CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 LITERATURE REVIEW ON SOLAR SYSTEMS AND MATERIALS

Solar energy harvesting technologies for PV self-powered applications, This paper gives detail information on solar energy harvesting by PV technology. In housing, health care, transport, sport more demand of electricity which is fulfill by conventional energy source and which make pollution, so we can replace this system by PV system. This paper gives you where we can use this system also gives design of self-powered system, various components of PV system. It gives you maximum power point tracking (MPPT) techniques and power managements systems. This paper gives you analysis of solar radiation, system design for PV applications and hybrid energy system design like hybrid PV – wind system and hybrid PV – wave system. (Daning Hao et.al 2022)

A study of renewable energy and solar panel literature through bibliometric positioning during three decades, This paper gives collected data of renewable energy and solar panel by using bibliometric technique. The research was carried out using bibliometric techniques. Data analysis as well as visualization utilizing VOS Viewer program and the Scopus function for analyzes search results. The study reveals that National University of Singapore and India Studies were the most active affiliated institutions scientists and nation in renewable energy and solar panel literature. In renewable energy and solar panel literature, the Engineering and Energy Procedia were the most areas of study and dissemination sources. (Mochamad Choifin et.al 2021)

Solar energy technology, In this paper focus on solar energy, improvement in the technique of solar energy. This paper gives weakness in solar energy technique and new technique of solar energy harness i.e. solar cell and its material. It discussed about increase in the efficiency of power generation with solar energy (Sumedha R.G. Weliwaththage et.al 2020)

A review paper on solar energy system, This paper gives information of solar energy conversion in to the electrical energy. Many solar cell combination form solar panel which is connected to each other. Solar energy falls on solar panel and converts in to the electrical energy. It gives calculation of finding the size of solar panel, load on battery and inverter and installation of solar thermal system. (Deepak Purohit et.al 2020)

Awareness and use of solar energy as alternative power sources for ICT facilities in Nigerian university libraries and information centers, In this paper get information and use of solar energy as renewable energy source for ICT facilities in Nigerian library and information centers. Survey method was used for the study and questionnaire were designed and in survey found that the people who participated in survey having good knowledge about the solar energy. (Samuel et.al 2019)

Solar energy: potential and future prospects, in this paper advantage and disadvantage of solar energy technologies is discussed also technical problems in a research of alternative energy sources. They disused solar energy technology with respect to potential, capacity, prospects, limitations and future policies. This assists you to understand on how much count on solar energy to meet the upcoming energy demand. There are few drawbacks of solar energy technology but this is the energy source will meet the future demand of energy. (Ehsanul Kabir et.al 2018)

Concentrated solar power in India: current status, challenges and future outlook, In this paper growth of CSP is explained with future challenges. Current status of CSP in India and PTC technology is the most used and mature technology in the world. Also this technology is not getting investor support due to low confidence and low availability of skilled labour. In India most of the components of CSP is imported due to the lack of indigenous manufacturing. CSP plant has initial cost as compare to PV plant. In CSP large energy is rejected in condenser so we can utilize this energy to run the some other processes then efficiency will get increase. (Suhas bannur 2018)

A review of the solar energy situation in Rwanda and Uganda, in this paper authors give information about the solar energy development and future of this energy in Uganda and Rwanda. In these two countries solar energy is playing big role in social development also getting solar energy market from beginning of 80's. In these two countries development of solar energy getting more support from investors, donors and government lastly will get information of future and challenges of solar energy in these two countries. (Jean Baptiste et.al 2018)

Empirical analysis of factors influencing price of solar modules, in this paper authors give overview of solar module price this price is depend on wage, oil price, exchange rate and interest rate. He also explained price reduction mechanism and R&D expenditure in the solar industry. This paper gives you information about the relationship between oil price and renewable energy and framework of solar module pricing model. (Farhard Taghizadeh-Hesary 2018)

2.2 LITERATURE REVIEW OF HYBRID INVERTERS

2.2.1. HYBRIDS SOLAR/ WIND SYSTEM

Hybrid solar Photovoltaic/Wind system is a parallel hybrid system that combined the PV array that depends on the abundant solar radiation which is not the same intensity during the same day and wind turbine that depend on the abundant of wind source. Thus, generate power that could meet the load consumption when the solar radiation is available, the hand when the sun goes down the wind turbine could cover power shorting when the wind source, Adopted both of wind and solar energy resources as one system (hybrid) by using both wind energy and solar energy like a combined system to the resolved issue of variability and optimization the production of the system by converting wind and solar energy into electricity that directly storage by batteries to meet the required loads Thus, to build a hybrid system it is very important to study the technical abilities of the local consumers for knowledge of the advances that include this sector. In 2012, a study had conducted to determine the performance and compatibility of the hybrid PV/wind system on the remote area power system (RAPS) around the year. Therefore, data analysis funded that for each hour around the year both wind and solar energy resources one of them completes the other with meet the specific loads without the need for additional batteries for charging compared with converting and storing for separate PV system. Therefore, increasing utilizing hybrid systems like solar and wind systems that considered as promising energy resources that use for residential and industrial applications. Although lowering usable in the rural areas due to the reduction of technical capacity such as break-even distance and low population size. In another hand, hybrid solar/wind systems are a little complicated regarding to their components

(non-linear properties) and other variables parameters among both of configurations to reach optimization technique for hybrid solar/wind system with the assistance of computer software which plays an important role to design safe energy systems.

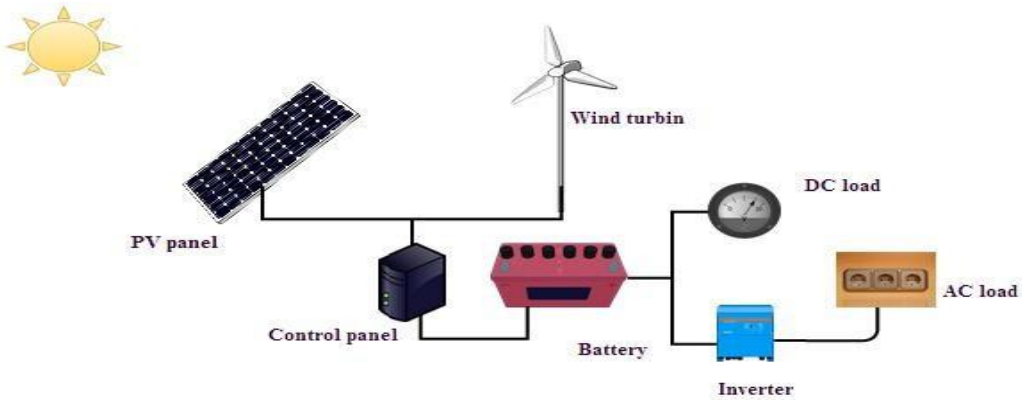

Figure 2.1 PV/ Wind Hybrid System

Both systems that combined use batteries as a back-up option for the stored energy generated in the case of one of the sources (solar radiation or wind) is not sufficiently available. However, in case of the solar hybrid PV/wind that connected by the grid, there is no effect on the stability of the system and in case of off-grid hybrid PV/wind system It is possible to reach stability in the system by increasing the number of batteries, it is necessary at design the hybrid system to specify equipment's with taking in consideration the capacity maintain the reliability of system when meeting the loads with reducing of system capital cost.

2.2.2 HYBRID SOLAR/GEOTHERMAL SYSTEM

Maximizing the benefit of renewable energy sources which has rapid growth in the recent period, several hybrid systems can be used in different applications areas like hybrid solar/geothermal systems to obtain thermal and electric energy. Hybrid PV/geothermal system has two configurations one of them is building- integrated PV/thermal, the other is earth-air heat exchanger both of them work as a heating and cooling modes adding to the electric energy production to achieve the efficient benefit of solar/geothermal energy as shown in Fig below. According to the thermodynamic performances of hybrid PV/geothermal, the results show improvement by performances of the hybrid system and achieve appropriate thermodynamic with improving the efficiency of the hybrid system. Hybrid solar/geothermal systems have promising features and it is applicable spicily at the regions that have high heat flux with surface radiation which leads to combined solar energy with geothermal is possible.

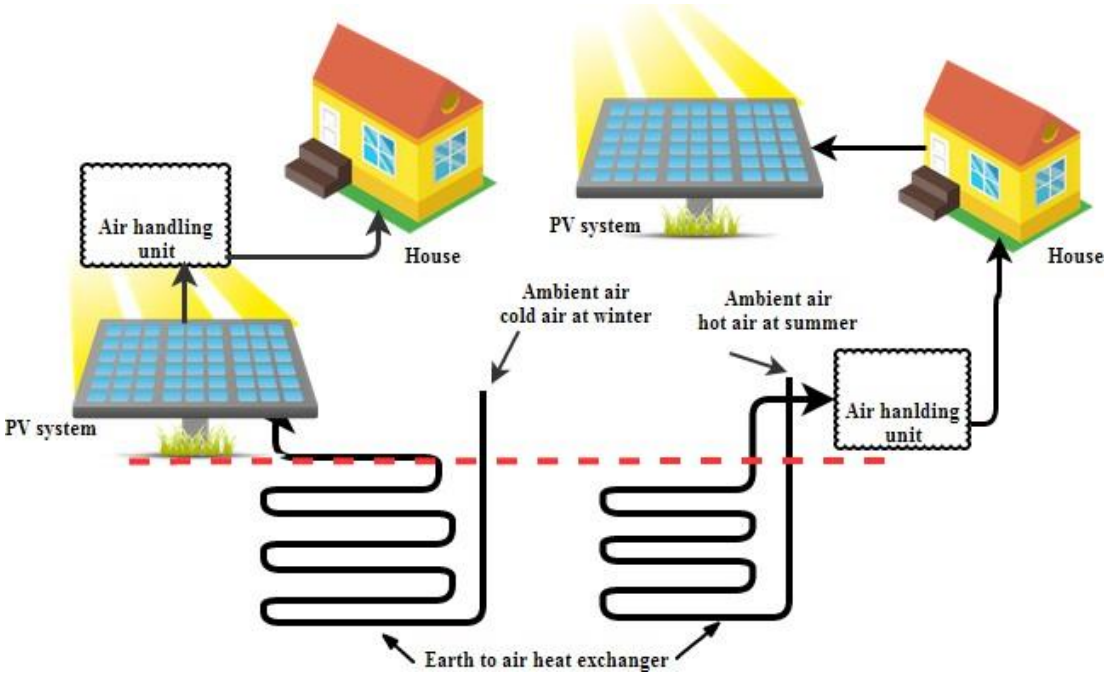

Figure 2.2. Hybrid solar/geothermal systems for heating and cooling mode

Hybrid solar/geothermal systems have proved it is a suited choice to processing the lowering of the capacity factor with the instability of the grid which leads to the fluctuated power supply. Combined solar with geothermal energy will contribute to compensation the lower capacity factor of solar energy by geothermal and improve the configurations of hybrid during heating geothermal fluid that has a low temperature of solar energy. Generally, geothermal energy has a temperature between moderate-low to raising the temperature of geothermal fluids it is important to make the efficiency of geothermal generation is better by combined with solar energy and to solve the instability of solar system by using geothermal fluids that gain high temperature as a storage system which leads to obtained mutually beneficial due to combined with promising renewable energy. The results of many studies show that hybrid solar/geothermal has a great performance comparing with separating systems and the efficiency of the system depended on the improvement of hybrid system components. However, as there are advantages of hybrid solar/geothermal systems there are disadvantages represented by high initial cost adding to the complexity in the components of hybrid systems. One of the suggested solutions to meeting the shorting in energy supply is geothermal energy that represents by stored energy that proposed as a combined concentrated solar array with geothermal depending on stored energy under the earth (water or steam) which effected by high pressure and temperature. In this respect, the productive lifetime of hybrid concentrated solar arrays/geothermal energy will extension and by reheating the fluid during reinjection in the well which leads to increase the thermal energy of concentrated solar collectors thus could use this system as alone grid with providing energy security when the energy consumption be high. (Goldmann, 2019)

2.3 .LITERATURE REVIEW ON SOLAR GENERATORS

Review of Related Literature Ali et al.(2015) presented the design and sizing of stand-alone solar power system which involves designing, selecting and calculating the various component ratings that should be employed during the system implementation. A stand-alone photovoltaic system which would power a medium energy-consumption residence was designed. The major parameters factored into the design were the orientation of the panels, days of autonomy, the best tilt angle for the solar panels and the likes. The system so designed is both robust and efficient. Abdelnaser, Kamaruzzaman, Ruslan & Ali (2016) in their paper showed the feasibility of powering remote desert area using PV power generation system. This is against the backdrop that it is not economically viable to supply the energy need of these remote areas from the conventional grid or from fossil fuel as the cost of the later is enormous. The authors designed a design of a stand-alone PV system to power a greenhouse in remote desert area. The energy model is based on Watt-hour demand. Based on the load estimation found to be 61,894kWh/ day, a stand-alone PV generator of 15.6kW capacity was implemented and tested. Morakinyo, Adu &Atayero (2014) proposed a solar powered street light with automatic switching mechanism. The proposed system would automatically turn on the luminaires at night and turn them off at dawn. At the off time of the system, the battery bank would charge via charge controller; the stored battery energy will deliver power to the luminaries via the inverter and thus the cycle continues. The proposed scheme was implemented and result showed a reliable, energy efficient power source for proper street illumination at night with little human supervision and maintenance. Sayed Salem Basyoni, Sayed Salem Basyoni & Al-Dhlan(2017) designed and implemented a small scale photo voltaic system (PV system) which would provide electric power for a living room, kitchen and bathroom. The load requirement was based on power saving mode rather than the conventional lighting. This option ensured that the overall energy demand on the PV system was minimal as well as the cost. The PV system was tested and it worked efficiently. Units of the Solar Generator This solar generator is made up of two units of 150 W PV panels, two units of 12 V, 40 AH storage battery bank, a charge controller and 1.5 KVA inverter unit. The PV panels draw sunlight energy and convert it to direct current electricity; the dc current charges the storage battery bankvia a charge controller (Nwankwo & Azubogu, 2016). The stored energy in the batteries can either converted into ac sine wave for feeding ac appliances. All the units of the solar generator are housed in a metallic casing equipped with rollers for easy movement from one place to another. To power dc loads, all dc loads are directly connected to the dc rail of the charge controller for 12V dc system. According to (SMA Solar Technology, 2009), apure DC coupled system hasall loads and generators coupled exclusively at the battery voltage level, but the system under consideration is a hybrid system. The battery bank feeds the inverter with dc current which the later converts into 240 V, 50 Hz ac signal using pulse width modulation technique. The ac output of the inverter supplies current to ac appliances as depicted in figure below (Ali et al. 2015)

2.4 LITERATURE REVIEW OF APPLICATION SOLAR POWER SYSTEMS

The integration of solar power systems into energy projects has gained significant momentum over the past few decades, largely due to the growing emphasis on sustainability, renewable energy

utilization, and reduction of greenhouse gas emissions. Solar power, derived from harnessing energy from the sun through photovoltaic (PV) panels or solar thermal collectors, has become an essential component of energy infrastructure in both developed and developing countries. Numerous studies have addressed the practical application of solar energy systems in residential, commercial, agricultural, and industrial settings, evaluating their effectiveness, performance metrics, and alignment with international and national project standards.

In residential applications, solar power systems are primarily deployed to supplement grid electricity and reduce dependency on non-renewable energy sources. Several researchers, including Luthander et al. (2015), have discussed the increasing popularity of rooftop PV installations, which conform to standardized installation procedures such as the International Electrotechnical Commission (IEC) standards (e.g., IEC 61730 for PV module safety and IEC 61215 for design qualification). These standards help ensure system reliability, durability, and safety, particularly in urban environments. Furthermore, project guidelines often require feasibility assessments, financial analysis, and regulatory compliance reviews before implementation. Studies show that compliance with these standards not only enhances the performance and lifespan of the systems but also simplifies integration with existing grid systems through net metering and feed-in tariffs. (Luthander et al. 2015),

In the commercial and industrial sectors, solar power systems are typically deployed on a larger scale, necessitating more complex project planning and execution protocols. The literature highlights the importance of standards such as ISO 50001 for energy management, which guides the integration of renewable energy into organizational energy frameworks. Yoon et al. (2016) and Sinha & Chandel (2014) examined case studies where industrial facilities reduced their energy bills and carbon footprints significantly by installing solar PV systems designed according to national electrical codes (e.g., NEC 690 in the U.S.). The authors emphasize the need for adherence to engineering standards related to electrical safety, voltage regulation, and structural integrity when implementing large-scale systems. Commercial solar projects also involve detailed project documentation, including risk assessments, system sizing models, performance simulations, and maintenance planning, all of which must align with engineering and quality management standards such as ISO 9001. (Yoon et al. 2016 and Sinha & Chandel 2014)

Off-grid and rural electrification projects also represent a significant area of application for solar power systems, particularly in developing regions. According to Palit and Chaurey (2011), decentralized solar energy solutions such as Solar Home Systems (SHS) and solar mini-grids are effective in addressing energy poverty. These systems must be designed in accordance with project standards that ensure sustainability, cost-efficiency, and community involvement. Organizations such as the World Bank and the International Renewable Energy Agency (IRENA) have published technical guidelines and performance standards for off-grid solar projects, emphasizing the importance of battery management, system modularity, and end-user training. The success of these projects often depends on detailed community needs assessments, clear maintenance protocols, and the inclusion of monitoring and evaluation components in the project cycle.(Palit and Chaurey 2011)

2.5 LITERATURE REVIEW OF SOLAR POWER SYSTEM BREED

The integration of solar power systems within Building Renewable Energy Efficient Design (BREED) frameworks is a growing area of interest in sustainable construction and energy engineering. BREED emphasizes the combination of architectural efficiency and renewable energy technologies to reduce the environmental impact of buildings. Among the renewable sources, solar energy—especially photovoltaic (PV) and solar thermal systems—has emerged as a cornerstone of BREED applications due to its scalability, availability, and rapidly declining costs. highlights how building-integrated solar technologies, such as photovoltaic panels embedded into façades and rooftops, allow buildings not only to consume less energy but also to produce clean electricity, thereby shifting toward nearly zero-energy or net-positive buildings. (Jelle et al. 2012)

The successful application of solar power in BREED projects is closely linked to adherence to international and regional project standards. These standards ensure that solar technologies are safe, reliable, and compatible with other building systems. For instance, the **IEC 61215** standard for PV module performance and **IEC 61730** for safety are commonly referenced in BREED-based solar installations. Additionally, building codes such as the International Energy Conservation Code (IECC) and standards like **ISO 50001** for energy management help structure energy efficiency practices during both design and operation. According to Peng et al. (2011), compliance with these standards ensures not only the functional integration of solar systems but also enhances long-term building performance and return on investment.

In terms of project planning and design, literature emphasizes the importance of integrated energy modeling and simulation tools. Tools like EnergyPlus, PVsyst, and BIM (Building Information Modeling) are frequently used to simulate building energy behavior and optimize solar system placement and sizing. These simulations help architects and engineers design BREED-compliant buildings that meet both energy targets and regulatory criteria. The use of such tools aligns with green building certifications including **LEED**, **BREEAM**, and **Green Star**, all of which increasingly incorporate renewable energy targets and efficiency standards in their evaluation frameworks. (Hernandez and Kenny 2010),

Furthermore, economic and policy-related project standards are essential in ensuring the viability of solar-powered BREED designs. Literature explores how financial incentives, such as tax credits, net metering, and renewable energy subsidies, can support widespread adoption. In this context, national energy strategies and local urban development plans often integrate BREED principles into broader climate and energy policies, creating a supportive framework for solar adoption. (Zinzi and Agnoli 2012)

In conclusion, the literature affirms that the integration of solar power systems within BREED frameworks is not only technologically feasible but also increasingly necessary in the context of global energy efficiency goals. Compliance with technical, environmental, and economic standards throughout the project lifecycle ensures that BREED projects deliver reliable performance, long-term sustainability, and measurable energy savings. Continued innovation in

solar technologies and standardization processes will further enhance the impact of BREED in transforming the built environment.