the interrelated technological challenges are the most important parts to be developed in the future. Developing a matrix with various renewable technology solutions can help solve RE challenges. The potential of the developed technological solutions is expected to be able to help and prioritize them especially cost-effective energy. In addition, technology solutions that are identified in groups can help reduce certain challenges. The categories developed in this study are used to assist in determining the specific needs and increasing transparency of the renewable energy integration process in the future.

2.2 INFERENCES DRAWN FROM LITERATURE REVIEW

Renewable energy technology is widely covered in the literature and clearly various challenges still exist. The review carried out in this study aims to map the challenges of VRE by describing what technology solutions are appropriate to overcome these challenges. The approach taken in this paper is the analysis of data from the literature used to compile and map the list of technology solutions and challenges based on their interrelations, and to identify any lack of consistency and classify challenges to VRE. This approach aims to distinguish the observed symptoms, e.g. performance characteristics that change. Furthermore, this analysis is complemented with information from several experts to strengthen and ensure more accurate results. The findings on challenges and their linkages to technology solutions are also discussed. The relevant implications for policymakers and companies are presented in the next section. The main contribution of this review is to provide up-to-date information and useful knowledge in the deployment of RET so that energy access across the country can be improved. The systemic approach within an RE framework for information on important components of the RE ecosystem is a feature of this article.

3 PROBLEM FORMULATION AND PROPOSED MEDHOLOGY

3.1 INTRODUCTION

Power system transformation in India will be supported by the transformation of electricity demand from passive consumption to more proactive participation by demand sectors. Agricultural users already play an important role in balancing power supply and demand through involuntary irrigation load shifting, and the IEA analysis foresees more active participation from the agricultural sector, buildings (including cooling) and industry by 2030.

The existing agricultural demand shift from high to low demand hours already provides a significant source of low-cost power system flexibility in India, and has assisted some states in reaching high levels of solar and wind penetration without major system events. This shift has been largely enabled by the availability and use of existing distribution networks dedicated to agricultural users in certain states, which allow the system operator to control irrigation loads without impacting other grid users. Looking ahead, transitioning from involuntary agricultural demand shift to proactive agricultural demand response (e.g. active response to a price signal) can be one of the most cost-effective solutions to improve power system flexibility, although its use must be balanced against the potential impact on the water stress of each region.

3.2 PROBLEM STATEMENT

Most states are concerned about the future role of existing coal-fired power plants. Coal plants are expected to operate less as renewable technologies supply more generation, which leads to reduced revenues. At the same time, to operate flexibly and meet stricter emissions standards, some coal plants may also require further investment. Such investment needs to be weighed against investment in flexibility sources in other parts of the system (storage, demand and grids) and emission reduction targets. Government officials are also concerned that historical dependence on long-term power procurement contracts as the tool for ensuring capacity adequacy creates an economic burden by locking in long-term fixed capacity payments to coal power plants.

3.3 DEFINITION OF PROBLEM STATEMENT TERMS

Energy Storage

The first of the seven challenges to consider is the issue surrounding efficient, affordable, and reliable energy storage. Historically, one of the major problems with renewable energy generation is that supplies are far more variable than other means of energy generation. Fluctuations in sunlight levels and wind mean that supplies are less consistent than those derived from fossil fuel plants. Owners, therefore, require batteries to store energy for later. And to even out discrepancies in the energy supply.

Economic and financial challenges

Perhaps one of the biggest challenges faced by the renewable energy sector is economics. Specifically, the financial issues involved in bringing renewable technologies and renewable energy to the masses.

Political Challenges

Inextricably linked with economic concerns are the political challenges of the transition to renewables. Political posturing, isolationism, popularism, and anti-science rhetoric threaten the renewable energy sector. As authorities in certain countries continue to take great strides in the right direction, other jurisdictions are being left behind.

Infrastructure Challenges

Wholesale, widespread use of renewables to meet the energy demand is essential. But the transition will be harder to achieve due to the lack of reliable large-scale energy grids in several developed nations. In the Western world, there is a huge and troubling infrastructure gap. Like other forms of infrastructure, energy infrastructure is, in many regions, shockingly underfunded, poorly maintained, and insufficiently stable or resilient to meet the demands of the future.

As the requirement for renewable energy continues to grow – due to growing domestic use, increased electric vehicle uptake, and industrial transition – the insufficiency of many electric grid systems will become an ever more apparent barrier to renewable energy uptake at scale.

Land Use

One of the other challenges for the renewable energy sector is balancing the demands for energy with other land-use requirements[1]. In a world where natural resources are increasingly strained, land use is often a significant point of contention. Which land should we use for farms full of solar panels and wind turbines? How can we balance this need with the need for land for housing, food production, flexibility, etc.

Industry – The Next Frontier for Renewable Energy

The problem in decarbonizing the industry is that energy transition pathways are not yet clearly defined. Things are changing – fast. Air pollution and environmental pollution in various forms continue to degrade our ecosystems. We strain our land and resources as never before.

The industrial sector is an economic powerhouse on a global scale, and yet also a major contributor to greenhouse gas emissions. The decarbonization of the industrial sector is crucial to meeting the targets of the Paris Climate Agreement and limiting global warming to no more than 2 degrees C. above the pre-industrial temperature.

Manufacturers have scaled up solar photovoltaic modules and other renewable energy technologies, thereby reducing their costs in recent years. Industry, by comparison, lags far behind. Less innovation and cost reduction have taken place in this arena, with the majority still relying on fossil fuels or natural gas, so the path for*Technical Challenges***

Yet this is not the only challenge posed by industry decarbonization. Technical reasons also make it more difficult to reduce CO2 emissions within this arena. We cannot alter 45% of emissions from feedstocks by a change in fuels, only by changes to processes.

Using alternative fuels such as zero-carbon electricity to generate the high temperatures required for the processes in the target sectors would be difficult. It would need significant changes made to the furnace design.

Industrial processes are highly integrated, so any change to one part of the process would have a knock-on effect and require further changes. Since production facilities have long lifetimes, changing processes would require extensive (and costly) rebuilds or retrofits.

Energy is central to industry decarbonization. Completely decarbonizing the industrial processes in the main industrial sectors will, of course, have a major impact on the energy system.

Research by McKinsey estimates that it would require around 25-55 EJ per year of low-cost, zero-carbon electricity. At present, in a business-as-usual world, the industry only needs 6 EJ per year. It is clear that decarbonization would lead to a significant increase in long-term electricity requirements

A collaborative approach from the public and private sectors is what has resulted in economies of scale, progress, cost reduction, and scale-up in renewable energy development. We now require the same thing for industrial decarbonization. The energy transition and industry decarbonization must go hand in hand. It is also clear that this will be one of the major challenges for the renewable energy sector moving forwards.

Public Perception

Economic realities further add to the challenge of the decarbonizing industry. Cement, steel, ammonia, and ethylene (the industrial products that account for the majority of carbon emissions) are commodity products, and the cost is a decisive consideration in purchasing decisions

There is not currently a willingness to pay more for sustainable products, so companies that decarbonize will be the ones who have to foot the bill, finding themselves at an economic disadvantage.

This brings up the last of these major challenges for the renewable energy sector: public perception. Public willingness not only to intellectually agree with but to financially support the energy transition for industry and utilities towards renewable electricity is crucial.

3.4 PROPOSED WORK

Through the recent development of power conversion technology and changes in the environment of the power industry, microgrid-based systems are recognized as latest version of power systems. With the increasing interest in environmental protection in the country, there is a growing interest in using various renewable energy sources. Many researchers have presented different optimizations and integrated energy source frameworks. Some of them are given as follows:

Kumar and Majid [15] provided an overview of the current status and challenges of renewable energy for development in India. They summarized many different reports and provided statistics on current trends, prospects, and opportunities in India's energy sector. Furthermore, they projected the consumption and production status in India as well. Installed capacity and demand also describe the investment and contribution of different sources. They suggested the comprehensive policies and regulation framework required for integrating renewable energy resources.

Meyabadi and Farajzadeh [16] provided the theoretical directions for optimization and planning for long-term power systems. They analyzed the photovoltaic and wind energy against the parameter availability and usability. Furthermore, they presented an overview of PV and wind energy in Shaanxi city and framed a plan against different parameters. It has been determined to avoid abandoning wind or PV and to promote the integration of different energy sources.

Worighi et al. [17] proposed a smart grid architecture. The proposed architecture consists of the smart grid controller, ESS, large scale integration, transmission, renewable energy system, distribution, and service provider. They tried to balance the demand-supply equation. In order to implement the proposed architecture, MATLAB/SIMULINK is used. They demonstrated the architecture using the system of system technique. For analyzing the system with load, they consider the intermittent duties as well as short-term duties of machines.

Cinar and Kaygusuz [18] described a large-scale internet data center using the stochastic optimization technique. An enhanced technique to minimize the electricity cost was proposed. The method's goal is to change the power consumption of electronic devices. Moreover, the study has also explained the dependencies and operating time effects.

Jiang and Wu [19] focused to minimize the peak load through the Min-Max objective function. A method prevents system outage but limited to small scale. However, this technique only works to reduce cost. The scheduled electronic devices are scheduled at the unscheduled time. A technique with peak load minimization as an objective function is proposed. Efforts have been made to balance power use, but it has a limitation that does not take into account the inconvenience of time.

These optimization algorithms are likely to explore the optimal global solution, but they have several problems in dealing with the algorithm's constraints of convergence time, accuracy, and complexity.

3.5 Conclusion

The main contributions of this research article are as follows:

(i)This article provides the critical *factors of nonconventional energy* sources

.(ii)This article also provides the vital components for managing the energy and forecasting the load.

(iii)The key point of this article is to propose a smart framework for a smart grid that can maintain power quality and availability.

(iv)The study not only simulate the framework but also performs the comparative analysis of the proposed framework with available existing latest research.

(v)This article also marks the work progress for future researchers who are seeking opportunities in this field.

Renewable Energy Resources

The energy is collected from various resources such as wind, wave, tide, and solar which are available naturally. The energy collected from these sources is converted into the desired energy with the help of transducers and electronic circuits [3].

A photovoltaic or solar cell, where the sunlight is fallen on the P-N junction, has a voltage across this junction. It has a two-layer structure consisting of a P-type semiconductor, known as the base, and an N-type semiconductor, known as the emitter. On the cell's periphery, an anti-reflection coating is coated so that incident light does not reflect. Metal contacts are provided at the surface for the electrical connection, depending on crystal solar cell efficiency described in the form of Table 1

Sr. no	Material	Efficiency (%)
1	Mono crystalline silicon cell	15–18
2	Poly crystalline silicon cell	14–16
3	Amorphous silicon cell	6–8

There should be a value for the wind. The generation of the power is performing at a specific wind speed. Below the rated speed, no power output will be obtained. The max power is obtained from wind power generation [4]. There are some limits to any system.

0<_Pw(t)<-Pw(maxt)

While collecting the energy from a wind turbine, there is a limit to the power generated from the wind power system.where *P* is wind energy and upper limit of generation from this source is P^{max} with respect to time. In particular, when renewable energy sources are included, the available power sources for power generation on a per-grid basis may differ due to environmental factors, so it is necessary to integrate and operate them [5].

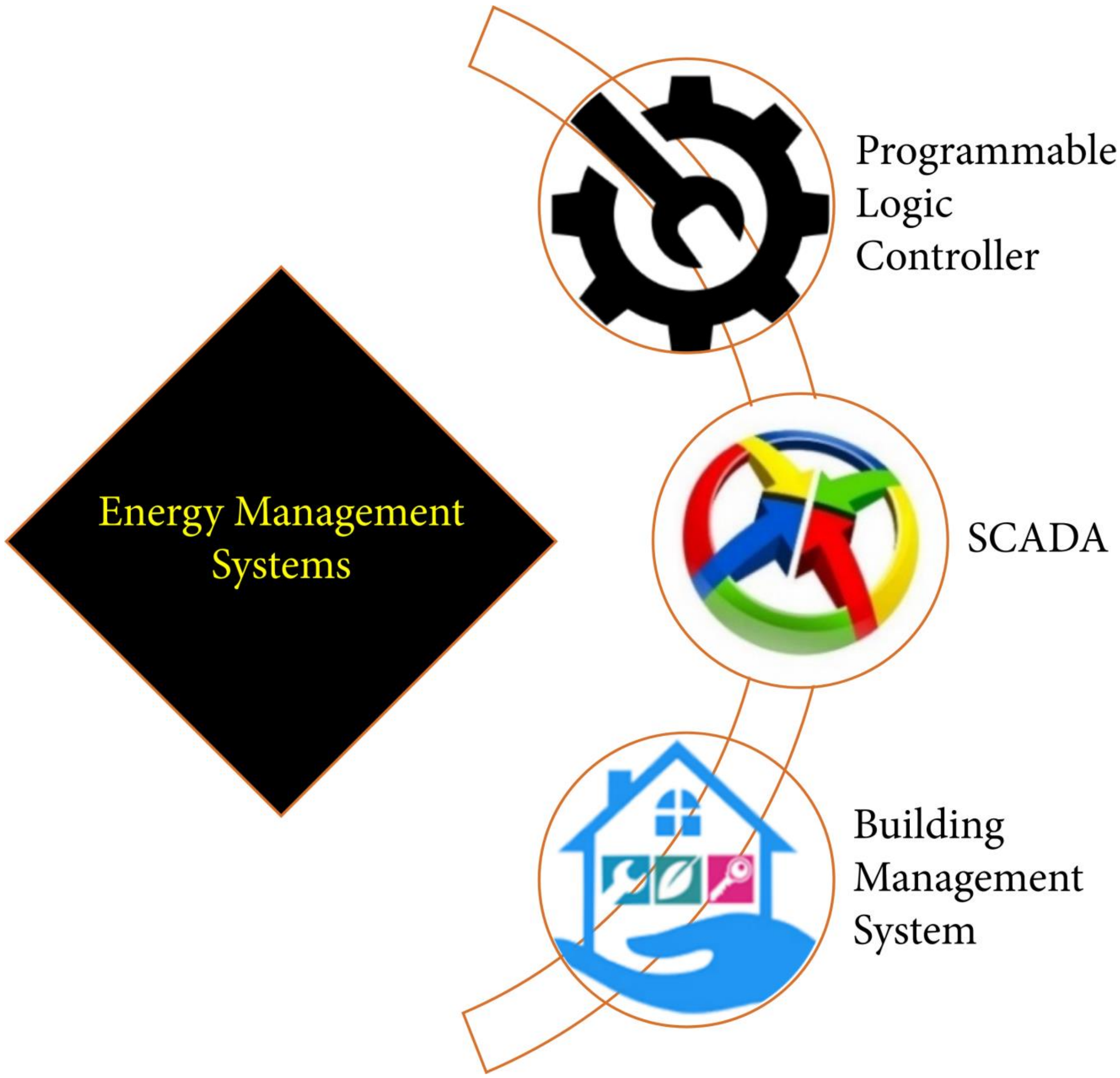
Management of Energy

Integrating of energy (solar, wind, hydro, storage system, etc.) improves the smart grid's capability to fulfill the demand of energy. Integration is applied, or the different energy sources are summed up; some challenges such as frequency and waveforms have arisen. Furthermore, intelligent technologies are used to overcome such challenges to make the system intelligent, efficient, secure, and stable [6]. The system may be identifying the brownout periods due to the unexpected availability of solar and wind.

Maximum Load = Diversity Factor * Connected Load

However, the present research focused on the sophisticated framework, algorithm, and model to reduce blackout, brownout, and energy costs [7]. The maximum demand is calculated using equation (2) [8], where connected load is referred to summation of all active equipment connected at time *t*

Most of the appliances were manual and followed basic automation control system techniques. Nevertheless, in today's hex, the Internet of Things (IoT) has become an excellent evolution for making systems smart and automated. Several information and communication technologies in the grid make the grid operation fast, secure, and efficient. The electrical energy converted from renewable, nuclear, fossil fuels, and other sources can be mapped with the help of energy management tools [9], as described in Figure 1. The tools mostly used to manage the energy are shown in the following figure:

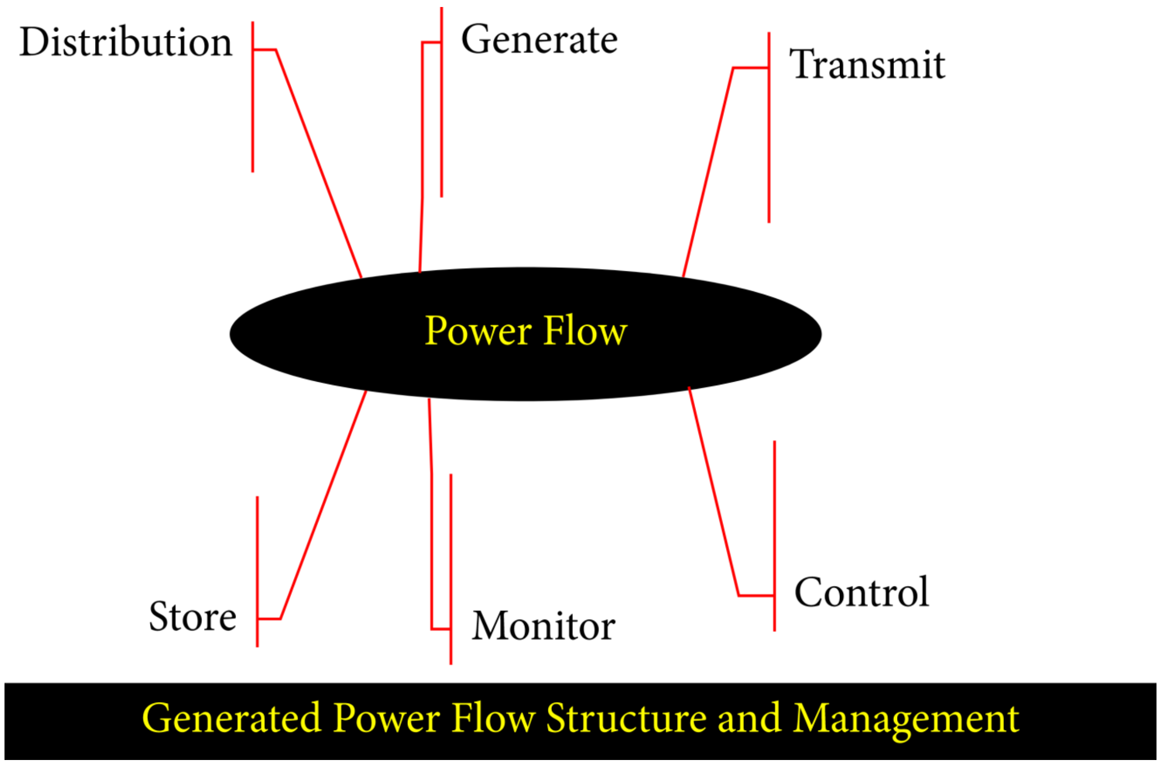


These tools help us out to monitor, control, and manage energy [11]. These tools can implement the tariff plans, demand-supply calculations, and mapping of the circuits [12].

IoT in the Smart Grid

The traditional grid is one-way communication, but the smart grid emphasizes to adopt smart technologies. The internet-based smart grid ensures the power quality and availability of the power. The electrical grid is a network of electrical generation, transmission, and distribution, like the internet, which is a network of networks [13]. The internet-enabled smart grid makes it easy to monitor, control, and operate the grid functions.

Figure 2 shows the power flow management along with its associated operation i.e., old pattern (generate, transmit, and distribute) and latest pattern (control, monitor, and store). After the introduction of IoT, power can be monitored and controlled easily [14]. Traditionally, after generation of power, it can be transmitted and distributed in a usable manner. The technology provides storage for later use after conversion of energy.



The rest of the article is organized as follows: Section 2 deals with the literature review of load optimization and cost minimization. Section 3 discusses about the implementation parameters, configurations, and constraints. Section 4 emphasizes on the proposed work along with the implementation and comparative analysis. Finally, Section 5 concludes the study.

4. Methodology

4.1 Introduction

The Government of India has been consolidating the grid integration of distributed solar energy and electrical storage to reach its national targets for renewable energy capacity.

Approach

The project works in the following areas:

- Supporting the Indian Ministry of New and Renewable Energy (MNRE) in developing options and models that allow a high share of renewable energy within the total electricity mix, especially with regard to rooftop solar power stations
- Identifying and supporting selected prominent cities for the development of a roadmap to power cities completely with renewable energy and set up demonstration projects.
- Support Discoms (electricity distribution companies) to enable a transformation towards a low-emission, climate-compatible energy supply.

4.2 Implementation Strategy (Flowchart, Algorithm etc.)

The steps taken by the Central Government to facilitate Renewable Energy (RE) integration in the National Inter-connected Grid include :

1.
    i. Construction of Intra-State and Inter-State transmission systems for evacuation of Renewable power.
    ii. Transmission plan for integration of more than 500 GW RE capacity by 2030 has been prepared.

iii. Setting up of Regional Energy Management Centers (REMCs) for better forecasting of renewable power and to assist grid operators to manage variability and intermittency of renewable power.

2.

iv. lnnovative products like Solar-Wind Hybrid Projects, RE projects with energy storage systems and supply of RE power balanced with power from non-RE sources launched to reduce intermittency.

3.

v. Flexibility in generation and Scheduling of Thermal/Hydro Power Stations through bundling with Renewable Energy and Storage Power.

4.

vi. Implementation of Green Term Ahead Market (GTAM) and Green Day Ahead Market (GDAM) for sale of renewable energy.

5.

vii. Waiver of lnter-State Transmission Charges on transmission of electricity generated from Solar and Wind.

(b). Following steps, inter-alia, have been taken to ensure that DISCOMs clear their dues to Power Generation Companies:

1.

i. Ministry of Power vide its Order No. 23/22/2019-R&R dated 28.06.2019 has made it mandatory for Distribution Licensees/Procurers of Power to open and maintain adequate Letter of Credit (LoC) as Payment Security Mechanism under Power Purchase Agreements (PPAs). As per the said Order, National Load Despatch Centre (NLDC) and Regional Load Despatch Centre (RLDC) would dispatch power only after it is intimated by Generating Company and/or Distribution Companies that LoC for the desired quantum of power has been opened.

2.

ii. Ministry of Power has notified Electricity (Late Payment Surcharge and Related Matters) Rules, 2022 on 03.06.2022 in order to ensure payment discipline in the power sector value chain. These Rules entail obligations upon the DISCOMs to clear their legacy dues as existing on 03.06.2022, in a time bound phased manner in equated monthly installments with benefits of non-applicability of late payment surcharge after 03.06.2022. However, failure to repay the installment of legacy dues in accordance with the Rules would invite Late Payment Surcharge (LPS) on the entire outstanding amount. The LPS Rules also provide penal framework to ensure time bound clearance of current dues and establishment of Payment Security Mechanism as provided in PPA through disincentives of progressive withdrawal of open access as well as power regulation if the provisions of the Rules are not followed. DISCOMs can avail loans from PFC Ltd. and REC Ltd. to clear their legacy dues to Generating Companies.

(c) : Government from time to time have conveyed to States that contracts must be honoured. The Standard Bidding guidelines for Solar, Wind and Hybrid Projects have specific provision for termination compensation in case of unilateral termination of PPA. The guidelines also provide for a three-tier payment security mechanism by way of Letter of Credit, Payment Security Fund and Tri- Partite Agreement (between the State Government, Reserve Bank of India and Government of India).

d. **:** Ministry of New and Renewable Energy (MNRE) has undertaken various awareness programmes about the benefits of renewable energy through electronic, print and social media.
e. **:** Under Rooftop Solar Programme of MNRE, 4.3 Lakh beneficiaries have installed solar panels on their rooftop.

4.3 Tools/Hardware/Software to be used

Software tools for IRES RET Screen RET Screen is an Excel based clean energy management software tool that helps the energy planners and decision makers to determine the technical and economic viability of renewable energy potential, energy efficiency and cogeneration projects. It is a most widely used tool for performing the feasibility studies in IRES and is freely downloadable software developed by Ministry of Natural Resources, Canada. It uses visual basic and C language as platform and was released in the year 1988. This software can be accessible in more than 30 languages and has two separate versions RET Screen 4 and RET Screen plus. In this software, there are a number of worksheets available for performing project analysis including modeling, analysis, optimization, etc. RET Screen has certain limitations which includes data sharing problems, limited options for search and retrieval features, etc. HOMER Hybrid Optimization Model for Electric Renewables

(HOMER) is user friendly, freely available and most widely used software, which was developed by National Renewable Energy Laboratory (NREL), USA in the year 1993. Is uses visual C++ as a programming language. Suresh and Meenakumari, 2018. Software tools for analyzing the integration of various renewable energy systems ©2018 The Authors. Published by G J Publications under the CC BY license. 137 HOMER uses the inputs like resource availability, manufacturer's data, component costs, etc and generates the list of feasible configurations based on the Net Present Cost (NPC). It also displays a variety of tables and charts along with graphs which helps the user to compare the various configurations and analyze them based on their economic merits. HOMER has fewer disadvantages which includes, allowing single objective function for minimizing NPC, does not considering depth of discharge (DOD) of battery, etc [11].

HYBRID 2 HYBRID 2 was developed by Renewable Energy Research Laboratory (RERL) in University of Massachusetts, USA along with National Renewable Energy Laboratory, USA in the year 1996, whereas HYBRID 1 was developed in the year 1994. It uses Microsoft Visual basic as a programming language and uses a Microsoft Access database. HYBRID 2 is a probabilistic/time series based computer model which uses statistical model to analyze the performance of IRES. HYBRID 2 consists of four parts namely Graphical User Interface, Simulation Module, Economics Module and Graphical results Interface. iHOGA Improved Hybrid Optimization by Genetic Algorithm is a C++ based hybrid system

optimization tool developed by University of Zaragoza, Spain. This software uses solar PVs, WTGs, MHPs, fossil fuels, etc for modeling the IRES with either single or multiobjective function for optimization. It has two versions namely PRO+ and EDU. Some of the limitations of iHOGA includes, it can simulate within a total average daily load of 10kWh [12].

INSEL Integrated Simulation Environment Language was developed by University of Oldenburg, Germany which allows the users to make a structure with the help of its library with a specified execution time. INSEL is a modular simulation environment which offers more than a conventional simulation program. This software can be used to understand, plan, monitor and visualize the energy systems. It supports the users with datasets for PV modules, thermal collectors and meteorological parameters, which is fully compatible with MATLAB and Simulink. This software is not most widely used, which is under continuous improvement during the last 2 decades.

TRNSYS Transient Energy System Simulation Program was jointly developed by University of Wisconsin and University of Colorado in the year 1975. Initially, this software was developed for thermal systems simulations and later it has been promoted to include solar PV systems and some other energy systems along with thermal systems. It allows the user to program in FORTRAN code, which does not provides optimization of energy sources, but it can be used for carrying out the simulation part in designing the renewable energy systems. TRNSYS 17.0 was released during the year 2010 and TRNSYS 17.1 was released during the year 2012.

EMPS EMPS is (EFI's Multiarea Power market Simulator) is a computer tool developed for forecasting and energy planning in electricity markets. It has been actually developed for simulating and optimizing the hydrothermal energies with hydro power. It also considers the transmission constraints and hydrological differences between two areas. Its main objective is to minimize the total expected cost of the whole systems considering all the constraints like fuel cost, cost of energy, emissions, etc. EMPS software can also be used for analyzing the overflow losses, calculating energy balances, forecasting electricity prices, scheduling of power, etc

EnergyPLAN EnergyPLAN is a computer model designed for performing energy system analysis. It is a deterministic model which can optimize the operation of a given energy system based on the inputs and outputs defined by the users. It was developed and maintained by Sustainable Energy Planning Research Group at Alaborg University, Denmark in the year 2000. It simulates the operation of national energy systems on hourly basis including all the energy sectors. The main advantage of EnergyPLAN tool is that it aids to design and develop the 100% renewable energy systems. Suresh and Meenakumari, 2018. Software tools for analyzing the integration of various renewable energy systems ©2018 The Authors. Published by G J Publications under the CC BY license. 138 HySim

HySim is a hydrological simulation model which can uses rainfall and potential evaporation datas to simulate and execute the hydrological cycle on a continuous basis. It can use data on rainfall, potential evaporation, snow melt and abstractions from discharges, etc. It is also flexible in terms of sub catchments and the reaches for outflow routing can be either channels or reservoirs. The main advantages of HySim are: useful for predicting long term rainfall and data, flow naturalization, flood studies, etc.

SolSim SolSim was initially introduced in Germany by Fachhochschule Konstanz for integrating the renewables like solar PV, wind turbines, DG sets, biogas and biomass energy systems. It performs economic analysis with limited control options and uses large amount of data to perform the simulation of IRES. Nowadays, SolSim is not widely used to perform the energy generating options. Hybrid Designer Hybrid Designer was developed and initially used by the Energy and Development Research Centre of University of Cape Town in South Africa for simulating the renewable energy models in off grid mode employing genetic algorithm concepts for minimizing the net present cost of a system. SOMES Simulation and Optimization Model for Renewable Energy Systems (SOMES) was developed in the year 1987 at Utrecht University, Netherlands. It can simulate hourly basis energy generating options with an average electricity production from renewable energy sources. Also, it can perform optimization of leveled cost of energy from the combination of various energy sources [13].

SOLSTOR SOLSTOR was introduced by Sandia National Laboratory in the year 1980s to perform the simulation, optimization and economic analysis of integrated renewable energy systems. It can minimize the life cycle cost of energy by choosing optimum number of solar panels, optimum tilt angles, and optimal wind energy system components. It can be suited for both on grid and off grid applications, but it is not widely used by the researchers for simulating the energy systems.

iGRHYSO iGRHYSO (improved Grid Connected Renewable Hybrid System Optimization) is an improved version of GRHYSO, uses C++ as the platform for optimizing the energy systems. It can simulate and perform the analysis to find the net present cost at low value. It has an advantage over other simulation softwares that the effect of temperature on solar photovoltaics, effect of wind velocity in wind power generation can be taken into account .

HybSim HybSim was developed by Sandia National Laboratory for performing the economic analysis of a remotely located area, wherein the energy demands were met out by the renewable energy sources along with the conventional fossil fuel generators. It requires detailed load demand profile along with weather characteristics, solar radiation, wind velocities, etc. IPSYS Integrated Power System tool, sometimes called as IPSYS uses C++ language as the platform for simulating the various energy sources for a remote located area. It is possible to simulate the various energy sources like solar PV, wind energy generators, micro hydropower plants, biogas reservoirs, biomass plants, etc. ARES Autonomous Renewable Energy Systems (ARES) is a program developed by Cardiff School of Engineering, University of Wales, UK for performing the simulation and analysis of solar-wind-battery based energy systems. It can calculate the LPSP (loss of power supply probability) based on the input datas provided by the user. It employs a separate subroutine program for each of the sources considered. It is not widely used. Other software based studies for IRES Among the various simulation software discussed above, many of the researchers were using HOMER for simulating the integrated renewable energy systems with various parameters and constraints. In the field of IRES, Suresh and Meenakumari, 2018. Software tools for analyzing the integration of various renewable energy systems ©2018 The Authors. Published by G J Publications under the CC BY license. 139 apart from computer based simulation software like HOMER, RET Screen, etc for integrating the renewables, some of the conventional methodologies like artificial intelligence, multiobjective design, analytical approach, iterative technique, probabilistic approach, graphical construction method, etc were used. Artificial Intelligence Approach Artificial Intelligence approaches includes artificial neural networks, genetic algorithms, particle swarm optimization, biogeography based optimization, ant colony optimization, fuzzy logic control were mostly used by the researchers and energy planners to simulate and analyze the various renewable energy systems. Multi Objective deign In multi-objective design approach, there are two common approaches used, ie. One approach is to merge all the individual objective functions into a single composite and the second one is an entire Pareto optimal solution set is to be determined. A solution is said to be pareto, if the obtained solution is dominant over the other solutions obtained. A pareto optimal solution cannot be improved with regards to any objective without deteriorating at least one objective. Iterative approach An iterative approach uses a recursive program which ends when the optimum system design is obtained while evaluating the performance of integrated renewable energy systems. In this methods, the system cost is minimized either by linearly changing the values of parameters or by linear programming techniques.

Analytical Method In analytical method, Computational models are being used for characterizing each of the components of integrated renewable energy systems to find the feasibility of the system. Hence, the effect of feasibility can be improved by changing the blocks inside the computational models in each of the considered components. Also, the best configuration of integrated renewable energy system is evaluated by comparing single or a multiple performance index of the different configurations. Probabilistic approach While modeling the integrated renewable energy systems, the effect of insolation, change in temperature, changes in wind speeds were taken into account by using the probabilistic based approaches. But, this optimization technique cannot characterize the dynamic changing performance of the system considered. Graphical Construction method In graphical construction method, only two decision variables were considered for optimization i.e, either solar and battery or SPV and wind turbine. But it does not considers the parameters like the number of SPV modules, tilt angle, wind velocity, wind turbine installation height, etc [14

4.4 Expected Outcome (Performance metrics with details)

In the 1920s, when electricity was being extended to all households of the United States, one Tennessee farmer commented on this transformation, saying: “The greatest thing on earth is to have the love of God in your heart, the next greatest thing is to have electricity in your home”.1 Throughout history, the provision of affordable and reliable electricity has been one of the keys to transforming lives for the better. India has taken remarkable strides in this regard in recent decades, with electricity shortages declining and connectivity approaching 100 percent of households. However, there is still a long way to go. India’s per capita electricity consumption is some 900 kWh, as against a world average of almost 3000 kWh. Electricity generation is also the largest contributor to India’s energy-related CO_2 emissions, and a major contributor to local air pollution and other environmental problems. Can India grow its electricity consumption and transform the lives of its citizens, without a concomitant worsening of its environmental footprint? In recent years, a positive answer to this question has been emerging, as the costs of renewable energy have fallen precipitously. However, renewables have problems: they only produce when the sun is shining or the wind is blowing. Does this intermittency condemn renewables to always be a small-time player in the Indian electricity mix? This question has not been sufficiently studied in the Indian context, with both proponents and detractors of renewable energy tending to treat it only superficially. The Energy Transitions Commission India (ETC India) project aims to provide a thorough and scientific answer to these questions. This summary paper presents the main findings of the three detailed technical reports on how India can grow the share of renewables in its electricity system by 2030

4.5 Conclusion

Modern electricity systems must balance electricity demand and supply at every instant, and at every location. To continuously match supply with demand, system operators must: • Reserve some powerplant capacity to replace energy lost if a powerplant or transmission line suddenly fails, or to meet an unexpected surge in demand. • Ramp (increase) output fast enough to meet expected sharp increases in demand, such as when the sun sets and consumers turn their lights on at once. • Balance daily demand and supply over the course of each day, for example balancing high solar output at midday against solar output's rapid decline to zero as the sun sets. • Balance seasonal supply and demand to meet seasonal cycles, for instance, when cold winters or hot summers drive up electricity demand, or windy monsoon seasons drive up wind and hydro electricity supply

CHAPTER 5 RESULT & DISCUSSION

If India is to increase the flexibility of the power system, it is not just a question of investing in new power plants. I Increasing flexibility needs can be met cost effectively and reliably using a combination of investment, incentives and technologies that: • Change how and when consumers use energy (demand-side management and demand response) • Increase the flexibility of power generation (supply-side flexibility) • Encourage development of new energy storage options (storage)

To assess the potential scale and cost of integrating demand, supply and storage-based flexibility options, the project has developed a series of "supply curves" for meeting each of the aforementioned flexibility needs. The figure below shows the example of the supply curve to meet daily balancing needs (e.g. to shift excess solar production to the night through storage, or shift demand to times of excess solar production). The quantum of daily balancing that can be obtained by each option is represented by the width of each block on the horizontal axis, its cost by the height of the block. India has substantial potential supply of daily balancing, exceeding the estimated average need of 870 GWh/day by 2030. Demand measures and existing hydro provide the cheapest means of meeting this particular need, for example through cycling the output of hydro to balance the daily cycles of solar output, or shifting agricultural pumping to the daytime to match the output of solar. If, on the other hand, demand-side flexibility cannot be tapped at scale, other options such as supply-side flexibility and storage would be required to a greater degree.

CHAPTER6 CONCLUSION& FUTURE SCOPE

The objectives are to provide grid observability, controllability of assets, enhance power system performance and security, reduction in operating cost, maintenance and system planning. To accommodate a wide variety of generation centralized and distributed, intermittent and dispatchable. To communicate with energy management system in smart buildings to enable customers to manage their energy use and reduce their energy cost. To provide improved power quality to the users. To provide real time information, lower operation cost and electricity available to everyone. To use information technology for monitoring and control to optimize its capital and operational cost. To predict and instantly respond to system problems in order to avoid power outages and power quality problems. To make the nation energy independent. To provide employment. Smart Grids is not felt to be a necessity only for the integration of distributed generation, renewable energy sources and plug-in (hybrid) cars into the electricity grid but also for active participation of consumers for improvements in overall system efficiency, meet the peak demand without investment in generation and variable pricing system.

Renewable Energy Sources (RES) are increasing rapidly in the electrical grid due to the reduced dependency on conventional energy resources and the high demand of power to meet the requirements. The microgrid can be used to integrate renewable energy resources and the Energy Storage Systems (ESS) efficiently. Industries such as manufacturing, transportation and communication have significantly increased the demand of electrical energy [1]. To meet this high energy demand, RES play a crucial role. The usage of RESs is critical as they are abundant in nature, eco-friendly, scalable and can be applied in industrial, commercial, agricultural and residential areas [2]. However, RES are non-dispatchable and exhibits poor load following. The successful implementation of ESS can overcome these limitations. There are several options to store the energy generated from RES: batteries, flow batteries and supercapacitors. Supercapacitors have capabilities more than conventional capacitors and secondary ion batteries.

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