Reewable Energy Generation System connected to Micro Grid and Analysis of Energy Management: A Critical Review

**Pranita Rathod1, Sanjoy Kumar Mishra2, Sujit Kumar Bhuyan3**

1,2School of Electrical Engineering, G H Raisoni University Amravati-444701, India

3Resource Assesment & Asset Analysis (RAAA), Manikaran Analytics Ltd., New Delhi, India

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| **Article Info** |  | **ABSTRACT**  |
| ***Article history:***Received May 31st , 2021Revised Aug 7th , 2021Accepted Aug 29th , 2021 |  | Renewable Energy Generations have been utilized in many places such as industries, homes, and other sectors so as to enable the fast requirement of load demand. Above all it is pollution free and abundantly available across many parts of the world. The generation cost is surprisingly less now a days. As one renewable energy source individually like solar or wind is not sufficient enough to provide continuous energy to the grid because of some constraint of weather condition. Sometimes solar generation can’t generate whereas wind power can generate. But the better choice is to consider both solar and wind power. The author suggested to consider a hybrid mode (more than two renewable energy sources connected together) and its impact so as to deliver the energy to the grid in a continuous manner. Thus a proposed hybrid renewable generation system is considered on the basis of energy management strategy to provide continuous and reliable supply to the grid. This is needed to maintain the continuous supply of energy as per the load requirement of the grid. If any adverse situation arises then there is a provision of an alternate energy storage system which may work as a backup generation system. Therefore, a detail study of different component of renewable energy and alternate sources of power generation connected together in a hybrid mode so as to provide continuous, reliable and cost effective to provide the energy to the grid under adverse situation of load demand. This paper will be helpful for new researcher to access power management strategy of different sources while connected to grid. As the power management in a hybrid renewable energy generation is very difficult to study, so authors have taken an attempt to analyse one by one to consider various factors for designing well advanced hybrid renewable energy system.  |
| ***Keywords:*** Hybrid Renewable Energy Lithium Batteries PV SystemWind PowerAuxillary UnitSuper CapacitorSolid Oxide Fuel CellEnergy Management   |
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| ***Corresponding Author:*** Sanjoy Kumar Mishra, Associate Professor, School of Electrical Engineering, G H Raisoni University, Amravati-444701, Maharashtra, India Email – sanjay29y@gmail.com |

1. **INTRODUCTION**

In recent years, renewable energy has been the primary source of generation which contribute major parts of generation across the world. The renewable energy generation is attracting more attention due to pollution free activity on the environment. It’s used because of economic operation and long-life span but installation cost is more to save electricity cost in the long run.Its generation is supplied through isolation mode and grid connected mode. The merit of renewable energy sources used because it is available abundantly in nature and environme0tntal friendly. The rate of increase in electricity consumption is expected to raise by approximately 40% to 45% by 2030. Renewable energy source captures the attraction for environmental consideration; pollution-free, easy availability, and continuous in nature. Out of other renewable energy sources available in the market, the PV cell energy generation is the most promising resources because of its affordable cost, simple implementation, and portability. In order to have the continuous power supply and the efficiency improvement, it is coordinated with other renewable energy sources like wind farm, fuel cell, electrolyzer and diesel-generator set etc. to form hybrid renewable energy sources. This is generally combined with a battery storage system. Thus, the implementation of the hybrid renewable energy system is formed where more than two renewable energy sources are implemented. The lithium-ion cell is the most important energy storage system used to store the electricity generation on an emergency need. Lithium-ion batteries are one of the most advanced alternate sources for storing power. In the past few decades, it has the most attracting domain for the researchers to utilize in many applications like electric vehicle, electric train, tram etc. A micro porous polymer membrane is used to separate the electrodes from each other and allows to exchange of Li-ions between the two electrodes.They compare various families of battery materials and analyze the performance, limitations, and problems in commercial battery material development [1]. Chengyu Mao et. al. investigates the limiting electrode in the lithium-ion battery for fast charging and analyze the behavior of cathode and anode in XFC condition. They designed an asymmetric cell of three electrodes to analyze the performance behavior of cathode and anode in the lithium-ion battery in an XFC situation [2]. Yan Lu. et. al. presents the review on conversion type anode material of lithium-ion battery and their storage structure. They also discussed the problems faced in the implementation of nano-engineering with high-performance conversion-type anode materials including low-dimensional structure, hollow structure, and hybridization with various carbonaceous materials [3], [4]. Osamu Shimamura et. al. stated the performance of advanced lithium-ion for vehicles and present the various aspects of design, construction, and output power of lithium-ion battery has improved the performance of vehicle [5]. Lithium-ion batteries will also be stored green energy from renewable energy sources like solar and wind [6], [7]. Renewable energy sources such as diesel, PV, wind and PV / wind are used to generate energy. Such energy systems are called hybrid energy systems. For the most remote areas, Hybrid Renewable Energy Sources is considered to be the cheapest and most efficient system for power generation.

This review paper discusses in two sections. The first section describes in detail the features, mechanism, design, construction, and working principles of lithium batteries and its challenges, advantages, disadvantages, and limitations of different types of batteries. The second section introduces hybrid renewable energy systems and reviews various techniques for diagnosing defects. Several emerging technologies for fault detection have developed using different converter topologies for fault clearing. Finally, its material review, and critical review have introduced energy management in hybrid renewable energy systems based on renewable energy sources. Lithium-ion batteries are more powerful batteries than any other family of rechargeable batteries in terms of volume, size, density and capacity. Figure 2 shows the comparative analysis of existing research of lithium-ion battery density and specific energy concerning other commercial batteries of chemistry.

**1.1. Basics of Lithium-ion Batteries**

First, in the 1970s, non-rechargeable lithium batteries were developed. After the 1980's lithium rechargeable batteries were developed based on anode materials. All light materials used in lithium batteries with high electrochemical properties and large specific energy. Lithium batteries are based on cell connection in parallel as well as cell or a combination of both. Multiple cells can be combined from a module, and multiple sections can be combined from a battery. Lithium-ion batteries have cathodes and anodes that are connected using electrolytes. Electrode material selection is an important task for the performance of batteries; probably it depends on Capacity, cell voltage, and cycling. But they suffer from various issues like volume expansion in the lithiation process [7]-[10], bad electrical contact, and decrease cycling performance. Lithium batteries increase the unwanted reaction (dendrite) between the Li and electrode which causes decreases the battery life.



Fig. 1: Year wise demand of Lithium Batteries Fig. 2: Specific Energy and Energy Density [7]

1. **PV SYSTEM**

Over the past few decades, a lot of research has been done on renewable energy generation such as solar energy, wind energy, fuel cell energy, due to environmental and economic implications [11], [12]. A summary of various PV system is discussed in the Table-1 from the referred paper [13]-[18].

Table 1. Summary of Various PV System

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Author** | **Technique** | **Microgrid** | **Implementation** | **Operation Mode** | **Advantages** | **Contribution** |
| H. Kim et. al. [13] | Reconfigurable Solar Converter | Power Plant | Hardware | PV-to-Grid/PV-to-Battery/PV\_Battery-to-Grid | A single electrical conversion system was used to operate in different operation modes. The solar plant is more easily controlled and due to the ease of operation its maximum energy can be transferred at low cost. | Additional AC inductors have been added if AC filter inductance is not available for charging. Frame ratio-integral current has been proposed for energy control |
| I. Mazhari et. al. [14] | Reconfigurable Solar Converter/PV Battery | PV Solar Plant | MATLAB | PV-to-Grid/ PV-to-Batteries/Batteries-to-Grid/PV\_Battery-to-Grid | Slowly energy variation is achieved.Various PV modules and small energy storage techniques were used. Maximum power conversion losses is achieved | Ramp rate control technique used for power controlling The battery is used to control the ramp rate |
| N. Sasidharan et. al. [15] | Reconfigurable Solar Converterand DC | AC/DC Microgrid | Hardware | PV-to-Grid/PV-to-Batteries/Batteries-to-Grid/PV\_Battery-to-Grid | Improves performance, and increases reliability Current Harmonics reduced by 16% | The DC load is connected directly to the DC link without connecting to the AC side using an AC / DC converter. |
| R. Rizzo et. al. [16] | ReconfigurableSIDO inverter | Microgrid | Hardware/ MATLAB | DC mode/Grid output mode/Double Grid Output mode | Able to operate different energy conversion modes.bvThe demand for mixed power supply (AC/DC) was met using a single converter. Cost Effective | 11 static switches are added to the single input dual buckbust converter. |
| M. Chen et. al. [17] | - | Microgrid | Hardware/ MATLAB | Grid /Islanded Connect | Suppose a grid failure makes it easier to provide uninterrupted power supply for critical loads. Solar PV system performance is improved | Single-phase quasi -Z source inverter has been used as solar PV converter. A controller based on indirect current control is activated. |
| A. Chub et. al. [18] | Reconfigurable quasi-Z sourceInverter | -- | Hardware | --- | Ability for a wide range of voltage regulation for MPPT. Partial shading and impedance mismatch have reduced energy loss | Magnically integrated synchronous QZS network and resonant voltage-doubleler rectifier (VDR) and its controller are used |

1. **AUXILIARY UNIT**

Auxiliary unit is used for power generation under emergency condition when all the generation unit and battery storage unit fail to generate the power supply. It is a backup power when the other generation fails to supply the grid. It may be the power of PV, battery and wind and other fuel cell system is unable or insufficient to supply the required load and auxiliary unit is used to charge the BSU when PV module is not sufficient to charge the battery. In this section mainly discuss the wind power system, Diesel generator system and fuel cell used as alternate source of energy connected to micro grid.

**3.1. Wind Power System**

Wind power provides the major share of renewable energy generation in all over the world. The Wind exposed the huge potential of the various regions in matter of wind energy where mountain chains on the coasts create a natural corridor that enhances the stability of winds. The Most of the areas of coasts have the benefit of being next to where electricity is most demanded. The wind generator considered here is a gearless direct driven PMSG. Basically, three types of wind power generation system available, they are classified as follows

(1) Fixed Speed Induction (2) Permanent Magnet Synchronous Generator and (3) Doubly Fed Induction Generator. The MPPT control mode uses PMSG and DFIG depending on the wind conditions, so the production of a single FSIG cannot be controlled [19]. The summary of some review papers of wind power generation system is presented in Table-2 from the referred paper [20]-[23].

Table 2. Summary of some review papers of Wind Power generation system

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Author** | **Technique** | **Implementation** | **Advantages** | **Contribution** |
| Mohamed Benkahla et. al. [20] | DFIG/ P I/ SMC/AFLC | Hardware | Use of robust decoupled DFIG gives better performance. | Designed the electrical power conversion system based on DFIG connected to the grid using stator and fed.  |
| Habib Benbouhenni et al [21]  | NSVM/FSVM/NSOSMC | MATLAB | Low ripple factor Low stator current harmonic distortion | Presented study is on fuzzy space vector modulation (FSVM) and neural space vector modulation (NSVM) inverter based on neuro second order sliding strategy in wind system. |
| C H Chong et al. [22] | PMSG/SCIG/DFIG/SRG | -- | This study showed that a permanent magnet synchronous generator is most suitable for wind power systems. | Presented comparative analysis of various generators of wind turbine and discussed the various component required for wind energy system. |
| Franco Canziani C H Chong et al. [23] | MPPTWT | Hardware | Cost effective system As per load demand power supply is reliable | Proposed the algorithm to calculate the number of generating unit of wind turbine and PV for hybrid microgrid. |

**3.2. DG Set**

Diesel Generator (DG) acts as the main energy source in microgrid power systems. The entire energy storage in the microgrid can be operated in 𝑉 / 𝑓 mode, but only a single 𝑉 / 𝑓 source is allowed when the microgrid is in separate operation. Therefore, in order to make better use of the energy storage system of the diesel generator, two control methods 𝑉/𝑓 and 𝑃/𝑄 are used as the mode of operation of the diesel generator [24]. The fuel consumption of the diesel generator is described as a straight line with a y-intercept and can be calculated from the equation 1,

$C\_{DG}=p\_{0}P\_{DG}+ q\_{0}PN\_{DG}$ (1)

Where, $P\_{DG}$is the nominal capacity in kW and $PN\_{DG}$the electrical output of the diesel generator in kW. The coefficients $p\_{0}$and $q\_{0}$are the intercept of the fuel curve which is the unleaded fuel consumption of the generator divided by its nominal capacity and the slope of the fuel curve representing the marginal fuel consumption the generator. Table 3 presents the summary of integration of Diesel System with various renewable energy system is referred from [25]-[31].

Table 3. Summary of Integration of Diesel System with various renewable energy systems

|  |  |  |  |
| --- | --- | --- | --- |
| **Author** | **Combination** | **Simulation** | **Contribution** |
| S. Rehman et. al. [25] | PV-Wind-Diesel | HOMER | Presented the different hybrid system using various renewable energy sources for village in Saudi Arabia. |
| G. Merei et. al. [26] | Wind-Diesel | Matlab | Presented the hybrid system of PV, Wind and DG system using genetic algorithm. In this approach optimization was done for battery storage. |
| W. Krueasuk et. al. [27] | PV-Diesel | -- | The presented the project of PV and DG system and analyze the last 10-year energy generation in Thailand. |
| S. Rehman et. al. [28] | Wind-PV-Diesel | HOMER | Wind-pv-diesel hybrid system was designed for village in Saudi Arabia. The main aim of research is to reduce the diesel consumption and maintain constant supply. |
| Q Hassan et. al. [29] | PV-Wind-Diesel | HOMER | Presented the computer-based modeling for hybrid power generation in rural areas of Iraq and analyzes the cost of power generation of PV and diesel.  |
| Abdul Muhaimin Mahmud et. al. [30] | PV-Diesel | -- | Presented the work to analyze the performance of 11 different PV systems. The result showed that 10 PV systems were highly reliable and fulfills the load demand. |
| Hussein Ibrahim et. al. [31] | Wind-Diesel | -- | Developed the Wind-Diesel hybrid system for reducing the use of diesel with integrating high penetration system and compressed air energy storage to improvement in renewable energy and reduces the cost. |

**3.3. Energy Storage System for microgrid-Supercapacitor**

Super-capacitor is a double layer capacitor. The energy is stored by charge transfer at the boundary between electrode and electrolyte. The amount of stored energy is function of the available electrode and electrolyte surface, the size of the ions, and the level of the electrolyte decomposition voltage. Super-capacitors are constituted of two electrodes, a separator and an electrolyte. The two electrodes, made of activated carbon provide a high surface area part, defining so energy density of the component. Usually, super-capacitors are divided into two types: double-layer capacitors and electrochemical capacitors. Table-4 presents the summary of published paper of super capacitors [32]-[37].

Table 4. Summary of some review papers of Supercapacitor

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Author** | **Technique** | **Microgrid** | **Implementation** | **Advantages** | **Contribution** |
| A. Yasin et. al. [32] | WEG/PVEG/load sharingPID controller | Yes | MatLab | Using supercapacitor in microgrid solve the issue of slow dynamic of diesel generator during the startup | Designed energy management scheme for standalone DC microgrid. Improvement in power signal quality. |
| V. Germanovich et. al. [33] | Buck-Boost DC-DC converter | No | -- | Performance of proposed system was improving the life of battery. | Presented the hybrid approach for energy storage using Lithium and Super-Capacitor. |
| Y. Ren et. al. [34] | voltage source converter | Yes | PSCAD/EMTDC | It improves the performance of bus voltage and reduces the usage of battery. | Proposed the energy management scheme for batteries and supercapacitor for standalone microgrid. |
| P. Wongdet et. al. [35] | -- | Yes | MATLAB | Fast response High energy density | Presented model reduces the fluctuation of output load in microgrid. |
| R. Jegedeesh Kumar et. al. [36] | PEC, MPPT, P and O algorithm | Yes | MATLAB | Ability for a wide range of voltage regulation for MPPTPartial shading and impedance mismatch have reduced energy loss | Proposed energy management scheme for microgrid in autonomous and non-autonomous mode based on PV array and storage system. |
| Gustavo Navarro et al. [37] | EDLC | Yes | PSCAD/EMTDC | Low Price High densityReliability of microgrid is improved | To design the energy storage system based on supercapacitor for the microgrid operation. |

**3.4. SOFC**

Solid oxide fuel cell is a type of fuel cell based on its electrolyte content. It operates at very high temperatures in the range of 500 to 10000 C. This type of fuel cell can be used in electrical vehicles or microgrids as auxiliary energy up to 2 MW. Solid oxide fuel cells can be widely used for high efficiency for integrated heating and energy systems. The power conditioning system can be designed by converting DC power into AC power using such a system in the utility grid by generating common solid oxide fuel cell DC energy. Power conditioning systems are used to control energy quality and supply in real and reactive form [38], [39]. PEMFC (Proton Exchange Membrane Fuel Cell) were utilized in microgrid [40]. A fuel cell is a type of electrochemical device that generates electricity by converting any chemical energy into electrical energy [41]. The fuel cell can act as a fuel by converting substances like hydrogen and oxygen into electrical energy, while oxygen can be used as an oxidizer. Substances like potassium, sodium hydroxide can be used as electrolytes [42].

**3.5. HYBRID MICROGRID SYSTEM**

A microgrid consists of a set of various loads, batteries for storage, and a generation system. In a hybrid system, energy can be generated using renewable sources with an energy storage system (Batteries) or other storage system is connected to provide stability to microgrid. For improvement of the microgrid, continuous solar and wind energy is used. The microgrid can be operated separately or integrate into a grid-based on the type of energy sources were used [43]-[45]. The most important part of microgrid is to maintain continuous power supply based on demand but it is very difficult to predict and energy generation may variations depends on availability of renewable energy sources such as solar, wind etc. The grid is connected to the grid utility called as grid-tied mode. When microgrid is disconnected from grid utility then it is in autonomous mode. During the fault diagnosis; microgrid automatically switched to the autonomous mode. The problem arises in microgrid is major challenges i.e. voltage dips, Hormonic current/voltage and power flicker etc.



Fig. 3: Hybrid System for Microgrid

**4. Power Management in Hybrid Microgrid**

In Grid energy storage system, Power management is core part to enhance the renewable energy consumption and stable their operation. The Power management techniques is presented in [46] for economical beneficial in grid and various optimization obijectives, constraints and techniques were designed. Table-5 presents the summary of microgrid power management [46]-[53].

Table 5: Summary of microgrid power management

|  |  |  |
| --- | --- | --- |
| **Sr. No.** | **Authors** | **Contribution** |
| 1 | Hafeez Ahmad et. al. [46] | Author Present the power management strategy to efficiently utilize energy in microgrid. The relation between the overall hourly loads fulfilled by local resources and the total hourly load transferred by the main grid is present in this strategy. It is very obvious that there can be a relatively limited amount of energy fed to the main grid for loading. |
| 2 | T. Sha et. al. [47] | Author presented the overview of energy management system for DC microgrid. Authors also discussed on intelligent devices for better utilization of energy, control strategies, and load scheduling techniques. |
| 3 | O. Djelailia et. al. [48] | Author initiated hybrid system for specific energy control based on pumping servitudes and online fuel utilization optimization. |
| 4 | K. Sayed et. al. [49] | Author suggested the hybrid energy storage system for energy management used various batteries and supercapacitors and preventing the fluctuation of DC link bus of the microgrid. |
| 5 | B. Zhao et al [50] | Author present the novel architecture for power management of multi-microgrid based on hierarchical bi-level optimization to resolve renewable energy sources issues. |
| 6 | D. M. R. Korada et. al. [51] | Author proposed power management algorithm in DC microgrid based on MPPT to extract the maximum energy from solar. |
| 7 | F. Valencia et. al. [52] | Author designed strong mathematical model for energy management in microgrid based on fuzzy prediction. These models predict the non-linear behavior and uncertainty in wind energy. |
| 8 | U. B. Tayab et. al. [53] | Author present the smart energy management system in AC microgrid for distributed generation based on adaptive neuro fuzzy interference techniques. The Solar and wind energy were used as source of distributed generation. |

The most important aspects in hybrid microgrid are power management strategy is presented in Table-6 [54]-[59]. Energy management approach in microgrid confirms the output active and reactive power of Distributed Generation and Storage Elements and at the same time control voltage and frequency.

Table 6: Critical Summary for Energy Management system in Hybrid microgrid

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sr. No** | **Author** | **Techniques** | **Work done** | **Limitations** |
| 1. | J. Almeda. al. [54] | Linear/Mixed Integer Linear Programming | Sustainable running, Power sharing based ON/OFF mixed mode strategies for power management of Microgrid is proposed. | Due to the high depth of discharge of the b**a**ttery, it can deteriorate rapidly. |
| 2 | S. M. Ashabani et. al. [55] | Mixed IntegerLinearProgramming | Optimization of fuel cost effective model based on piecewise linear function of fuel generator and battery operated has been proposed. | Uncertainty between PV power and load demand was not considered. |
| 3 | N. Anglani et. al. [56] | Non-linear Power Flow Control, Hamiltonian Surface Shaping and Power Flow Control | To design a HSSPFC control section was integrate with the energy storage unit for providing the stability to AC/DC microgrid. | The integration with the battery is disappointing. However, no alternative solution to Renewable energy resource mediation is proposed |
| 4 | Feixiang Jiao et. al. [57] | multi-objective optimization Techniqie | P**r**oposed the multi-objective optimization model for energy management for plug in elctric vehicle bettery, and prevent the bettery from overcharging and overdischarging. | The effects on the plug and play characteristics of an electric vehicle on microgrid stability have not been discussed. |
| 5 | B. Heymann et. al. [58] | DynamicProgramming Approach  | The functional value of a conventional generator and the cost of load shedding are considered as objective tasks. To reduce the counting time, the PontriaginMaximul principle has been used. | A high depth of discharge rate is set which can lead to rapidly discharging of the battery. The response to the energy demand was not considered |
| 6 | M. Strelec et.al. [59] | ApproximateDynamicProgramming | The approximate value of the cost-function in economic transmission and unit charge operations is considered to be the minimum of the microgrid daily energy schedule. | DOD of battery for MG optimized operation with battery ageing status is not discussed. |

1. **CONCLUSION**

The study of review on hybrid renewable energy sources connected to grid and its important component study like Li-ion battery, PV cell, wind power, fuel cell, super capacitor, Auxiliary Unit and DG set are discussed. A critical review paper is prepared and has been presented in the above table. The energy management system of different renewable energy sources connected to grid is discussed. The objective of this paper is to present the performance of power allocation to the grid in a reliable and continuous manner as per the load demand. Thus the paper suggests the performance of different component study and to build a hybrid renewable energy generation considering best performance wise component or renewable energy sources so as to provide the energy as per the load requirement of the grid in a continuous manner through out the year. The detail structure of hybrid renewable energy system connected to grid is shown in Fig. 4. Different tables from Table-1 to Table10 are prepared to summarise the comparision of parameters and performance of conventional system in relation to proposed system. For example the importance of Li ion battery is suggested in our proposed system due to the significant property of high energy density and long life cycle. The need for a different defense plan from the current one has been clarified based on different approaches. The paper suggests a hybrid renewable energy system connected to grid so as to manage the energy as per the load requirement of the grid. The authors have taken an attempt to present the paper based on the component study and critical energy management strategies to cater the load demand in a continuous, effective, economic and reliable way in an adverse load condition.

**ACKNOWLEDGEMENTS**

This research paper has not supported by any funding agency

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**GRAPHIES OF AUTHORS**

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| S.K Mishra | He has received the Ph.D in Electrical Engineering from KIIT University, Bhubaneswar, India. Master in Engineering from UCE ( now VSSUT), Burla and Bachelor in Engineering from Bangalore University, India. Currently, working as Associate Professor in Electrical Engineering from G H Raisoni University, Amravati, India. Total experience of 25years in the field of teaching, research and industry and area of interest includes soft computing tools applying in power system stability, signal processing algorithm in power system protection and hybrid energy and microgrid. He published many number of international journal and conference. He is also the reviewer of Elseviere, IEEE Acess and IEEE system Journal. |
|  |  |
|   | **Pranita V Rathod** has born in Maharashtra, India in 1991. She has graduated in Electrical and power Engineering from Govrment College of Engineering, Amravati, India in 2012 and received her M.E. degree in Electrical Power System Engineering from Amravati University, India in 2017. Her research interests include Hybrid Renewable Generation Systems, Power System Analysis, Energy Conservation and Management, Hybrid Energy System Simulation, etc. |
|  |  |
|  | He has born in Odisha, India in 1984. He has graduated in Electrical Engineering in 2007 and received his M.Tech in Power System and Control Engineering in 2012 from BPUT, Rourkela (India). He has completed his Ph.D in 2019 from KIIT University, Bhubaneswar, India. Currently, he is working as a head of Resource Assessment and Asset Analysis (RAAA) in Manikaran Analytics Limited, Delhi, India. His research interests include Renewable Energy Generation Systems, Power Electronics Converters and Inverters, Hybrid Energy System Simulation and Optimization, Power Quality, Machine Learning etc.  |