INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH
H. Baby and J. Jayakumar, Vol.10, No.4, December, 2020

Smart Management in the Modernization of Intelligent Grid Incorporating with Distribution Generation: A Systematic Scrutiny

Honey Baby*‡, J. Jayakumar*‡

*Department of Electrical and Electronics Engineering, Karunya Institute of Technology and Sciences, Coimbatore

(honeybaby@karunya.edu.in, jayakumar@karunya.edu)

‡ Honey Baby; J. Jayakumar, Department of Electrical and Electronics Engineering, Karunya Institute of Technology and Sciences, Coimbatore, Tel: +918547965019, honeybaby@karunya.edu.in

Received: 06.10.2020 Accepted:10.11.2020

Abstract- The fascination about the smart grid technology worldwide depicts the deployment of smart management in grid monitoring and protection. A probe into a plethora of challenges about the smart organization of grid explored in this paper. A ground level review about the incooperation of distributed resources with smart protection in demand response and demand side management enhanced the performance of the grid infrastructure. The adequate support of the information technology provides incessant monitoring for grid control and protection. This survey comprehensively examined various research proposals on the environmental, technical and economical remuneration of distribution generation incorporation like stability, reliability, cost analysis and green energy optimization. These benefits result from the smart management of each renewable distribution generation elements. This paper also reviews the current technologies for the grid incorporation with distribution generation.

Keywords Smart Grid; Metering Infrastructure; Smart Control; Demand Side Management; Distributed Energy Resources.

1. Introduction

The impact on pilot growth of the advanced software and communication technologies steer towards the operation and control of the future grid. The distribution of smart technologies using smart meters, sensors and incoperation of the distribution generation enhanced the security of the system. Even though the existing grids are the greatest attainment of the 20th century, its economic impacts due to blackouts and burnouts are retort by smart grid automations. The global evolution of renewable energy increased. According to International Energy Agency (IEA), the progress declined to 13% due to Covid-19 crisis contrast with 2019. Fig.1 demonstrates forecast overview of electricity market [1].

Digitization in the power system boosts the performance of the grid in terms of grid elements, communication, advanced meters, sensors, artificial intelligent and the information management technologies are sketched in this work.

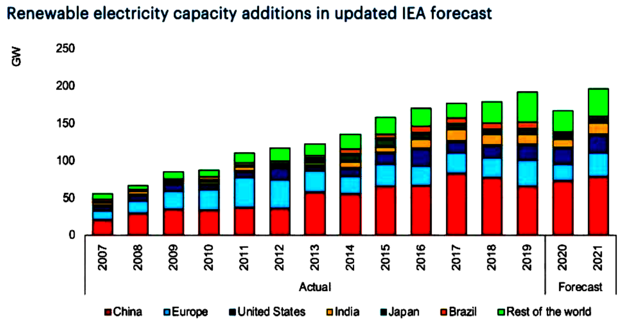

Figure 1. Renewable Electricity Capacity, World Electricity Market 2007–2021.

Generally, the smart grid operations deployed by the following constraints. Firstly, smart devices, which monitor the grid parameters and send the signals to the control by sensors thus the more accurate measurement and control occur as compared to the traditional methods. Secondly, advanced communication system for the data transfer and finally the information technology which is analyzed, operate and control the data for the smart grid with the help of digital technologies [2]. The constraints enhanced the grid smarter illustrated in fig.2.

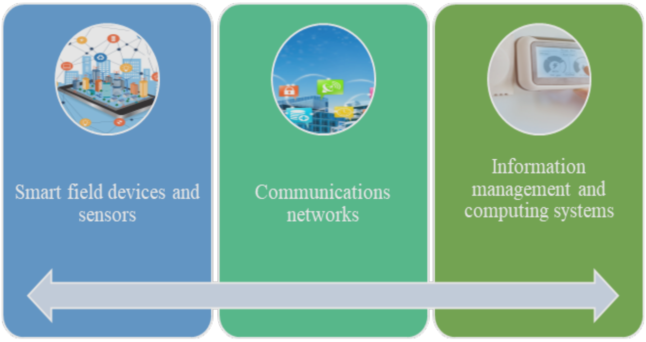

Figure 2. Smart Grid Deployment Essential Elements.

Principally, DER (Distributed Energy Resources) integration in smart grid resolves grid performance faults in the DG (Distribution generation) and operated in parallel with the utility. Moreover, it protects the sensitive loads in the system [3]. Optimal placement of Distribution generation (DG) by incorporating FACTS devices, one of the enticements in the power region. Eminent role of metaheuristic techniques like Particle Swarm Optimization, Firefly Algorithm, Differential Evolution, Kill Herd Algorithm, Bacterial Foraging Algorithm, Evolutionary Algorithm despite conventional optimization techniques enhanced the significant modification in terms of power loss, stability, performance explained in [1].

Further, Demand side management [2] improved the optimization of consumer embarrassment, cost minimization, load reduction by various approaches like Monte-Carlo based programming [3], Linear programming-based algorithm and Least enthalpy estimator (LEE) [4]. An innovative evolutionary aggregation algorithm (EAA) is anticipated in [5] to acquire the minimum number and locations of the smart grid. Demand side resources scheduled by binary particle swarm optimization (BPSO) and a detailed survey related to the demand side management by considering six aspects described in [6]. A real time distributed algorithm used for the real time pricing in demand side management and the maximum utilization of the resources as well the cost minimization is accomplished by this algorithm [7].

This paper classified into a different section, section 1 deals with the introduction path. Section 2 analyses the smart grid performance with modern technology. Section 3 analysed by the methodologies cyber security in smart grid. Overview of Smart Energy Management (SEM) deliberated in section 4. Further, Section 5 elucidated DG (Distribution Generation) performance with modern grid technology. This section also explains smart devices and generally used standards in smart grid. Section 6 designated future scenarios in the smart grid. Finally, section 7 depicted the conclusion.

The motivation of this review is a detailed study of smart grid technologies which boost the performance of the power system in a most reliable path and find scope the future studies.

2. A paradigm to Smart Grid with Smart Technology

The smart grid infrastructure is competent to connect renewable energy resources and energy storage system intending to sustain the quality of the power system. A high-level smart grid architecture depicted in Fig.2 and the optimum flow of power enabled through this scheme explained in [10]. Additionally, the grid architecture portrayed the key components and the flow power generation through different devices. The departure of energy flows from the generation station and terminates in end user. Additionally, piece of communication comprises both wireline and wireless schemes supported by IEEE 802.15.4 protocol applications [11].

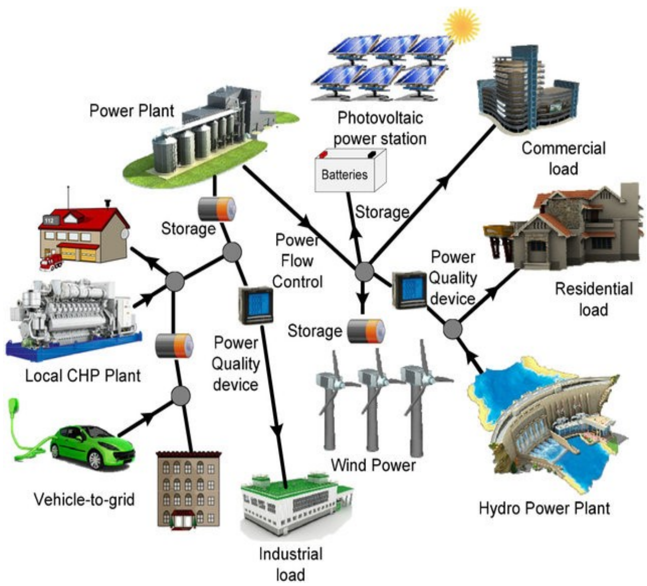

Figure 3. Smart Grid Architecture

The technology development in the power system formulates the grid more consistent than the existing models. Grouping of smart technology with current power system creates economical rose in the present grid network. Furthermore, to balance the demand response, advanced intelligent techniques, as well as the sensors, are enabled in the grid. Fig.4 depicts the smart technology-enabled smart grid model. proposed model permits the grid more efficient and reliable [8].

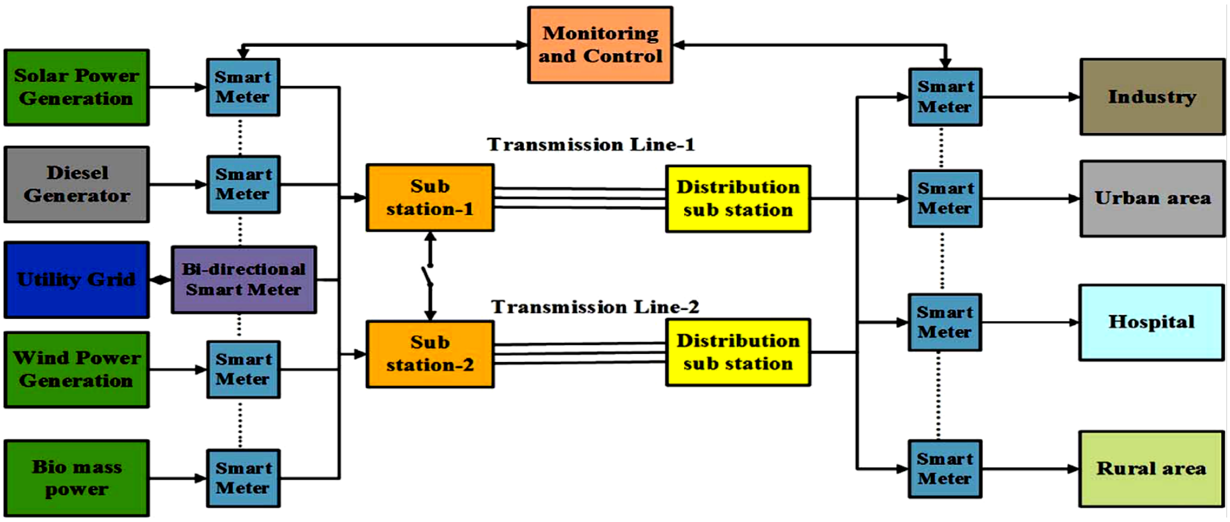

Figure 4. Smart Technology-Enabled Smart Grid Model

Additionally, Management and control of domestic smart grid technology for achieving demand supply by the real-time control explained in [9]. This paper proposed a three-step methodology for operation and control. It produces smart real-time management and control of domestic appliances. Electric Springs used as the smart grid technology in [10]. Electric springs provide more stability in the distribution generation than existing scenarios.

3. Key Approaches to Cyber Security in Smart Grid

Cybersecurity, one of the significant addressed safety exposures faced by the grid infrastructure. Several control administrations faced cyber-attacks [15]. There are four parameters used by hackers for the attack to acquire control of the smart grid. Generally, they termed as cyber-attack cycle. Fig.5 demonstrate the major steps involved in hacking procedure [16]. The cyber security depends on the steps depicted in fig.6.

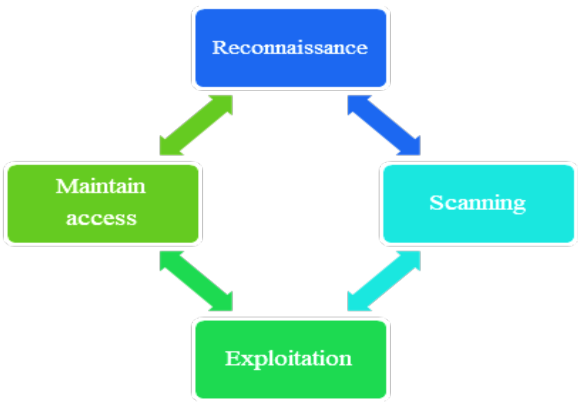

Figure 5. Cyber Attack Cycle

3.1 Steps in Hacking Procedure

The key aspects on steps in hacking encompassed in this section. Section 3.1.1 to 3.1.4 explain the major steps in hacking in detail.

3.1.1 Reconnaissance

Firstly, reconnaissance represents the first phase which contains social engineering and traffic analysis. Thus, combination of human skills as well as technical skills enabled in this phase. Advanced communication encourages the cyber-attacks in this phase. Phishing [11] and password pilfering, DoS/DDoS, Eavesdropping attacks [12] are well-known technologies used in reconnaissance phase.

3.1.2 Scanning

Secondly, scanning represents the next phase followed by Reconnaissance. The objective of the scanning is to analyze the host alive in the network. As illustrated in fig.4, scanning consists of four pillars IP, Port, Service and Endangered Action. IP address attacks by the hackers done by creating site errors so, they easily access the IP address of the server. Further, the attacker approaches the port to hack the vital information from substation automation control (port 102 open) and PMU (Phasor Measurement Unit) (port 4713 open) [13].

3.1.3 Exploitation

Thirdly, malicious activities described in this phase like virus, worms, Trojan, jamming channels, reply attack and integrity and privacy violation. A virus is a program to contaminate the server to damage. Worms are the replica of the products that confuse the operator thus, the failure of the system occurs. First worm attack reported in 2010,Stuxnet [14] which affect the control system performance.

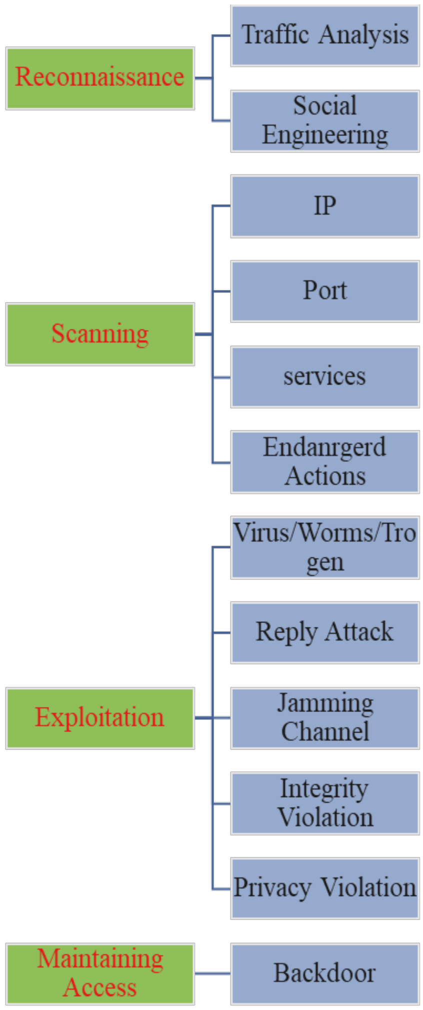

Figure 6. Steps in Hacking Procedure

3.1.4 Maintaining Access

The final phase of the cyber-attack cycle deals with the sustainability of the network. In this section, the modes of attack ensue in the backdoor. Moreover, parameters like confidentiality, credibility, accountability and integrity affected in cyber-attacks. Using Diversity Technique, attack slowdown procedure so, we can sort out the issues in this phase [15].

For instant, fig.7 proposed an effective control strategy [16]. Modes of control classified as Pre-Attack, Under Attack and Post Attack. Pre-Attack deals with security of the system specialized in the network, Data and Device Security. In under Attack region, the attack detection as well as the attack mitigation process examined. Finally, in the Post Attack section detailed investigation by forensic analysis mentioned.

Table 1 depicts the cyber security attacks during different years. İn 2003, countries like US, Canada, Italy and Switzerland face a huge extent blackout record before. Most of the cyber attacks materialized in US. As a result, the motivation towards security facilities enhanced with the help of smart technologies. İn short, a comprehensive analysis of cyber-attacks and security explained in this section.

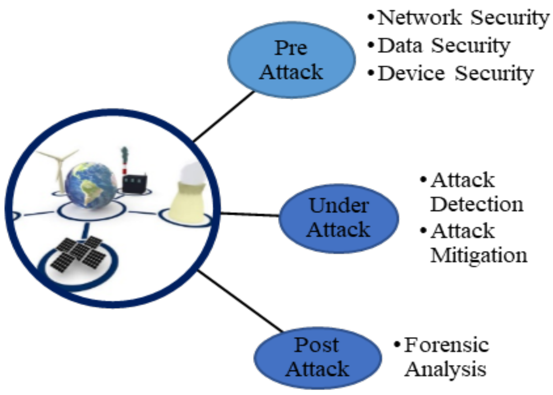

Figure 7. Cyber Security Strategy for Smart Grid

4. Organization of Smart Energy Management

In general, the Smart Energy Management (SEM) required essential parameters like demand profile, energy efficiency, energy losses, cost and pricing of components, metaheuristic algorithm, Artificial Intelligence, and machine learning proposed in [17]. Communication as well as the intelligent system associated with the management system. Distribution monitoring, controlling and optimization are enhanced by the energy management system. Additionally, the smart substation can be improving the productivity of the existing grid. So, penetration of distributed generation, power quality improvement and reliability improvement occurred due to the smart management [18].

In fact, a smart energy management steps at different level of power system [19] and the effective tools for the management shown in fig. 8. The energy management steps contain four chief elements energy policy, energy planning, implementation and operation finally checking. Continuous improvement performed by the management review under accurate checking process. Checking process in energy management delivered by continues monitoring measurement and analysis, non-formalities and correction and prevention action and internal audit of the EMS (Energy Management System).

Table 1 Analysis of Cyber-Attacks in Smart Grid

Year	Country	Reason	Consequences
2003[20]	US&Canada	Malfunction in the software program of the cyber system	An electric power blackout which persisted for up to 4 days and it affects about 50 million people and 61,800 MW of electric load.
2003[20]	Italy& Switzerland	Technical complications by the human error and Futile communication inside the power grid operators	Major power supply interruption and it affects 56 million people for 18 hours.
2006[20]	South West Europe	Intolerable communication	Large blackout occurred for few hours.
2007[21]	US	Manipulation in control system	Physical damage of generators
2009[22]	US	Virus	It affects the electrical and control system
2010[23]	Iran	Stuxnet (worm)	Directing the industrial control system of Siemens
2015[24]	Spain	Injection of malicious commands	Energy stealing

The organizational components of the smart grid are its power and communication infrastructure. Power infrastructure is accountable for generation and distribution and the communication infrastructure responsible for the transfer of data. Smart management provides an established platform for continuous monitoring and control [25]. Significant technologies and its features of the implementation of smart management enumerated below:

- Unified communication amidst the grid
- Innovative control techniques
- Advanced sensors, monitoring and measurement
- Modern communication technology
- Emerging trends in decision assistance and human interface

4.1 Demand Response

DR (Demand Response), one of the crucial parts of the grid technology. Moreover, its response with time depend on the end user. The different demand response programs also support in extension of capacity exploitation of existing network.

Apparently, Sequential Monte Carlo Simulations are used for the reliability checking. The interaction of smart home and the distribution service operator explained in [26]. Thus, DR programs converts the existing grid into smart grid. A plethora of energy management tools which are categorized in the following section. Firstly, game theory, a strong tool for scheming future smart grid structure which accomplish the promise of an utterly unified solution with a paradigm consist of computer, sense, communication and control [27].

4.2 Smart Energy Management Tools

The proliferation of innovative paraphernalia and services in smart system suggests that disciplines like game theory and optimization techniques become prominent tool in the design and analysis of smart grid [28]. Optimization techniques are the next promising energy management tool. A taxonomical analysis with different energy management tools described in this section.

Later, to resolve management problems researches adopted tools like optimization, game theory, machine learning and auction. Table 2 shows the cataloguing of interrelated work. For optimization methodology, the mathematical tools like convex programming [43-45] and dynamic programming [13, 46, 47] are generally used. The disparity in renewable energy resources and time-varying process emerge Stochastic Approach [39-41] and Robust Programming [51] in the system. Further, the complexity in the optimization problems demands accuracy in the precision of the management. Thus, particle swarm optimization [48-50], evolutionary algorithms [35-38] and distribution algorithms [42] are used for the convoluted situation.

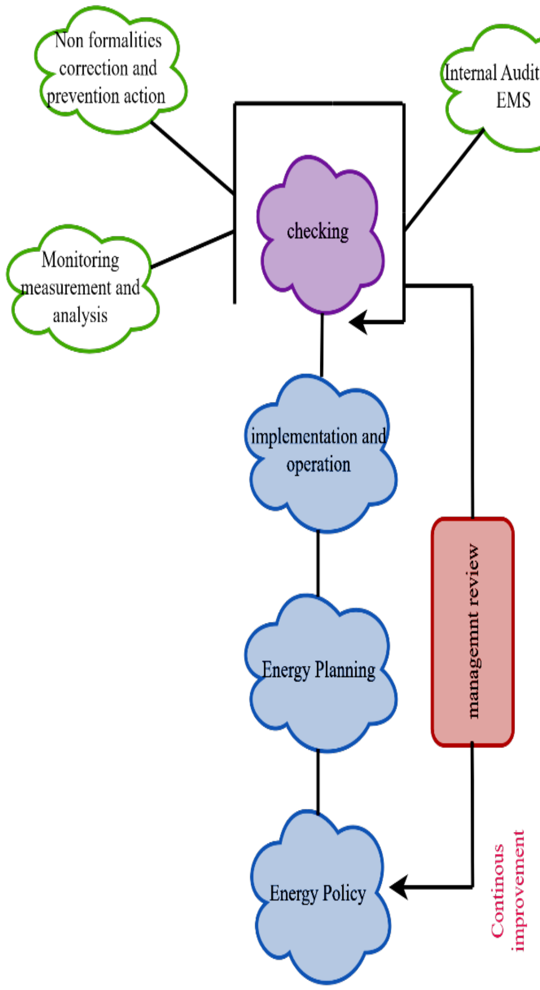

Figure 8. Smart Energy Management Steps

Game Theory [33, 52-54], focus on the management scheme design. Depend on the objective function game theory operates. Electric markers demand the game theory described in [30].

Machine Learning, enabled for the design and development. The schematic layout collected from the sensors and PMU. In [31], the online design support explained. The detailed analysis proceeds with machine learning. The energy use, cost analysis, energy policy are other fundamentals described in this work. The control of renewable energy sources designated in [56].

Auction, the data collection agent from bid and market [32]. The electrical sale management analysed in this method. It also encourages demand response for the customer fulfilment.

5. Distributed Generation and smart grid technology

Total production of electricity demand in every country of the world is satisfied with conventional power plants. Apart from these benefits, it causes global warming due to the use of fossil fuels. Currently, most of the developing countries used the distribution system for the power generation due to its reasonable features and production. Major motives towards the penetration of distributed energy resources are cost minimization and less outage problems [33].

Moreover, advancement in Penetration of renewables in the power system enhanced in several developed as well as the developing country by developers in the advancements ready to prevent spillages from the penetration. Conserving reliability, power quality, security and control are the key drivers of the DG. Grid-Edge - Technologies used as the emerging trends in the power system for a more reliable system [34].

A hypothetical approach towards integration of distributed energy resources commended in starting of 20th century. Initially, several comprehensive study of resources and the storage system reviewed in [35]. The system security, reliability, efficiency and the cost are optimized through the penetration indicated in[36]. The smart grid application in the distribution generation explained in fig.9. From distribution to the customer end, the chief components reveled in this scheme. The voltage performance of the grid stability within the presumed limit. Switching of transmission and distribution network more manageable by smart grid application. Integration of renewables and power transfer between transmission and distribution are the significant features of smart grid application [37].

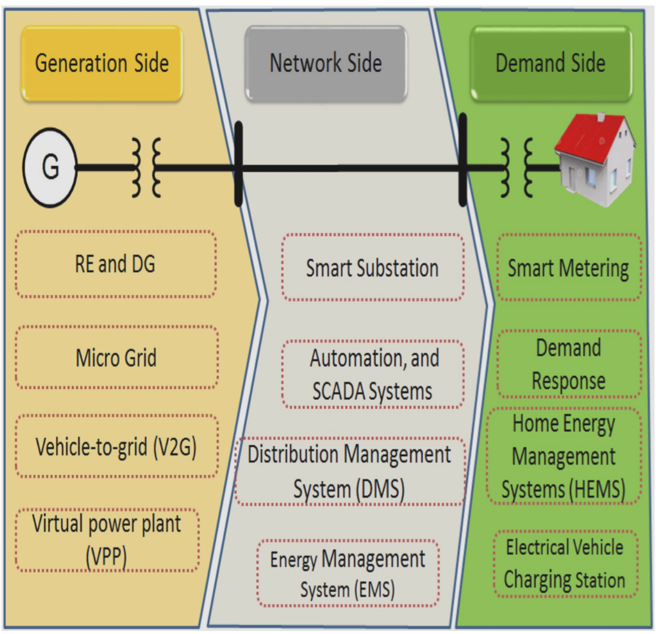

Figure 9. smart grid application in Distribution Generation

Table 1. Taxonomical study of SEM Tools

SEM Tools and Methods	Reference						
Optimization	Evolutionary algorithms [38][39][40][41]	Stochastic approach [42][43][44]	Novel distribution algorithms [45]	Convex Programme [46][47] [48]	Dynamic Programmin g [9][49][50]	Particle Swarm optimization [51][52][53]	Robust Programming [54]
Game theory	[30][27] [29][55]						
Machine Learning	[31][56][57]						
Auction	[32]						

5.1 Performance of Renewable Energy Resources and Energy Storage Devices – A Review

In 2006, integration of renewable energy sources increased to a great scope. The innovative technologies enhanced the system performance in terms of economic, robust and environment friendly. Analysis with electric vehicle and control system depicted in [58]. Modelling and analysis of grid integration of renewable energy system expound in [59]

Enormous benefits of renewable energy system make them important to establish distributed generation. Technology advancement handled many challenges like small size of distributed generation, low load factor, demand response and energy storage depicted in [19].

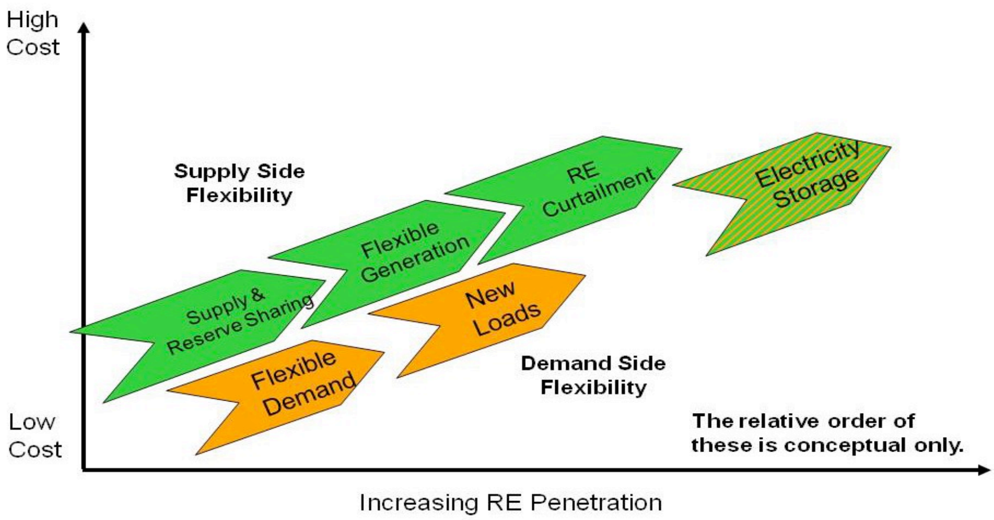

Figure 10. Flexibility Supply Curve

Further, Fig.10 explained the flexibility curve, the key parameter in storage application. It depends on the factors supply and reserve sharing, flexible generation, RE curtailment, old and new loads and cost. Supply of renewables and conventional supply included in reserve sharing. The use of different flexibility elements varies, the cost and the energy storage depend on each other. The flexibility supply curve in terms of the cost is less than that of energy storage.

Microgrid voltage stability with a bidirectional converter expressed in [60]. A selector-based algorithm used for the implantation of this work. In [61], Zhao described the influence of nanomaterials in penetration of RERs for more efficient energy storage in the grid. Flexibility analysis of energy storage with the help of FLEXIN [62], a flexibility index enabled for the parameters affects flexibility established in this paper. The results exhibit the advantages of the proposed model over flexibility challenges. Complex Network Framework for the optimal placement of microgrid described in [63]. Optimal placement referred to the stability, power loss and increased grid resilience. The organization of energy flow in an integrated renewable energy system examined continuously. For this, a well-intended scheme implemented in [64]. This paper proposed an intelligent energy system and a centralized control arrangement for the gratification of objectives.

5.2 Smart Devices

In general, Smart devices enable the smart metering and the communication by smart meters, smart control of loads[65]. Information security and commutation are compensated by these smart meters. Distribution algorithm used for the demand side management[66]. Advanced metering scheme depicted in [67] fig.11. A recent study in Europe shows the distribution of smart meters in cost and outcome analysis.

5.3 Smart Grids Standards

The chief characteristics associated with grid is its interoperability performance between communication and operational devices. A list of standards enabled for this seamless operation and control. Generally, National Institute of Standards and Technology (NIST) are referred and widely accepted [68]. Developmental form of these standard is also implemented in India.

On the whole, numerous smart grid mechanisms in detail to accomplish today's world energy necessities in green manner, where conventional energy generation sources weaken to deliver. Many research papers prosed the need of a smart management system in the grid.

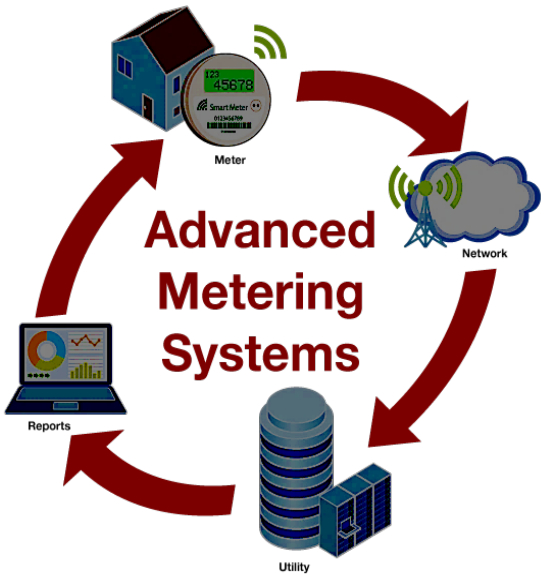

Figure 11. Advanced Smart Meter

6 Smart Grid Projects: Future Scenarios

The modification in the existing grid enabled with different smart grid projects across the world. The database applied in the new project transform the existing system more efficient and cost effective. Participation of different countries in smart grid projects enhance the overall performance of the system. Smart grid projects are categorized into two Research and Developments projects (R&D) and Demonstration and Deployment Projects (D&D) described in [69]. Fig.12 deliberates the distribution of smart grid elements per degree of application.

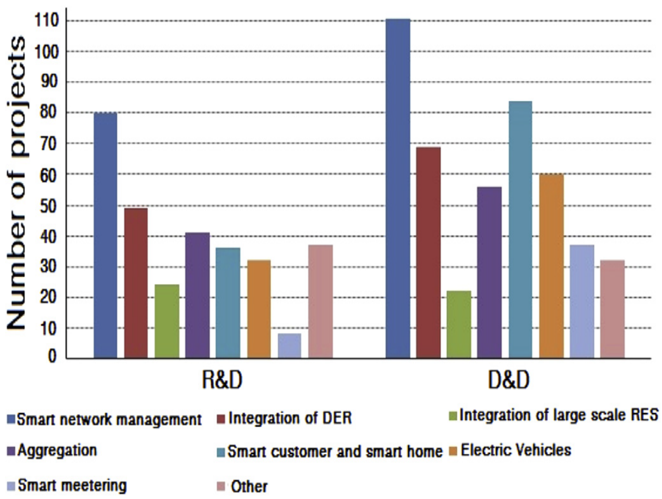

Figure 12. Distribution of Smart Grid elements in R&D and D&D projects

Later, Fig .13 demonstrates national as well as the multinational projects. 65% of national projects belongs to Denmark and 48% national projects under UK. Some European countries have only multinational projects only.

From fig.14, in 2012, the greatest number of starting projects available and by 2014, most of staring projects are finished.

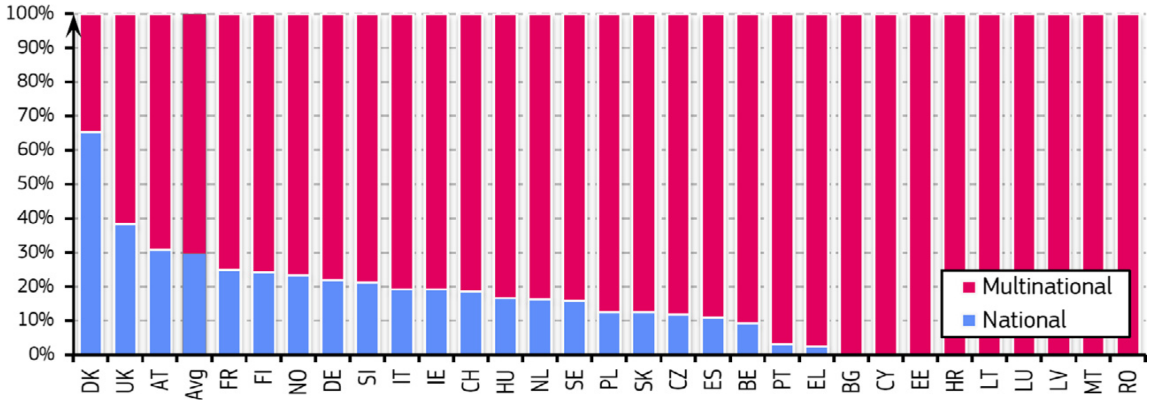

Figure 13. Percentage of National and Multinational projects worldwide

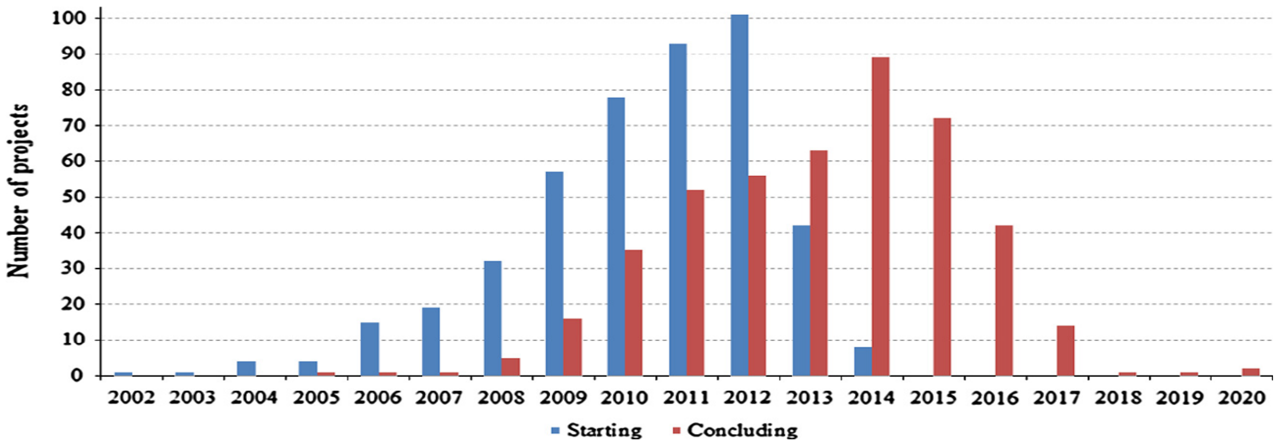

Figure 14. Annual Number of Starting and Completed Projects

7 Conclusion

This paper describes the importance of smart management in the smart grid. By the penetration of distributed energy resources in the grid, the overall performance of the system enhanced. Many research works conducted in the area of smart technology, smart metering, demand side management and the control system. Establishment of smart meters in the smart grid needs some supplementary requirement for the data analysis. The discussion mainly concerned with smart technology in terms of demand response, demand side management, cyber-attack, placement of DG, optimization and different smart management tools. Smart grid projects evidently explained the future of the energy market as well as the reliability of the future grid. İn brief, plethora of challenges like security, modification in technology, advanced sensors are the future scope of this work

Acknowledgment

We acknowledge the Department of Electrical and Electronics Engineering, Karunya Institute of Technology and Sciences (Deemed to be University) Coimbatore, India. Their assistance in data collection and organization of the manuscript. Thanks to Dr J. Jayakumar for his suggestions on formulating the data and support. None of the authors had a conflict of interest in this work.

References

[1] W. S. Tan, M. Y. Hassan, M. S. Majid, and H. Abdul Rahman, "Optimal distributed renewable generation planning: A review of different approaches," *Renew. Sustain. Energy Rev.*, vol. 18, pp. 626–645, 2013.

[2] S. Kakran and S. Chanana, "Smart operations of smart grids integrated with distributed generation: A review," *Renew. Sustain. Energy Rev.*, vol. 81, no. July 2017, pp. 524–535, 2018.

[3] M. Cui, J. Wang, and M. Yue, "Machine Learning-Based Anomaly Detection for Load Forecasting Under Cyberattacks," *IEEE Trans. Smart Grid*, vol. 10, no. 5, pp. 5724–5734, 2019.

[4] A. S. Shah, H. Nasir, M. Fayaz, A. Lajis, and A. Shah, "A review on energy consumption optimization techniques in IoT based smart building environments," *Inf.*, vol. 10, no. 3, 2019.

[5] H. Miao, G. Chen, Z. Zhao, and F. Zhang, "Evolutionary Aggregation Approach for Multi-hop Energy Metering in Smart Grid for Residential Energy Management," vol. 3203, no. c, 2020.

[6] N. Mohammad and Y. Mishra, "Demand-Side Management and Demand Response for Smart Grid," pp. 197–231, 2019.

[7] Y. Zhang, N. Rahbari-Asr, J. Duan, and M. Y. Chow, "Day-ahead smart grid cooperative distributed energy scheduling with renewable and storage integration," *IEEE Trans. Sustain. Energy*, vol. 7, no. 4, pp. 1739–1748, 2016.

[8] L. Peng and G. S. Yan, "Clean energy grid-connected technology based on smart grid," *Energy Procedia*, vol. 12, pp. 213–218, 2011.

[9] A. Molderink, V. Bakker, M. G. C. Bosman, J. L. Hurink, and G. J. M. Smit, "Management and control of domestic smart grid technology," *IEEE Trans. Smart Grid*, vol. 1, no. 2, pp. 109–119, 2010.

[10] S. Y. Hui, C. K. Lee, and F. F. Wu, "Electric springs - A new smart grid technology," *IEEE Trans. Smart Grid*, vol. 3, no. 3, pp. 1552–1561, 2012.

[11] H. Holm, W. R. Flores, and G. Ericsson, "Cyber security for a Smart Grid - What about phishing?," *2013 4th IEEE/PES Innov. Smart Grid Technol. Eur. ISGT Eur. 2013*, pp. 2–6, 2013.

[12] M. Yevdokymenko, E. Mohamed, and P. Onwuakpa, "Ethical hacking and penetration testing using raspberry PI," *2017 4th Int. Sci. Conf. Probl. Infocommunications Sci. Technol. PIC S T 2017 - Proc.*, vol. 2018-Janua, pp. 179–181, 2017.

[13] H. Berger and A. Jones, "Cyber security & ethical hacking for SMEs," *ACM Int. Conf. Proceeding Ser.*, vol. Part F1305, 2016.

[14] D. Kushner, "The real story of stuxnet," *IEEE Spectr.*, vol. 50, no. 3, pp. 48–53, 2013.

[15] S. McLaughlin, D. Podkuiko, A. Delozier, S. Miadzvezhanka, and P. McDaniel, "Embedded firmware diversity for smart electric meters," *HotSec 2010 - 5th USENIX Work. Hot Top. Secur.*, 2010.

[16] Y. Yang, T. Littler, S. Sezer, K. McLaughlin, and H. F. Wang, "Impact of cyber-security issues on Smart Grid," *IEEE PES Innov. Smart Grid Technol. Conf. Eur.*, pp. 1–7, 2011.

[17] A. Evans, V. Strezov, and T. J. Evans, "Assessment of utility energy storage options for increased renewable energy penetration," *Renew. Sustain. Energy Rev.*, vol. 16, no. 6, pp. 4141–4147, 2012.

[18] Azizivahed A, Arefi A, Ghavidel S, Shafie-khah M, Li L, Zhang J, Catalão JP. Energy management strategy in dynamic distribution network reconfiguration considering renewable energy resources and storage. IEEE Transactions on Sustainable Energy. 2019 Feb 25;11(2):662-73.

[19] Y. E. G. Vera, R. Dufo-López, and J. L. Bernal-Agustín, "Energy management in microgrids with renewable energy sources: A literature review," *Appl. Sci.*, vol. 9, no. 18, 2019.

[20] E. Hossain, I. Khan, F. Un-Noor, S. S. Sikander, and M. S. H. Sunny, "Application of Big Data and Machine Learning in Smart Grid, and Associated Security Concerns: A Review," *IEEE Access*, vol. 7, pp. 13960–13988, 2019.

[21] A. R. Khan, A. Mahmood, A. Safdar, Z. A. Khan, and N. A. Khan, "Load forecasting, dynamic pricing and DSM in smart grid: A review," *Renew. Sustain. Energy Rev.*, vol. 54, pp. 1311–1322, 2016.

[22] J. J. Q. Yu, Y. Hou, A. Y. S. Lam, and V. O. K. Li, "Intelligent fault detection scheme for microgrids with wavelet-based deep neural networks," *IEEE Trans. Smart Grid*, vol. 10, no. 2, pp. 1694–1703, 2019.

[23] X. Fang, S. Misra, G. Xue, and D. Yang, "Smart grid - The new and improved power grid: A

survey," *IEEE Commun. Surv. Tutorials*, vol. 14, no. 4, pp. 944–980, 2012.

[24] M. Zadsar, S. S. Sebtahmadi, M. Kazemi, S. M. M. Larimi, and M. R. Haghifam, "Two stage risk based decision making for operation of smart grid by optimal dynamic multi-microgrid," *Int. J. Electr. Power Energy Syst.*, vol. 118, no. August 2019, p. 105791, 2020.

[25] J. R. Roncero, "Integration is key to smart grid management," *IET Semin. Dig.*, vol. 2008, no. 12380, pp. 23–24, 2008.

[26] G. Kleineidam, M. Krasser, and M. Reischböck, "The cellular approach: smart energy region Wunsiedel. Testbed for smart grid, smart metering and smart home solutions," *Electr. Eng.*, vol. 98, no. 4, pp. 335–340, 2016.

[27] W. Saad, Z. Han, H. V. Poor, and T. Başar, "Game Theoretic Methods for the Smart Grid," 2012.

[28] H. Haddadian and R. Noroozian, "Multi-microgrids approach for design and operation of future distribution networks based on novel technical indices," *Appl. Energy*, vol. 185, pp. 650–663, 2017.

[29] C. Ibars, M. Navarro, and L. Giupponi, "Distributed Demand Management in Smart Grid with a Congestion Game," pp. 495–500, 2010.

[30] A. H. Mohsenian-Rad, V. W. S. Wong, J. Jatskevich, R. Schober, and A. Leon-Garcia, "Autonomous demand-side management based on game-theoretic energy consumption scheduling for the future smart grid," *IEEE Trans. Smart Grid*, vol. 1, no. 3, pp. 320–331, 2010.

[31] X. Fang, D. Yang, and G. Xue, "Online strategizing distributed renewable energy resource access in islanded microgrids," *GLOBECOM - IEEE Glob. Telecommun. Conf.*, 2011.

[32] N. Li, L. Chen, and S. H. Low, "Optimal demand response based on utility maximization in power networks," *IEEE Power Energy Soc. Gen. Meet.*, 2011.

[33] R. Majumder, A. Ghosh, G. Ledwich, and F. Zare, "Load sharing and power quality enhanced operation of a distributed microgrid," *IET Renew. Power Gener.*, vol. 3, no. 2, pp. 109–119, 2009.

[34] M. Kolhe, K. Agbossou, J. Hamelin, and T. K. Bose, "Analytical model for predicting the performance of photovoltaic array coupled with a wind turbine in a stand-alone renewable energy system based on hydrogen," *Renew. Energy*, vol. 28, no. 5, pp. 727–742, 2003.

[35] D. C. Kullay Reddy, S. S. Narayana, and V. Ganesh, "Towards an enhancement of power quality in the distribution system with the integration of BESS and FACTS device," *Int. J. Ambient Energy*, pp. 1–9, 2019.

[36] T. Ackermann, G. Andersson, and L. Söder, "Distributed generation: A definition," *Electr. Power Syst. Res.*, vol. 57, no. 3, pp. 195–204, 2001.

[37] S. S. Refaat, A. Mohamed, and H. Abu-Rub, "Big data impact on stability and reliability improvement of smart grid," *Proc. - 2017 IEEE Int. Conf. Big Data, Big Data 2017*, vol. 2018-Janua, pp. 1975–1982, 2017.

[38] V. V. S. N. Murty and A. Kumar, "Multi-objective energy management in microgrids with hybrid energy sources and battery energy storage systems," *Prot. Control Mod. Power Syst.*, vol. 5, no. 1, 2020.

[39] B. Li, R. Roche, and A. Miraoui, "Microgrid sizing with combined evolutionary algorithm and MILP unit commitment," *Appl. Energy*, vol. 188, pp. 547–562, 2017.

[40] G. Celli, E. Ghiani, S. Mocci, and F. Pilo, "A multiobjective evolutionary algorithm for the sizing and siting of distributed generation," *IEEE Trans. Power Syst.*, vol. 20, no. 2, pp. 750–757, 2005.

[41] S. Reddy, A. R. Abhyankar, and P. R. Bijwe, "Reactive power price clearing using multi-objective optimization," *Energy*, vol. 36, no. 5, pp. 3579–3589, 2011.

[42] F. Hafiz, A. Rodrigo de Queiroz, P. Fajri, and I. Husain, "Energy management and optimal storage sizing for a shared community: A multi-stage stochastic programming approach," *Appl. Energy*, vol. 236, pp. 42–54, 2019.

[43] F. van den Bergh and A. P. Engelbrecht, "A cooperative approach to participle swam optimization," *IEEE Trans. Evol. Comput.*, vol. 8, no. 3, pp. 225–239, 2004.

[44] Giaouris D, Papadopoulos AI, Patsios C, Walker S, Ziogou C, Taylor P, Voutetakis S, Papadopoulou S, Seferlis P. A systems approach for management of microgrids considering multiple energy carriers, stochastic loads, forecasting and demand side response. Applied energy. 2018 Sep 15;226:546-59.

[45] J. Schiffer, T. Seel, J. Raisch, and T. Sezi, "Voltage Stability and Reactive Power Sharing in Inverter-Based Microgrids with Consensus-Based Distributed Voltage Control," *IEEE Trans.*

Control Syst. Technol., vol. 24, no. 1, pp. 96–109, 2016.

[46] M. G. Kallitsis, G. Michailidis, and M. Devetsikiotis, "A Framework for Optimizing Measurement-Based Power Distribution under Communication Network Constraints," pp. 185–190, 2010.

[47] P. Samadi, A.-H. Mohsenian-Rad, R. Schober, V. W. S. Wong, and J. Jatskevich, "Optimal Real-Time Pricing Algorithm Based on Utility Maximization for Smart Grid," pp. 415–420, 2010.

[48] E. Sortomme, S. S. Venkata, and J. Mitra, "Microgrid protection using communication-assisted digital relays," *IEEE Trans. Power Deliv.*, vol. 25, no. 4, pp. 2789–2796, 2010.

[49] S. Kishore and L. V. Snyder, "Control Mechanisms for Residential Electricity Demand in SmartGrids," pp. 443–448, 2010.

[50] S. Han, S. Han, and K. Sezaki, "Development of an optimal vehicle-to-grid aggregator for frequency regulation," *IEEE Trans. Smart Grid*, vol. 1, no. 1, pp. 65–72, 2010.

[51] C. Hutson, G. K. Venayagamoorthy, and K. A. Corzine, "Intelligent scheduling of hybrid and electric vehicle storage capacity in a parking lot for profit maximization in grid power transactions," *2008 IEEE Energy 2030 Conf. ENERGY 2008*, 2008.

[52] J. Mitra, S. B. Patra, and S. J. Ranade, "Reliability stipulated microgrid architecture using particle swarm optimization," *2006 9th Int. Conf. Probabilistic Methods Appl. to Power Syst. PMAPS*, 2006.

[53] A. Y. Saber and G. K. Venayagamoorthy, "Unit commitment with vehicle-to-grid using particle swarm optimization," *2009 IEEE Bucharest PowerTech Innov. Ideas Towar. Electr. Grid Futur.*, 2009.

[54] A. J. Conejo, J. M. Morales, and L. Baringo, "Real-time demand response model," *IEEE Trans. Smart Grid*, vol. 1, no. 3, pp. 236–242, 2010.

[55] Shakeri M, Shayestegan M, Abunima H, Reza SS, Akhtaruzzaman M, Alamoud AR, Sopian K, Amin N. An intelligent system architecture in home energy management systems (HEMS) for efficient demand response in smart grid. Energy and Buildings. 2017 Mar 1;138:154-64.

[56] S. Ghosh, J. Kalagnanam, D. Katz, M. Squillante, X. Zhang, and E. Feinberg, "Incentive Design for Lowest Cost Aggregate Energy Demand Reduction," pp. 519–524, 2010.

[57] P. Ghamisi, R. Souza, J. A. Benediktsson, X. X. Zhu, L. Rittner, and R. A. Lotufo, "Extinction Profiles for the Classification of Remote Sensing Data," *IEEE Trans. Geosci. Remote Sens.*, vol. 54, no. 10, pp. 5631–5645, 2016.

[58] Y. He, G. J. Mendis, and J. Wei, "Real-Time Detection of False Data Injection Attacks in Smart Grid: A Deep Learning-Based Intelligent Mechanism," *IEEE Trans. Smart Grid*, vol. 8, no. 5, pp. 2505–2516, 2017.

[59] S. Omran and R. Broadwater, "Grid integration of a renewable energy system: Modeling and analysis," *Int. J. Renew. Energy Res.*, vol. 10, no. 3, pp. 1201–1212, 2020.

[60] K. R. Bharath, H. Choutapalli, and P. Kanakasabapathy, "Control of bidirectional DC-DC converter in renewable based DC microgrid with improved voltage stability," *Int. J. Renew. Energy Res.*, vol. 8, no. 2, pp. 871–877, 2018.

[61] X. Zhao, B. M. Sánchez, P. J. Dobson, and P. S. Grant, "The role of nanomaterials in redox-based supercapacitors for next generation energy storage devices," *Nanoscale*, vol. 3, no. 3, pp. 839–855, 2011.

[62] P. Mazidi, G. N. Baltas, M. Eliassi, and P. Rodriguez, "A Model for Flexibility Analysis of RESS with Electric Energy Storage and Reserve," *7th Int. IEEE Conf. Renew. Energy Res. Appl. ICRERA 2018*, vol. 5, pp. 1004–1009, 2018.

[63] M. Saleh, Y. Esa, N. Onuorah, and A. A. Mohamed, "Optimal microgrids placement in electric distribution systems using complex network framework," *2017 6th Int. Conf. Renew. Energy Res. Appl. ICRERA 2017*, vol. 2017-Janua, pp. 1036–1040, 2017.

[64] D. Icaza and D. Borge-Diez, "Potential sources of renewable energy for the energy supply in the city of cuenca-ecuador with towards a smart grid," *8th Int. Conf. Renew. Energy Res. Appl. ICRERA 2019*, pp. 603–610, 2019.

[65] S. S. Refaat and A. Mohamed, "Smart management system for improving the reliability and availability of substations in smart grid with distributed generation," *J. Eng.*, vol. 2019, no. 17, pp. 4236–4240, 2019.

[66] B. Ismail, M. M. Naain, N. I. A. Wahab, L. J. Awalin, I. Alhamrouni, and M. F. A. Rahim, "Optimal placement of DSTATCOM in distribution network based on load flow and voltage stability indices studies," *2017 Int. Conf. Eng. Technol. Technopreneurship, ICE2T 2017*,

vol. 2017-Janua, pp. 1–6, 2017.

[67] Y. Kabalci, "A survey on smart metering and smart grid communication," *Renew. Sustain. Energy Rev.*, vol. 57, no. January 2018, pp. 302–318, 2016.

[68] W. Osterhage, "Smart Energy," pp. 115–118, 2019.

[69] I. Colak, G. Fulli, S. Sagiroglu, M. Yesilbudak, and C. F. Covrig, "Smart grid projects in Europe: Current status, maturity and future scenarios," *Appl. Energy*, vol. 152, pp. 58–70, 2015.