Demand Side Management in Micro Grids Integration

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Abstract

The intermittent nature of renewable energy is the principal drawback of grid integration of decentralized energy resources necessitating the development of intelligent energy management systems aimed at increasing power system reliability and improve efficiency. Demand Side Management (DSM) in microgrids refers to alteration of the way and when consumers use electricity aimed at matching demand and supply, which is vital in balancing mostly the variable renewables and fluctuating demand to keep the local grid stable, and economical. Demand-side management refer to effective tools employed in managing renewable energy to enable consumers to actively monitor and control their energy usage, leading to significant cost savings by minimizing peak time grid consumption and improved overall efficiency. The DERs constitute many different technologies like diesel engines, micro turbines, fuel cells, photovoltaic, small wind turbines, among others using local energy resources which require a coordinated operation and control involving variable sources, controllable loads and storage devices, including batteries. This study examines demand side management as a strategy for micro grid integrating of distributed and decentralized energy resources. The Integration of distributed Energy Resources (DERs) into GRIDS provide several benefits, like enhanced reliability better power quality, and enhanced energy independence. However, this integration is associated with multiple technical challenges in terms of grid stability, quality of power, and the need for robust control and communication system. To enhance power system performance, it is crucial to address the issue of low efficiency by intelligently integrating energy sources or functional smart grids. Increasing the efficiency of the power system using traditional methods is difficult, hence the intelligent energy management offered in demand side management programs lead to improved power system reliability, cost-effectiveness, and enhanced power system stability. Enhancing reliability and cost-effectiveness is the primary goal of demand-side-based energy management. The use of traditional energy management systems, it is challenging to enhance power system performance hence the need to address low-performance power systems by intelligently integrating energy sources or functional smart grids.

Key words: decentralized generation, sustainable energy; distributed generation

I. INTRODUCTION

A leading challenge with renewable energy planning and integration into the grid is the intermittence management and customer demand uncertainties attributed to changes in weather and resource availability. The emergence of distributed generation and micro grids and state-of-the-art optimization techniques enable control of cost and reliability objectives[1]. Micro grids, fueled by renewable energy sources and managed by smart grids offer higher reliability, cost effective and more efficient energy systems. The integration of Distributed Energy Resources (DERs) into micro grids involves the use small-scale energy sources, conversion technologies, and storage systems to form a controllable power system. Micro grids either operate independently, or are connected to the main grid, which improves the reliability and grid resilience. The integration of renewable energy systems into microgram especially in rural areas and in underdeveloped countries is important to advance sustainable energy systems.

The flexibility of local energy generation and energy use has increasingly become relevant for planning energy systems having high share of renewables, electrification, and decentralization. The integration of distributed energy resources (DERs) into micro grids presents immense opportunities and challenges for the improvement of power system efficiency, reliability, and sustainability. The intermittence and variability, of variable renewable sources, is the main challenge to grid stability, while enhancing grid resilience, increased uptake of renewables and reduction of transmission and distribution losses, as well as creation of new business models are the opportunities presented by decentralized generation. Methods available for increased integration of renewable energy to micro

grids include the use of grid scale storage, integration of the cellular approach in the energy system planning and operation, use of virtual power plant concepts, use of V2G technologies and electrification of transport, application of demand side measures, use of smart grid features and infrastructure in micro grids (Smart micro grids) by upgrading the traditional grids and micro grids, the use of dc micro grids and application energy management and optimization tools and techniques and micro grid operation[1].

The integration or interconnection of distributed energy resources is an evolving power sector scenario globally on the significant issues, like fossil fuel scarcity, widespread deployment of advanced Distributed Energy Resources (DERs) technologies, deregulation in power sector, and growing awareness on environmental impact of traditional electric power generation[2]. Decentralized generation has opened up new opportunities as well as challenges in power generation and distribution markets, as small-scale non-conventional systems become attractive in the generation of electricity with limited environmental impacts, highly efficient and easy to install, and operate with increased power system reliability[3]. With increasing awareness on environmental impacts like global warming and impacts, the renewable energy sources have become important in modern power systems. The different political, social, geographical, financial and environmental, factors in different national create opportunities for renewable and sustainable energy resources like solar, wind, geothermal, and biomass resources[4, 5]. Additionally, low power generation capacity of DER generate incentives for integration of multiples sources and loads to create micro grid for better power generation capacity, reliability and marketability of the micro sources aimed at reducing the load congestion on the conventional power system or utility grid and enable localized generation close to point of use by customers[6],[7].

The versatile nature of decentralized systems influences the effective integration of DERs that have the potential to support the traditional power systems in terms of interconnections. As a result, the IEEE P1547- 2003 has become a benchmark model for interconnecting DERs with Conventional Electric Power System. The standard provides guidelines for interconnection like the response to abnormal conditions like , power quality, and safety conditions like operation in utility grid connected and islanded mode[4]. IEEE Std 1547-2003, published in 2003, was the first standard in the IEEE 1547 series that established uniform criteria and performance requirements for the interconnection of distributed resources (DR) with electric power systems (EPS). This standard addressed key issues in integrating distributed power resources by providing requirements for safety, performance, operation, and testing at the point of common coupling

To balance the demand and supply, micro grids can be designed to trade energy and ancillary commodities to the electric grid. During the isolated mode, the micro grid is usually disconnected from the main grid; hence, customers get the electricity from DERs connected to the micro grid alone. The integration of DERs into a distribution network creates new opportunities for technical, legal, and economic methods for safe and efficient operation. The integration of DERs ito the distribution network enhances its flexibility enabling the distribution system to supply supplementary services power transmission systems. It is advantageous to integrate distributed systems having enhanced functionality, and deploy measuring and analysis devices on the feeder and demand, for isolated micro grids to operate an active distribution system.

There are different levels of decentralization e.g. totally decentralized and hierarchical control that can be applied in micro grid control systems [3, 8, 9].The world has experienced growth in significance or importance of deregulated power systems leading to positive effects in reliability, stability, innovation, and investment in new technologies in power systems that have empowered consumers in terms of saving money on their energy, supplying power and incorporate sustainable energy sources into the grid [6, 10]. Smart grids and micro grids are required for efficient power distribution in deregulated power systems. A comprehensive electricity grid integrating smart grids and micro grids is a solution, to the evolving energy needs of the society with benefits like improved grid reliability, stability, and higher uptake renewable energy sources (RES). Micro grids and smart grids can enhance the management of distributed generation by optimizing operations for profitability and efficiency enabling consumers, businesses and stakeholders to enhance the efficiency and responsibility leading to economic and e environmental benefits [11, 12]. Therefore, the efficient and maximum uptake of variable renewables can be increased significantly by use of smart micro grids

Access to modern energy services is necessary for people to live a civilized and more productive life. Energy It is also a precondition for the realization of many of the sustainable development goals (SDGs)[2], and indeed it is explicitly listed as a goal in its own right. Modern energy services are crucial ingredients for reduction of energy related environmental impacts, while increasing opportunities that reduce extreme hunger and poverty to achieve socio- economic development [3, 13]. In the last few

decades, energy research has intensified focus on assessing the impacts of global warming and growing greenhouse gases on our daily lives like climate change, which severely affect human health and economic growth, yet over 750 million people globally still, have no access to clean energy services. Most of these people are located in the developing countries and in remote locations far away from the grid. Therefor most of the people with no access to clean electricity also face poverty and economic challenges [14].

Energy has an important role in achieving the Sustainable Development Goal 1 (SDG 1), whose aim to “End poverty in all its forms everywhere." Energy is essential to uplift people out of poverty because it facilitate economic growth, it creates jobs and improves the living standards through provision of essentials in the form of electricity which powers modern life, and all important sectors like transportation, industry, agriculture, education, health, and human comfort and welfare like thermal comfort, refrigeration, electronics, and beyond [15, 16]. Therefore, modern life cannot be realized without electricity. There is a close link between energy poverty and poverty alleviation.

Early power systems developed as local generation supplying local demand in which individual power systems were developed and operated by independent organizations. It was however recognized that that a centrally planned integrated system, operated by a specific utility creates an efficient system that was economic, secure and reliable leading to the centralized generation system where large power plants supply electricity to consumers who are widely distributed vial long high voltage and long distance transmission and distribution networks[17, 18].

A. **Problem Definition**

Higher penetration of distributed generation in secondary distribution networks is associated with challenges related to renewable intermittency and bidirectional power flow like under or over voltages. There are impacts and challenges of a renewable-based micro-grid on a secondary distribution network [19].The integration of DER and micro grids into the utility grids induces several major challenges in terms of meeting Renewable Portfolio Standard (RPS) requirements while ensuring adequate levels of power reliability, resiliency, and quality for customers[19, 20]. Micro grids have significant promise, but have a challenge in handling the renewable energy sources because of their variability especially for wind and solar making it difficult to supply reliable power. Therefore, measures must be put in place to balance the demand and supply e.g., use of storage systems and intelligent system to manage the technical challenges like power quality, grid synchronization and voltage management. The development of renewable energy micro grids is also limited by economic factors like high upfront investment costs, market structures and legal constraints. To manage these requires new technology, appropriate rules and an enabling regulatory framework for efficient integration of renewable energy into micro grid systems and overcome these barriers [21]. Integrating renewables, especially the variable sources like wind and solar may cause several adverse effects like reverse power, voltage rise thus reduction in power quality, reverse power flow, high line losses, creation of harmonics in the distribution systems. However, renewable source offer a solution to the global search for clean energy as a solution to the environmental crisis and global warming, hence the need to maximize their share. Optimal sizing and location of renewable decentralized generation (DG) units is important because the units in DG should be deployed and operated within limits for power system quality and stability to deliver technical and economic benefits [22, 23]

Increased uptake of renewable energy sources is one of the multiple solutions for reduced reliance on fuel-based power generation and associated greenhouse gas (GHG) emissions. Higher penetration, of variable renewables to the micro grid significantly increases system uncertainties with adverse effects on the proper operation and stability. These calls for efficient forecasting of the availability of renewable energy resources where the power systems has high RES penetration to improve power efficiency and system reliability. Aspects of generation forecasting required include penetration rates, demand and supply imbalance projections, and optimal system operation. The most common methods and approaches used in forecasting are the time-series statistical model, which is a mathematical formulation of the time-series method developed and can be applied for observation of near-future predictions based on historical data available.

Utilities benefit from accurate demand forecasting by aiding them to make critical decisions like purchasing and generating electricity, load shedding, and power system infrastructure upgrades. Additionally demand variation is an issue in electricity market management in electricity markets because the demand variation has implications on the distribution network’s vulnerability and has economic implications electricity like effect on the spot price. Therefore demand forecasting is another critical aspect in decentralized generation [24].

The latest global data on energy access indicate that the world is not yet on track to realise any of the SDG7 targets. In 2021, about 675 million globally had no access to electricity, with about 567 million people, about 80% of them living in Sub-Saharan Africa. In addition to limited access of electricity to these millions of people, close to 2.3 billion people globally have no means to clean cooking, with most of them located in sub-Saharan Africa and Asia. At this progress, about 660 million people will still have no access to electricity in 2030, and 1.9 billion will continue relying on polluting cooking fuels [25]. On the positive note, the deployment of renewable energy has increased significantly in electricity sector with about around 27% rise between 2010-2020 and 7 percent between 2019-2020 which is the largest annual growth recorded in three decades. In 2020, renewables accounted for about 19.1% of final energy consumption globally compared to 16.7% in 2010. Unfortunately, at this rate of progress in renewable energy deployment, the global targets still cannot be achieved by 2030. Especially in heat and transportation sector. Statistics on the progress in energy efficiency measures also indicate that it is off track, because only 0.6% improvement was achieved in 2021. Although energy intensity improved, it the improvement in intensity should not be less than 3.4 percent annually until 2030 to compensate for the shortfall. In terms of financing, the flow of public finance to the developing nations to support clean energy reduced for the third year running, to reach USD 10.8 billion in 2021, which is just about 40% of the 2017 amount of USD 26.4 billion [25, 26]. This shows that financing clean energy is a major concern for developing country, which host the close to 80% of the global population targeting in SDP 7 targets.

Although renewable energy resources are key to the energy transition, they face challenges in terms of resource availability, resource access, and resource location, security of supply, sustainability, and affordability [27, 28]. The intermittence and variability of sources like wind and solar makes their use and reliability complex making it necessary to use dispatchable sources, most of which are non-renewable[29]. Therefore, optimal planning and dispatch in distributed generation is very important. This requires pertinent information on all feasible energy sources, both renewable and non-renewable to ensure that the power systems are affordable, reliable and have limited environmental impacts [30, 31].

B. Challenges of Integrating DERs into Microgrids:

i.) Grid Stability and Control:
The intermittence nature and need for sophisticated control systems and strategies makes the integration of DER challenging in maintaining grid stability

ii.) Power Quality Issues:
Power quality issues like harmonics, voltage fluctuations, and others can result from having uncontrolled integration of DERs to the grid

iii.) Communication and Control Complexity:
Micro grids need a robust communication and control systems so as to manage diverse sources of DERs and have a coordinated power system operation.

iv.) Interconnection Standards:
The interconnection standards and regulations are evolving which adds complexity to the DERs integration to the grids

v.) Cybersecurity Risks:
The grids with that rely on communication and control systems i.e. smart grids and micrograms are made vulnerable to cybersecurity threats.

vi.) Planning and Design:
There is need for careful planning and analysis for optimal sizing and placement of DERs within grids to attain maximum benefits and minimize potential integration issues.

vii.) Uncertainty Management:
Since DERs are predominantly renewable energy sources that are inherently intermittent, and variable in supply, they require sophisticated forecasting and management strategies to guarantee reliable grid integration and operation [32, 33],

C. Rationale of the study

The role of distributed generation system has been growing in power system with micro grids becoming more prevalent in the power sector globally. Micro grids mainly consist of low-voltage distribution networks incorporating configurable loads and storage devices [12, 28]. A micro grid is a cluster of interconnected distributed generators, intermediate storage and loads, that cooperate with each other as a controllable load or generator towards an evolutionary power solution acting as a substitute of fossil fuel formed by the integration of distributed generators mostly based on renewable sources of energy (RERs) and micro sources like photovoltaic, Wind turbine, fuel cells , micro turbine , CHP system, and storage batteries with storage facilities [34], [33],

A micro grid equipped with modern power electronic based technology can offer higher dependability of service, at better quality, and better efficiency of energy use by exploiting available waste

heat. The ability to exploit less polluting and affordable renewable energy is attractive and continues to gain more interests globally. Distributed generation can also benefit from electric utility through reduction of grid overcrowding, reduced demand for new generation and transmission capacity, and offer of supplementary services like voltage support and demand response measures[23, 35]. Advances in power electronics and control technologies have enables large-scale, and effective integration of many forms of distributed generation and energy storage to the power grid infrastructure economically [4], [28].

The world needs a reliable and secure energy grid, regardless of the weather the weather or unpredictable events by adoption of distributed energy resources (DER) and micro grids. DER are spread over a wider area, generally supply electricity in small quantities from sources like rooftop solar panels, backup batteries, and emergency or back up diesel generators connected to low voltage distribution grid like homes and businesses [7], [9], compared with the traditional generators which are largescale and are connected to high-voltage transmission grids,. Micro grids o are localized electric grids designed such that they can disconnect from the main grid to, operated autonomously when necessary, and like the main grids, multiple energy sources and generators including storage power micro grids. Therefore the micro grids are used to strengthen grid resilience, and help mitigate grid disturbances, and is a grid resource that enables faster system response and recovery in case of a disturbance [2].[3]. Interest in micro grids has significantly grown over the last decade globally, although the technology and concept remain an early stage of development. Micro grids offer opportunities for greater self-sufficiency in electricity to smaller where access to the main grid is limited. Micro grids provide solutions to the growing energy needs, limited access to electricity for many remote areas , power outages and demand for greater power system reliability[36]. It is desirable to have a more flexible electricity networks in power distribution instead of rigid centralized power systems where the operators just transmit power and keep the grid stable. The future electricity grid should have inbuilt flexibility and methods like demand-side response, intelligence, and reliable energy storage which creates momentum for a transformation to distributed generation which incorporates these technologies and approaches in the in the power sector[37].

Distributed generation additionally offers new possibilities like local power during emergencies leading to more benefits in terms of reliability of the power supply and even local jobs and local revenue streams. With new technologies, new types of electrical loads and sources have emerged like electric vehicles, battery storage and even heat pumps, which may introduce new challenges and opportunities to the local power systems and consumers. Therefore, this chapter provides first an overview of existing publications on decentralized generation with real and potential challenges and proceed to propose various interventions and solutions to enhance decentralized generation.

There is notable progress so far in the global energy access rate over the past two decades, However, if the current trends continue, them just about 75-81% of the global population will have access to clean energy for cooking and other applications as well clean energy conversion technologies by 2030 [38]. This is below the universal target set for the year 2030, and nearly 1.8 billion people will still be exposed to the adverse effects energy related pollution from cooking fuels and technologies that is harmful to human health, livelihoods, and the environment [15, 25]. Therefore, measures should be made to ensure all humanity has access to clean energy and realise the aspirations of the sustainable development goal number 7 (SDG 7) which so far has remained elusive. Electricity access has another significant role in the realisation of the sustainable development goal number (SDG 1) which addresses poverty alleviation, and decentralisation of electricity can play a central role in this agenda.

There exist significant Interrelations between other SDGs and SDG 7, which is centred on affordable and clean energy, which directly curtails the reliance on costly and polluting energy sources, thus helping in combating poverty, which is addressed in (SDG 1). In the process, clean energy enables delivery of healthcare services addressed in (SDG 3) and sustainable urbanization of rural and remote areas addressed in (SDG 11) by supply of reliable power and energy infrastructure. All of these combined align with responsible consumption and production addressed in the SDG 12, with reduced consumption of resources and lower negative impacts on the ecosystem. Therefore, realisation of the SDG 7 directly and indirectly supports agricultural practices that promote sustainability in agriculture addressed in SDG 2, and uplifts the quality of education addressed in the SDG 4. Another important impact on access to clean and affordable energy is that it empowers

women by through creation of local Jobs addressed in SDG 5, and access to affordable clean water access in SDG 6. Clean and affordable energy also drives economic expansion addressed in SDG 8, and spurs technological innovation addressed in SDG 9), while also advancing social equality as envisioned by the SDG 10. Access to affordable and clean energy directly aids climate change mitigation anticipated in SDG 13, as it also safeguards biodiversity, which is a target in SDG 14, SDG 15. Affordable and clean energy also fosters peace, justice, and enhances collaborative partnerships as stipulated in SDG 16, SDG 17 [15, 39] . All these interconnectedness emphasises the importance of clean and affordable energy, which is the main objective of this study on the economic sustainability of decentralised energy sources in this study, the importance of this study.

This study provides a comprehensive overview of sustainable energy solutions and the complex relationship between energy and the economy in decentralised power generation. It creates significant opportunities for economic and financially sustainable deployment of renewable and sustainable energy sources that a locally available to enable maximum benefits and higher access to clean energy for the remote and off grid communities, in an environment where international financial flows for financing clean energy projects continue to diminish[25, 40]. Decentralization of generation in an economically viable manner addresses two sustainable development goals namely, goal number 1, which seeks to eliminate poverty for all, and goal number 7, which seeks for universal access to modern, clean and affordable energy[41, 42]. Additionally, the transition to clean and ow carbon energy is essential to cut down on greenhouse gas emissions, enhance air quality, and mitigate the impacts of the triple planetary crisis of biodiversity, nature and climate change as well as energy related pollution and waste generation and disposal. With global conflicts like the war Ukraine affecting the supply chain for conventional energy sources, and global economic uncertainty continuing to rise has caused significant volatility in energy prices, forcing countries to raise investments in renewables and sustainable energy sources [41].

II. DECENTRALIZED GENERATION

The main characteristic of decentralized energy systems compared with centralized energy systems is their location closer to the site of energy consumption [43, 44] . This allows for more optimal exploitation of energy resources and a wider application energy at increased eco-efficiency. Decentralization is a relatively new concept in electricity sector of many countries[34, 45]. The traditional power industry is based on development of large, central power stations which transmit power across long transmission and distribution lines to consumers often located far away from energy sources and power plants unlike decentralization which seeks to locate power stations closer to the end uses [6, 28]. Since end users are widely spread across a region, sourcing energy and electricity in a similar manner reduces the transmission and distribution costs and environmental costs [43, 46]. In this study, decentralized energy systems are defined as small-scale energy generation systems designed to deliver energy to local customers. These energy systems may be stand-alone or may be grid connected or both [47, 48].Therefore the focus of this study is energy sources and related power systems that are small enough to be located close to the consumers and that can be connected to the distribution networks.

When compared with the centralized energy systems, integration of distributed power systems in distribution and transmission networks effectively changes the commercial mechanisms of the power system in aspects of operation, maintenance, investment costs and financial benefits which should be resolved before deployment [49, 50]. Managing energy sustainably needs a set of adequate energy resources and corresponding conversion technologies for optimal delivery of energy from different sources for various electricity applications [51, 52]. To attain sustainable power systems, focus should be placed on key areas like energy efficiency and diversity, social value and public acceptance, power supply reliability, technological innovation, competitive and cost reflective pricing, market-sensitive interventions, standard requirements, regional integration, and power quality. Successful energy transition requires progress in these key areas [53, 54]

The flexibility of future energy systems has become increasingly important because of the growing share of variable Renewable Energy Sources (RES) thus a stronger temporal and spatial variability of energy supply and electrification of transport and heating. Although this will lead to higher overall energy system, efficiency it may lead to higher peak demand. Growing decentralization of generation implies higher levels of local energy generation and supply into local distribution grids, which offers enhanced flexibility in local energy use [55, 56]. Decentralized generation is an evolving paradigm shift in the system of producing electricity from large, centralized power plants to small power plants and generators using predominantly renewable and sustainable sources of energy. In this system, small

generators that were initially mainly as back up sources without being connected to the grid are have emerged the primary source of electricity in micro grids[57]. These small generators based distributed energy resources (DER) promise to satisfy the ever-growing demand for heat and power, which is both reliable, and of good quality [3, 57].

Decentralized systems may be used for different functions, e.g. Renewable DG systems may be the grid connected for peak shaving or may be used as stand-alone power systems to for given area or customers. On the other hand high penetration of renewables may be associated with adverse effects like voltage rise, high line losses, reverse power flow, harmonics and reduced power voltage quality. Therefore, the decentralized power systems should be operated within limits for optimal power quality making optimal sizing and location of units in decentralized generation (DG) important for technical and economic benefits.

Many terms and definitions are used for decentralized generation e.g., the Anglo-American often use 'embedded generation', 'dispersed generation'. In North America, decentralized generation in Europe and parts of Asia, '[58, 59]. Distributed generation (DG) is an important power generation system that is evolving rapidly in the competitive electricity markets. It is regarded as generation system within the distribution networks or customer side of the network [48, 60]. .This implies that distributed generation does not have to supply reactive power to the power system[60]. The generating units in distributed generation are directly connected to distribution network or on the customer side of the meter[60]. A transmission system is usually operated by an independent institution that is not involved in power distribution and retailing or sale of power to consumers. The distribution network is a low voltage network operated or owned by power retailing or selling companies who deliver power to the consumer meters[60]. In terms of ownership, independent power producers or consumers themselves may own the DGs. The utility companies can also install their own distributed generators for different users. With the required number of units needed being determined by the level of decentralization, i.e. whether it is full or partial decentralization partial or fully implemented. Transmission lines and large-scale centralized power plants are not needed in complete decentralization, but in partial decentralization, the distributed generation is a fraction of local energy demand [5, 60].

Increased access to energy is pivotal to ensure humanity fulfils basic needs and facilitate sustainable development, however the progress remains slow and this puts close to the 733 million people with no access to modern clean energy at risk of being further left behind [41]. This is further compounded by the fact that about 2.3 billion people globally still cook with unsafe and polluting fuels, which pollutes the air and worsens health impacts, with women and children being disproportionately affected. About 7 million people die annually because of the combined effect of ambient and household air pollution, which is also associated with many diseases. Electricity is an important input in the daily life of man, with most of it being produced from conventional energy sources i.e. coal, oil and gas, which are non-renewable fossil fuels. These conventional sources of energy sources are diminishing even as the energy demand continuous to increases significantly [61-63]. Other challenges facing the energy sector is decreasing land availability, reduced or low budget allocation for energy, and weather-dependence by the renewable sources leading to poor energy management. All this is happening at a time close to 750 million people globally have to access clean electricity [64, 65]. This calls for proper management of conventional energy and development of affordable and reliable alternative energy sources, which has become a prime concern of energy researchers [66, 67].

The centralised power generation systems make use of very expensive and large-scale centralised structures that effectively limit the direct and democratised access by multiple stakeholders with different interests. As a result, individuals has historically low power over their own destiny. This widened a gap in terms of inequality existing between rich and poor and thus access to reliable electricity. which has significant implications in terms of attainment of sustainable development goal number seven (SDG 7) [47]. There are significant implications of the transition to a low carbon society (LCS) on the economic and financial wellbeing.

There are several controversies and challenges surrounding decentralised generation that should be addressed for society to fully accept and adopt decentralised generation e.g. cost and regulatory hurdles which impede deployment of decentralised energy systems. Social-economic impacts like cost of electricity, economic impact and creation and loss of jobs are important considerations in acceptance of power systems by society [68]. The sustainable energy transition needs a major revamping of the energy sector with improvements needed in terms of the energy resources and technologies for power generation, transmission and distribution system [69, 70]. Decentralised generations enhances flexibility, efficiency, and economy, and therefore it is an integral part of a sustainable energy future[71]. Energy access

remains a global challenge with close to 1.2 million people mostly in rural areas in developing countries have no access to electricity [56, 72]. Lack of access to clean energy has led to energy poverty and diseases like acute respiratory illness due to in-house pollution, high infant mortality caused by to the lack of refrigeration facilities for medicines and vaccine as well as inability to power incubators and negative impact on education quality and access. This energy related challenges could be addressed by adoption of distributed energy systems [73-75].

The national policies and International political negotiations on climate change mitigation are focusing more on the mobilisation and scaling up investments in clean energy infrastructure, making costs and other economic considerations important in the energy transition. It is for this reason that thus study aims to develop the understanding of the cost competitiveness of energy sources for clean power generation [76] . Although decentralised generation presents many advantages, it also has controversies as well as challenges. For example, affordability and financing still possess significant limitations to many interested investors and communities. Grid integration challenges and regulatory hurdles also impede the widespread deployment of decentralised power system. Additionally controversies exist in terms of social and economic impacts like the potential to create or loose in the fossil fuels sector. It is therefore important to address these challenges to ensure acceptance and growth and acceptance of decentralised power system[68]. The integration of affordable and low-cost and energy sources in decentralised generation enhances the economic and social sustainability of decentralised generation which in turn will make it attractive and thus stimulate investment [14, 77].

Decentralization of power generation remains an effective way the world can use to electrify millions of people without electricity most of them in rural and remote areas. Over 700 million people globally have no access to electricity; most of them are located in developing countries, where poverty reigns. According to [78], 750 million had no access to electricity in 2023, with about , 600 million Africans alone lacking access to reliable and affordable electricity in 2025, which is about half of the continent's population. Even with this scenario, the global electricity demand increased by 4.3% in 2024 and which is more than the average growth of the past decade, mainly driven by consumption across many sectors, like of transportation, industry, heating etc. This demonstrates the significance of costs in generation and the need to have cost competitive decentralized power to achieve the sustainable development Goal (SDG) 7 by 2030 [2, 3].

The correlation between energy and sustainable development was officially recognised in the Johannesburg world summit of 2002 where energy brought significant global concerns [5, 79]. Therefore selecting most appropriate energy systems for the energy mix is a crucial strategic decision required for energy to play its role as an enable in sustainable energy and sustainable development [80, 81]. The world community is grappling with an urgent need for sustainable energy options of which decentralized generation has emerged as a promising option to the centralized power systems by producing power at or near the customers or consumers [82]. This offers multiple benefits like lower transmission and distribution losses, higher efficiency, and greater power system resilience to power outages. However, decentralisation comes with challenges like high upfront costs and hence higher electricity costs, which can make decentralisation financially unattractive to consumers and investors.

Mitigating the global climate change caused by anthropogenic emissions requires reduction in carbon emissions and integration of renewable and sustainable energy resources within the energy sector[83] The traditional centralised power generation is transitioning distributed generation which requires careful selection of energy options to achieve this objective for sustainable transition. An optimal mix of different sources of energy to power the distributed generation system is not definite or obvious and is subject to an analytical consideration. Most researchers focus on how to integrate the various distributed generation energy sources and technologies into centralised or distributed electricity systems by considering. optimality from narrow viewpoints targeting a particular aspects of the electricity network like distribution network within the confines of a future or current objective where the centralised infrastructure is retained [84]. A gap in literature exists on how to prioritize the choice of options for maximum benefits in a sustained transition from centralised to decentralised systems [85, 86]. This paper explores the economic dimension of decentralised generation and how to select the best energy options to achieve the economic objective of decentralised generation. These study review concludes that there is no one indicator to consider but a variety which include the price of the resources, job creation potential, the levelized cost of generation/energy, cost of electricity produced and other socioeconomic considerations.

There are economic benefits of decentralised generation and transformation to sustainable energy. These benefits include improved energy security, high uptake and adoption of renewable energy sources, and the higher economic growth. The relationship between the economy and energy is a valuable contribution to the academic literature on sustainable energy. This study underscores the importance of transitioning to sustainable energy through decentralization of generation and hence use of local energy resources their environmental and economic merits. The study findings offer valuable insights useful to policy decisions and sustainable generation planning. This study seeks to promote decentralised generation and advancement of sustainable energy technologies hence the development of a more sustainable global energy economy [65, 87].

There is global consensus that that the global climate is changing because of greenhouse gas emissions [26]. There has been a rise of about 1 ºC in average global temperature above prehistoric level mainly because anthropogenic emissions and this rise is expected to reach 1.5 ºC between the year 2030 and 2052 if emissions rates are maintained at the current rate [27, 28]. The main objective of the Paris Agreement of the 21st UNFCCC Conference of Parties (COP21) of 2015 is to reduce the average global temperature to below 2 °C above pre-industrial levels and preferably 1.5 °C. This calls for measures to reduce anthropogenic greenhouse gas emissions [29]. Although the report by Intergovernmental Panel on Climate Change (IPCC) for 2021 showed that many climate changes are already irreversible, we still have hope for the future if timely actions are taken to mitigate further changes [25, 30].

Because of electricity market liberalization, advances in power technology, growing energy security concerns, environmental concerns, and concerns over energy cost, and use distributed energy units in distribution network is a growing trend [88, 89]. Distributed generation (DG) has emerged as very important generation system for the future in a rapidly evolving and competitive electricity markets [60, 75].

Decentralisation and sustainable energy practices, policies, and technologies have significant economic benefits, like saving costs, creating local rural jobs, and increased competitiveness. Decentralisation of generation significantly reduces the dependence on fossil fuels, which ae vulnerable to global price volatility and supply disruptions as opposed to local energy sources like solar and wind power that are currently cost-competitive and are still expected to improve further. Decentralised generation can reduce energy costs through higher energy use efficiency, decreasing waste and limited transmission and distribution costs [7, 87]

Decentralization or distributed generation is novel concept in energy generation and supply in which electricity is generated close or near user facilities enabling simultaneous supply of thermal and electrical energy to homes and to industrial and commercial users usually connected along a distributed energy network. There exists some synergy in cogeneration, trigeneration and energy storage which enhances the diffusion of renewable energy technologies by integration[34, 74]. By adopting, multiple clean energy higher gross domestic product (GDP) and increased employment rates leading to improved resource consumption and reduced emission, thus positive effects on both economy and environment [90]. With many energy options for use in decentralized generation e.g. wind, solar, biomass, while generation infrastructure is limited, it is important to identify and select options with the highest positive impact and sustainability to realize sustainable energy development, which is the main objective of this study.

III. OPPORTUNITIES AND BENEFITS OF GRID INTEGRATION OF RENEWABLES:

The integration of decentralized systems, which mainly use the renewable energy, minimize the reliance on polluting fossil fuels, thus lowers g emissions and improves the quality of air. Other opportunities are

i.) Enhanced Reliability and resilience:
The use of Micro grids, incorporating DERs, are able to operate independently of the main grid, and this act as backup power source during outages of the main grid which enhances the overall power system resilience. Micro grids using energy storage systems supply backup for sustained power supply in case of outages, which enhances system resilience.

ii.) Improved Power Quality:
When well-integrated and controlled, the DERs, can assist in the regulation of voltage and frequency, which improves the quality of power supplied to connected loads.

iii.) Increased Energy Independence:
The use of DERs in form of Microgrids reduces reliance on the conventional centralized power systems, which are dominated by fossil fuels through

exploitation of locally available energy resources, which often-renewable energy sources like solar, wind and biomass.

iv.) Reduced Transmission Losses:
By generating electricity closer to the point of consumption, micro grids can minimize transmission and distribution losses, which improves energy efficiency and reduces impacts from wastes and emissions by reducing energy consumption.

v.) Cost Savings:
By producing power close to load centers, the DERs, particularly those based on renewable energy resources lead to reduction in energy costs for customers and utilities. The renewable energy sources, which dominate supply in decentralized systems, offer long-term cost savings over the fossil fuel-based centralized power generation.

vi.) Environmental Benefits:
The use of micro grids enhances the integration of renewable energy sources, which leads to reduction in the greenhouse gas emissions and a cleaner environment, hence plays a critical role in the unfolding global energy transition. Distributed generation guarantees a more sustainable energy future because they systems reduce greenhouse gas emissions thus lower the environmental impact from power generation

vii.) Improved grid management:
Where smart grid technologies and micro grids are involved in distributed generation leads to better energy resource management leading to higher energy efficiency and power system reliability.

viii.) Economic Development:
Investment in distributed power systems creates job opportunities and financial benefits, which stimulate e economic growth in remote and rural areas.

IV. DEMAND SIDE MANAGEMENT IN GRID INTEGRATION

The use of smart energy management and control improves the efficiency of power and maintains the balance between energy supply and demand[24]. Demand reduction is important in balancing the energy demand with available capacity without developing new facilities to carter for the demand [6]. Demand Side Management (DSM) is a set of activities, used to power or energy users to modify their level and pattern of consumption. Demand side management strategies include energy reduction, peak shaving, and load shifting, etc., which alter load profiles and allow more electricity to be supplied by cheaper base load generation. This reduces peak demand burden on the network by enhancing efficient utilization use of available generation options and capacity, which makes demand side management and demand reduction important in generation and consumption management [3, 91].

A. Demand Side Management As An Energy Management Systems

The energy management system (EMS) has been evolving since 1960s, whenit was termed a control center, that was later referred to as an energy control center (ECC) in the 1970s, only to be renamed as “supervisory control and data acquisition-EMS” or (SCADA-EMS). The SCADA system is based d on advanced computer, appeared in 1990s, and later evolved into a real time control system known as energy management system (EMS). The Energy management system (EMS) incorporates multiple control techniques including load control (LC), demand supply management (DSM), and distribution management system (DMS). EMS allocates energy to customers optimally while integrating sustainable power sources with no compromise to power system reliability, security, and safety. The system monitors, supervises, optimizes, and controls power generation, transmission, distribution, and consumption to create balance between supply and demand for cost efficiency. The energy manage net system also manages operational constraints and uncertainties on EMS architecture including intermittence and variability of renewable sources, price of power and customer behaviors [92, 93].

The energy management systems has become more and more complicated, because of growing use of plug-in electric vehicle (PEV) and growing share of variable renewables, energy storage systems (ESS), higher demand in buildings and industry among others. This has necessitated enhancement of functionalities of the energy management system with further enhancement due to advances in the internet of things (IoT) and machine learning by the energy sector [92]. The energy management system can be used for power dispatch, real-time SCADA applications, scheduling of generation, power system control, energy accounting and energy transmission security management.

The stability of power systems is threatened by higher integration of highly fluctuating distributed generations from solar PVs, wind electric vehicles, and energy storage because balancing power ratio between supply and demand is complicated and difficult. Excess or shortage in the generation or consumption leads to perturbations to the grid causing severe issues like voltage drop, voltage rise and blackouts. The energy management system ensures efficient balancing between power supply and

consumption demand to strike a quick balance [94, 95].

The energy management is divided into two main categories, i.e. the supplier side like electric utility, with generator being able to be switched ON or OFF or even follow demand (demand following). In the second category is on the consumer side, or demand-side management, and manages the consumption to match supply with the main goal being reduction in operation costs operation cost, consumption, losses and enhance system reliability. The performance of energy management systems is enhanced by use of sophisticated algorithms and models [94, 95].

Grid operators use the EMS as a tool for monitoring, control and optimization generation and transmission systems for power. The main functions of the energy management system include real time network analysis and contingency analysis, The EMS enables operators to carry out real-time functions by monitor, analyzing and control of power generation making automatic generation control possible. The EMS also establishes the economic dispatch and directs the dispatcher to set economic base point for selected generator combination. The EMS also monitors the reserve and establish spinning reserve, control reserve and operating reserve levels. The system also computes generation costs, forecasts load, schedules transactions. Functionalities like grid capacity and reliability enhancement, contingency awareness operations and cost management are also facilitated by the energy management system [96]. Hence, overall, the energy management system enhances reliability, increases efficiency and compliance with standards.

The energy management system applies two groups of bioinspired computing namely the evolutionary computing which involves incremental development of living organisms reacting to environmental conditions and swarm intelligence computing which focuses on agents' collective and social behaviors in the energy system [97]. These algorithms help in design, planning, and control for smart energy management systems [98]. For a smart system, a key objective is to minimize energy consumption through scheduling within specified time horizons [99]. The main functions of the energy management system are summarized in figure 1.

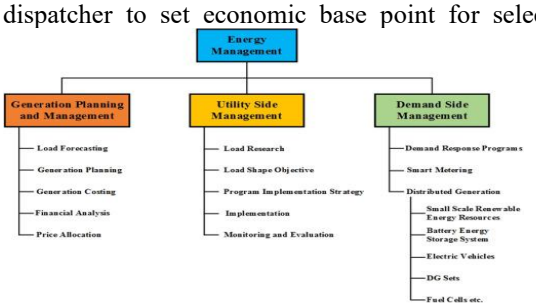

Figure 1 Functional view of energy management system in a smart grid.

From, figure 1, it is noted that the energy management system performs three main functions, i.e. Demand side management, utility side management and generation planning and management.

Interoperability developed by the National Institute of Standards and Technology (NIST) is important for effective planning and execution of grid activities by maintaining standards for the grids and related components needed for efficient operation. Grids and end users should also effectively play their roles in the implementation of energy management. Technologies like two way communication, cyber security, and advanced metering infrastructure (AMI) enable the smart grids to more realistic because they enable self-decision capabilities for the power grid [100].

B. Benefits of Demand Side Management

The benefits of demands side management accrue to different system participants making the development of a business case for these technologies a complex task, e.g., actions from DSM technologies can balance output and provide energy arbitrage opportunities that accrue as benefits to the portfolio owner or to intermittent producers using this resource. This action could also contribute to more efficient use current network capacity, and delay need for reinforcements and possibly and benefit other network activities like securing the supply for local demand or and reduce substation congestion. Hence, the benefits of storage and DSM participation is associated with many industry sectors that operate as individual businesses as producers, transmission and distribution network operators, etc. who may all be willing to reward specific aspects of this activity. With no traditional vertically integrated utility having ability to optimize the overall system value of such enabling technologies, there will be multiple recipients of services provided by storage and DSM technologies. Therefore it is not easy to develop a business case for the for DSM in a complex environment, and clearly, no individual recipient of the services is interested in

maximizing the overall system benefits by trading off the benefits between individual segments of the industry. Therefore this calls for an appropriate regulatory framework to optimize the benefits of storage and DSM in a deregulated environment, otherwise current regulatory arrangements may present a significant barrier to deployment of DSM[101].

Demand side management has many benefits taking the form of economic, environmental, and technical benefits. DSM leads to cost reduction, can alleviates electrical system emergencies, reminisce outages or blackouts, enhance system reliability, and delays or defers capital development investment new capacity expansion for generation, transmission and distribution networks [2, 3].

For efficient load management to be achieved in demand side management (DSM), the following measures are encouraged:

i. Promote adoption and use of energy-efficient products and equipment like efficient lighting bulbs and heaters,
ii. Encourage customers to shift non-critical power consumption away from peak hours to off peak hours.
iii. Built and modernize buildings to be efficient in energy use e.g. maximize use of natural light from the sun, and
iv. Create awareness on benefits of energy saving and efficiency through education and sensitization.

The deployment of demand side management views consumers as virtual power plants who actively participate in the grid stabilization through by planning and monitoring of their activities, because they are compensated for lowering, modifying and shifting, energy consumption. The ratio of controllable loads to the total system load in the grid is important for successful implementation of DSM.

The ration of controllable load to total system load is enhanced by the development and adoption of new types of electric equipment and technology like the plug-in hybrid electric vehicles (PHEV) , which enhances demand side management [102]. The energy storage in the plug-in hybrid electric vehicles (PHEV) facilitate electricity storage during off peak or during driving and use during peak hours, thus making the PHEVs a very important component in demand side management (DSM) balancing tool for electricity power supply and demand in smart grids and micro grids [2, 103].

C. Challenges of Demand Side Management

The concept of demand side management is no longer new and it has key technologies already developed for its implementation. The implementation of DSM is however sow, with numerous limiting factors. Several reasons can be identified which may be specific to a particular scheme and system where it is applied. These challenges are many and include lack of metering and ICT infrastructure, challenge of consumer engagement, and the competitiveness of DSM as compared to the traditional approaches, high power system complexity and inappropriate market incentives.
Here is a more detailed breakdown of the challenges:

i.) Metering

Metering could be insufficient, inappropriate or outdated which may hinder accurate tracking of energy consumption, which makes it difficult to implement and effectively monitor the DSM programs.

ii.) Lack of appropriate ICT infrastructure

Demand side management requires appropriate robust communication channels and data infrastructure information and Communication facilities, which may be expensive and lacking for the remote areas, thus impede flor of information between the consumers and utilities and hinder the required engagement and participation in DSM initiatives. It is impossible to implement the demand side measures where advanced metering, communications, control systems and information technologies are missing from the power systems. To support demand side management, significant deployment of various sensors, measurement and control devices is necessary together a sophisticated energy metering and trading functions to enable the control of generators, loads and various network devices[104]. ICT is important for the control of electricity networks leading to an integrated energy and communications system architecture, which couples the power system and information system consisting of the communication, networks and intelligence system for control [101].

iii.) Consumer engagement and understanding of the benefits of DSM

Demand side management may be limited if consumers are not fully engaged to understand the existing benefits of DSM or be motivated to participate in energy-saving programs, which lead to low participation rates. The benefits and value of

demand side management are e flexible in and apply to both system operation and system development. The challenge is limited with regard to the business case for DSM, because of a lack of quantification methodologies for costs and benefits. The magnitude of the value of DSM e.g., the value of demand controllability is driven by the key system operational features of the system especially the level of system stress, i.e., proximity of the system loading to its maximum capability thus the need for reinforcement. For application in segments of the systems that require reinforcement, the value of DSM is high, but for systems having huge spare capacity, the value of DSM is low. Therefore, the main barrier to DSM is network and generation capacity. Solutions that are based on network and generation capacity are dominant and DSM schemes are exceptions rather than routine practice[101, 104].

iv.) Complexity

The demand side management (DSM) programs may be too complex, which makes it difficult for consumers to understand their operation and participate effectively. The implementation of DSM-based solutions makes the power system complex compared with traditional solution, which also increases the operational complexity, which is a barrier to the implementation of demand side management. However, the flexibility of demand side management system makes it an important tool to manage uncertainty in future developments while continuous reduction in costs of DSM technologies, is expected making more appealing and significantly more competitive. Targeted trial schemes can help improve the confidence in the use of DSM schemes [101].

v.) Competitiveness:

The cost and Investment in DSM programs may be significant in terms of upfront costs of infrastructure and technologies, which may end up making it less cost-effective than traditional supply-side solutions. There is a need to comprehensively assess the economic, technical and environmental performance of existing and future DSM schemes in order to objectively compare DSM and traditional solutions and make informed choices on competitiveness [101].

vi.) **Market Dynamics**

There are cases where the DSM programs face challenges in competing with traditional approaches like developing new power plants especially where there is limited incentives for DSM

vii.) **System Complexity**

The adoption of demand side management increases the complexity of power system operation, which requires utilities to manage more energy sources and consumption patterns often in real-time.

viii.) **Weak Coordination**

Demand side management requires effective coordination between different stakeholders, like the consumers, utilities, and regulators for it to be effective.

ix.) **Inappropriate Market Incentives:**

The market may be inappropriate and unfavorable because of factors like weak regulatory Frameworks and market structures, which limit the development and implementation of demand side programs. Another factor is existence of pricing mechanisms that do not adequately reflect the true cost of energy and hence they do not incentivize energy efficiency and demand response making it ineffective.

D. DISCUSSION

Micro grids constitute a form of distributed energy resources, that can be used to complement the centralized grid, by providing greater reliability, local control mainly using renewable energy sources. For developing countries with many people having no access grid electricity, micro grids supply alternative to power as off grid systems [36]

Access to affordable and reliable energy is a critical requirement for economic development and improvement of the conditions of low-income households. Energy poverty, which is lack of access to sustainable modern energy sources, have negative impacts on the education, health, and economic development of countries[42]. Access to clean and modern energy spurs up economic activity, which enables businesses to function efficiently, create jobs and use other local resource inputs. Electricity supplies energy for heating, lighting, cooling and access to appliances, which cumulatively improves the people's quality of life. Clean and reliable energy facilitate more efficient manufacturing, farming, and other productive activities. Electricity also enables access to education through online learning and improves healthcare by powering medical equipment

and facilities[42, 105]. All this demonstrate the relationship between electricity access and economic development.

Many countries globally are putting priority to low-cost renewable energy sources for their energy and economic needs. This is because sustainable energy technologies and energy sources can deliver broader socioeconomic benefits to society [34, 106]. This has led to emerging generation concepts like decentralized or distributed generation and demand side management. Decentralized generation power systems refer to electricity generation systems that are normally located within distribution networks or are connected to the customer side of the electricity network. Distributed generation is the core function of decentralized energy systems which re also referred to as embedded generation systems, dispersed generation, on-site generation, or simply decentralized generation[107].

. Decentralized or distributed energy resources are generally small, modular energy resources and storage technologies that supply energy for conversion to electricity for nearby customers with less transmission and distribution [28, 34]. These energy resources range from utility-scale to residential scale energy supply systems[34, 108]. The entire world is currently gradually shifting from large centralized power generation and supply to small-scale distributed power generation[7]. The focus in this transition is to reduce greenhouse gas emissions since large portion of these systems are small-scale renewable energy systems, and electrify the remote communities who are general the poor making economic considerations significant [6, 34]. The key drivers of this transition are governments sponsored incentives for small-scale energy systems like solar power plants, biogas plants, wind and small hydro systems among others. The feeding in tariff or grid buy-up price for these systems can be as high as four times the retail price of electricity [28, 109].

Distributed generation applies different conversion or generation technologies to produce power from the various energy resources e.g. solar panels and wind to serve a single structure, or as part of a micro grids which ties together many sources to serve bigger facilities like industrial parks, a military base, a school or local community. Connection of electricity to distribution network supports delivery of clean, reliable power to more customers and limit transmission and disruption losses in the power system [89, 110, 111].

The main objective of demand side management (DSM) in the micro grids and smart grids is to maintain a real-time balance between generation and customer demands. Therefore, the aim of demand side management is to reduce energy costs emerging from growing demands and overstretching utilities. As a broder concept, DSM, consist of demand response (DR) programmes and energy efficiency (EE) easures, with demand response (DR) being designed for the short-term management of energy demands on the customer side of the electricity network. The DR enables customers to participate in the operations demand shifting to reduce electricity consumption and lower retail rates. The offerings that attract customers to respond to DR programs include the time-of-use (TOU) pricing, real-time pricing (RTP) and critical-peak pricing (CPP), critical-peak rebates (CPR). These programs provide opportunities for direct load control of heavy appliances like conditioners and water heaters. Automatic switching is applied in diverting or reducing power strategically to avoid overloads and power failure. The use of advanced metering infrastructure expands the range of time-based rate programs, which have. the potential to reduce peak demands and avoid expensive power and reduce management costs, and defer grid and generation expansion[1]

E. CONCLUSION

To enhance power system performance, it is crucial to address the issue of low efficiency by intelligently integrating energy sources or functional smart grids. Increasing the efficiency of the power system using traditional methods is difficult, hence the intelligent energy management offered in demand side management programs lead to improved power system reliability, cost-effectiveness, and enhanced power system stability. Enhancing reliability and cost-effectiveness is the primary goal of demand-side-based energy management. The use of traditional energy management systems, it is challenging to enhance power system performance hence the need to address low-performance power systems by intelligently integrating energy sources or functional smart grids.

Renewable energy sources especially wind and solar are environmentally friendly and sustainable options to conventional fossil fuels, and are therefore important in reducing greenhouse gas emissions and to mitigate the negative impacts on climate The main challenge facing the use of these resources is the variability and intermittent nature supply which requires measures to enhance grid stability and more effective energy storage integration. The role in sustainable energy supply is complicated by need for infrastructure improvements, policy realignments, and issues of economic viability. These require measures like public awareness, balancing with existing energy

sources and land usage policy and legal measures. These challenges can be overcome by establishing a comprehensive strategy that includes technological innovation, enabling policy environment, and public involvement to develop a sustainable energy future

The optimal planning and operation schemes of renewable energy systems is pivotal by application of \ methods that ensure economic selection and deployment of renewable energy resources based on location's resource availability. The operation of renewable energy systems covers the implementation of power dispatch and demand side management (DSM) schemes, with the dispatch of renewable energy systems being a strategic operation. The intermittence and demand uncertainties complicate power dispatch and make it uneconomical. The factors that contribute to uncertainties include unstable climatic conditions and varying customer demands e.g. the selection of electricity demand for space heating and lighting in buildings varies seasonally Therefore demand side man agent (DSM) becomes a preferred strategy since it follows supplies. Demand side management facilitate customer participation in the power system operational management. For emerging smart energy management systems like the zero energy buildings, there are conflicting objectives of the environment, economy, and customer preferences like comfort, which have to be reconciled. Therefore, DSM implementations by application of demand response (DR) programs are suggested with respect to energy cost and utility tariffs. This implies that DSM strategies may be implemented by integration with the customer-oriented tariffs for commercial and residential demands like the conventional time-of-use (CTOU), real-time pricing (RTP) or both

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