International Journal of Electrical, Electronics and Computer Engineering **10**(1&2): 01-05(2021)

ISSN No. (Online): 2277-2626

Traditional to Smart Microgrid Infrastructure in context to Indian Power Sector

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(Received 20 December 2020, Accepted 09 February 2021)

(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Generation, transmission and distribution has been an integral part of the conventional Power sector, interconnected over long distance through a diverse network of wire known as the electric grid. The grid has been an incredibly important system and complex, signifying the modern era's most remarkable engineering feats. With the evolution of cost-effective energy storage devices and the new green distributed energy resources concept of Microgrid and Smart grid has come into action and gained immense popularity. The aim of designing and developing a decentralized grid mainly focuses on operating autonomously, strengthening grid resilience. Moreover, it proves fantastic in mitigating grid disturbances with faster system response and recovery rate; it has been characterized by dual operative nature, which includes both grid-connected or island mode. In this paper, the authors have made an effort to undergo potential case studies and present a brief investigative report on the Indian Power Sector transition to techno-economic viability and strategic management to relinquish a specific outcome. In addition, significant & relevant fundamental information has been presented to provide a clear understanding to the readers interested in this very domain.

Keywords: Energy, distributed generation, management, grid, network, renewable.

Abbreviations: TMO: Technology Management Optimization; EMS: Energy-Management System; NREL: National Renewable Energy Laboratory; NIST: National Institute of Standards and Technology; µEMS: Microgrid Energy-Management System*;* DR: Distributed Resource; DER: Distributed Energy Resources;

I. INTRODUCTION

This Imagining a world without electricity, and that too in the 21st century is like a dark night as it has become an important aspect of our livelihood with numerous notable contributions for upliftment against socio-economic barriers. In present times the electric grid has been the only linker between Genco, Transco, and Discom. With technological modernization and the evolution of state-of-the-art technologies, scientists and researchers are capable of developing localized, sustainable grids using sophisticated equipment or machinery. Traditional grid very often undergoes stress and unwanted faults, mostly due to large dependence and diverse load demand nature with inferior technical accessories and affects power quality. Since the industrial revolution, it has been a challenge to connect every corner of the world with electricity. The adaption of an energy-efficient microgrid model with a deliberate roadmap allows wide scope & endless opportunities to connect even with the remotest rural areas with greater energy security and virtuous governance.

II. LITERATURE SURVEY

To support scientific planning, innovation and penetration of smart microgrids in the replacement of conventional electric grid are challenging and full of opportunities that allow the harnessing of natural renewable resources than exploiting fossil fuels. The field is relatively new, thus demanding the research community's involvement to provide strategic scope using new technologies for strengthening grid synchronisation, performance, and connectivity. A comprehensive framework for integrating modern edge technologies facilitates the convergence of acutely needed standards and implementation of necessary analytical capabilities. Authors have undergone a vast spectrum of research directories to investigate and highlight the critical factors regarding a smart microgrid and justification for the necessary revolution in the Indian power sector. Scope, challenges, probable solution, possibilities, future prospective, the specific outcome has been discussed. P. Kalkal *et al.*, in 2017 has presented a detailed review of the grid ecosystem and formulated significant elemental differences in the smart microgrid with the present-day grid [1]. In 2015 G. Tang *et al.* [2] has analysed topology and critical devices for DC grid facilities and accord a positive strategy to overcome multi nature fault [3]. Y. Wan *et al.* has worked on testing the feasibility of cybersecurity in modern-day power system, i.e., smart grid, in 2014 and proposed an integrated cyber-physical simulation environment. D. Wu *et al.* [4] 2012 conducted a real-time harmonics assessment to understand the transient pattern for an online Vehicle-to-Grid system. Apart from this, IT architectures for techno-commercial progress have been detected for remote monitoring, automatic fault diagnosis, and control operations [5-8]. In their previous work [9-10], authors attempted to optimised operational effectiveness in solar-powered and waste-to-energy conversion plant for better adaptableness. Moreover, the author has closely studied the fundamentals of smart microgrids and numerous faults associated with it, & troubleshooting them remotely. Harmonic assessment base power quality analysis and its impact over grid has been reflected in work.

III. PRESENT ENERGY SCENARIO

Energy is one of the major ingredients for the economic development of any nation, and it becomes critically important Energy is one of the primary ingredients for any nation's economic development, and it becomes critically important for developing countries such as India. The energy sector's present scenario can be assessed under several parameters, which include commercial energy pricing, conservation, production, end demand, reforms, etc. In-country like India, almost 50 percent of energy is dominated by fossil fuels as India has one of the largest coal reserves. Recent high energy demands have led to the forceful adaption of clean, renewable energy for prosperous development. Analyst describes that increased energy demand has a unique indication on the health of Gross Domestic Product (GDP).

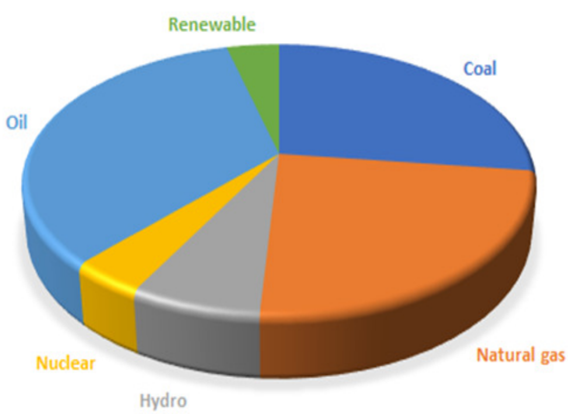

Fig. 1. Global energy share 2020 by MNRE.

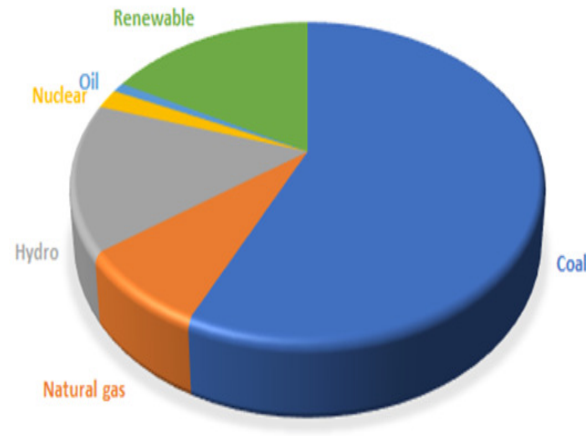

Fig. 2. India energy share 2020 by MNRE.

In this context, energy demand over GDP indicates the scope of a country's industrial and agricultural growth. It has a strong influence on multiple social indexes that represent the essential quality of living. Underneath are two different graphics which show the percentage of energy share for diverse resources across the globe and Indian subcontinent.

IV. CLASSIFICATION OF GRID

The microgrid can be often be classified into substantial sub-categories with respect to capacity, nature, configuration, location, DRs demand and future context.

1) **Capacity:**
   - *a) Simple*
   - *b) Corporate*
   - *c) Independent*
   - *d) Feeder area*
   - *e) Substation area*

2) **Nature:**
   - *a) DC*
   - *b) AC*
   - *c) Hybrid*

3) **Configuration:**
   - *a) Grid Connected*
   - *b) Remote off grid i.e., Island*

4) **Location:**
   - *a) Institutional*
   - *b) Community*
   - *c) Military*
   - *d) Commercial and Industrial (C&I)*

5) **Future microgrid:**
   - *a) Blockchain MGs*
   - *b) Networked MGs*
   - *c) Autonomous EV MGs*
   - *d) Desalination MGs*

6) **Functional Demand:**
   - *a) Simple*
   - *b) Multi DGs*
   - *c) Utility*

7) **Type of Distributed Resources:**

a) Traditional generation

b) Non-Traditional

c) Cutting-edge Technology Driven generation.

V. CHARACTERISTICS PROPERTY OF MICROGRID

The conceptualization of microgrid has been a small-scale power supply network to provide affordable electricity to the small community by enabling decentralized power generation for local loads by reinforcing Distributed Generations (DGs), which has received much attention because it reduces the burden from the conventional power systems with an eco-friendly sustainable approach and looks promising from future aspects. To better understand, some of the prominent characteristic's properties of microgrids have been identified &listed as follows:

1. Stability; 2. Autonomy; 3. Flexibility; 4. Scalability; 5. Efficiency; 6. Security; 7. Economy; 8. Compatibility 9. Interoperability; 10. Auto-troubleshooting

VI. NEED OF MICROGRID

Microgrids could be the best-suited option to fight an alarming worldwide energy crisis. Competent to deliver superior quality, reliable energy supply to critical loads, which enables grid transformations. Micrograds prove beneficial in minimizing transmission losses and also results in substantial saving and Promote community energy independence. To emphasize and promote the growing need for smart micrograds, a comparison table has been prepared, highlighting its superior characteristics over the traditional grid.

Table 1: Traditional vs Smart-micro grid.

Traditional Grid	Smart-Micro Grid
Large in size	Small and modular
Centralized generation	Decentralized generation
One-way energy communication/transfer	Single and two-way energy communication/transfer
Hierarchical structure	Network type structure
Manual restoration	Self-healing
Limited control	Modern pervasive control
No choice is provided to customer or end user	Infrastructure can be shared to a wide range of customer
Few sensors are employed	Equipped with sensors throughout
Technology used mainly electro-mechanical type	Information technology enabled Digital system
Not efficient	Effectively efficient
Significant losses due to T&D	Relatively less losses due to T&D

VII. STRATEGIC ROADMAP FOR DEVELOPMENT

Technological innovation and cutting energy technologies have made it possible to move towards the best alternative grid infrastructure, thus empowering and shaping a new nation of the next generation. In this context, the World Bank has introduced the Clean Technology Fund (CTF) to encourage microgrid-based distributed energy generation. India has been a critical player in the global race to achieve sustainable goals by taking several game-changing initiatives, among which proposal for a whole new concept of 'One Sun One World One Grid' with an ambitious vision to connect all microgrid network cluster through a centralized network and also witnesses formation of International Solar Alliance (ISA) as a founding member. Green energy corridor and Solar Transfiguration of India (SRISTI) are one of India's ambitious projects to enhance grid connectivity infrastructure. The evolution of intelligent power electronic devices and communication mechanization has considerably reduced the energy domain gap.

The government has made an extraordinary effort in setting up of Ministry of new and renewable energy (MNRE) as a National Nodal Agency, the formation of Non-Banking Financial Institution, i.e., Indian Renewable Energy Development Agency (IREDA) for providing monetary assistance in installation of captive microgrid model-based generation by individuals, farm or industry and establishes several world-class R&D institutions with high-tech laboratories to uphold the quality benchmark.

A variety of concerns need to be resolved in order to enforce a microgrid as a consumer product. A microgrid cannot function politically because the local utility did not see the value of eliminating and restoring the macro grid. It may take longer for microgrids to become predominant power supply agents. In comparison, entities also own wires and communication components. Utilities' approval is required to pass power via the macro grid. Besides, utility operators take on the microgrid as their rival and have begun investing in better macro grid stability. Besides, current grid codes must be modified to enable microgrid consideration.

Localized electricity is beneficial from the user/energy/environment viewpoint, but service providers politically do not see this way. The sector's condition undergoes a revolution and an essential assessment before specific problems are discussed, and decisions are taken. Nowadays, utilities slowly adopt emerging technologies, but microgrids would not be economically feasible until they release ownership and equipment access. However, further study is needed to address some crucial challenges and provide funding and motivation for micro-grids from manufacturers to local and federal governments. State of the art infrastructure, cutting edge technologies, and out of the box, innovation could prove beneficial in succeeding the traditional grid with all new smart microgrid.

VIII. FUTURE OF SMART MICRO GRID

The power sector is witnessing many technical obstacles, including growing electricity prices, energy efficiency, reliability, ageing facilities, widespread electrification, environmental dynamics, and so on. There may be systematic challenges to be overcome by producing low voltage distributed generation (DGs) at both origins and loads. The development of global micro-grid capability has been significantly increased since 2011 and is expected to exceed the complete deployed capacity by 2022 with more than 15GW. The industry has a potential of more than 5 billion dollars and is likely to cross over 27 billion dollars in market size for dealers by 2022. Campus/institutional microgrids are currently the highest by use and are projected to develop an 18.83% year-on-year (CAGR) compound growth rate between 2012 and 2022. Military, defence, and industrial microgrids could have comparable installed power by 2022. Off-grid microgrids aim to expand for the next 5-6 years at the fastest CAGR, whereas hybrid markets are projected to grow at their highest between 2012 and 2022 CAGR. For a fully developed microgrid, a more extended payback period is expected. Until microgrids begin to play an important role in cities, many study opportunities remain.

The smart grid refers to an advanced information infrastructure that enables efficient energy optimization, storage, production, transmission, and distribution of electrical energy. Emerging engineering tools that will shape the grid over the next decade are as follows:

1. Blockchain; 2. Database Management System (DBMS); 3. Big Data analytics; 4. Cloud Computing; 5. Artificial Intelligence (AI); 6. Internet of Technology (IoT); 7. Programmable Logic Control (PLC); 8. New Generation Communication Technology

IX. SALIENT FEATURES

Micro-Grid enablers clean and flexible generation-share of renewable energy sources to increase and move towards sustainability. It has now been essential to highlight some of the smart microgrid's salient embryonic features to have a clear understanding for the student, academician, industry personnel, and finally, policymakers.

1. Active Distribution Network
2. Sensors- Smart Meters, PMUs
3. Local, closed power network
4. Operates as a controllable unit
5. Physically separable from the grid
6. Market and Regulatory Framework
7. Wide Secure Communication Network
8. Grid-connected or island operation mode
9. Advanced Metering Infrastructure (AMI)
10. Allows Flexible Transmission - FACTS
11. Analytics-wide area monitoring and control
12. HTLS Lines, Multi-Circuit, Compact Tower
13. Automation of Substation, Digital Substation
14. SCADA/EMS, synchro phasor based automation

X. CONTEMPORARY CHALLENGES

Although, microgrid has several features, unfortunately, specific challenges primarily affect its growth, which includes intermittent generation, dependent on weather, need accurate forecasting, power balancing, complex voltage and frequency control as many of these sources do not have reactive power generation and sudden generation loss can lead to immediate system instability. Apart from this, an effort has been made to list some other dormant challenges.

1. Topological imbalance leads to a change in output
2. Reliability of technology with Economic aspects
3. Adaptive protection and stability issues
4. Information security and privacy-compromising
5. Dealing with intermittent generation
6. Inverter design for DC-AC Conversion
7. Controllers for Regulation of power flow
8. Minimizing harmonics in DC Microgrids
9. Optimal siting and sizing of storage devices
10. Customers' Acceptance of RES Deployment.

XI. SPECIFIC OUTCOME & DISCUSSION

With the increase of use of renewable and non-conventional energy resources, the Micro-grid system application is increasing day by day. To meet the ever-variable complex power demand, the micro-grid system's design and algorithmic operation need to be gradually updated. It has become essential to study such a system's quality issues and performance from the perspective of modern power system application. In this study, an attempt has been made to monitor various aspects of quality issues deeply, mainly in terms of harmonics and performance, to make the micro-grid system more robust, more flexible, and more reliable. Besides, Driver and Inhibitor are triggering parameters that regulate and partially influence the power sector, shown above. The driver and inhibitor have specific co-relation, which can be altered by a systematic approach, which endorses the novel smart microgrid installation. Future work would extend various performance assessments to determine behavioural physiognomies and validate captive microgrid infrastructure's characterisation.

Conflict of Interest. Ayan Banik *et al* agree & abide with the contents of the manuscript and further declare that they have no conflict of interest.

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