IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 8.021 ⋟ Peer-reviewed & Refereed journal ⋟ Vol. 13, Issue 2, February 2025

DOI: 10.17148/IJIREEICE.2025.13210

DC Homes with Scope of AI for Energy Security in Developing Nations

Akash Sao[1], Satish Sahu[1]

University Teaching Department, Chhattisgarh Swami Vivekanand Technical University, Bhilai Chhattisgarh, India[1]

Abstract: Nation development is closely tied to electrical energy consumption, prompting improvements in generation, transmission, and utilization to meet rising demand. In the U.S., demand doubled every decade until the early 1970s, while developing countries like India see a doubling every seven years, necessitating significant investments in the power sector. To meet rising energy demand affordably, reliance on fossil fuel-based power plants—such as thermal, diesel, and hydroelectric—has increased. However, their consumption significantly contributes to global warming and environmental damage, highlighting the need for alternative, eco-friendly energy sources like renewables. Many individuals are now adopting green energy solutions, such as solar, wind, and hydropower, with government initiatives supporting this shift. Additionally, dependence on fossil fuels raises national security concerns. Conventional power plants are often located far from load centers, primarily due to environmental factors. For example, large hydroelectric stations are typically situated hundreds of kilometers away from where the electricity is consumed. This results in significant costs and energy losses during the lengthy transmission process from generation to utilization. This paper addresses the challenges of long-distance power transmission, including the selection of suitable transmission systems and issues with electrification in difficult geographical areas. It explores Solar DC Homes as an alternative solution and discusses how integrating Artificial Intelligence with solar PV systems can enhance efficiency through various research and applications

Keywords: DC Homes, Artificial Intelligence, Solar PV System

I. INTRODUCTION

In the 70th session held on 25th September 2015, the United Nations (UN) General Assembly adopted a document titled "Transforming our World: The 2030 Agenda for Sustainable Development," which encompasses 17 Sustainable Development Goals (SDGs) and associated targets. These goals address social, economic, and environmental aspects of development. Recognizing the vital role of energy in providing sustainable opportunities, Goal 7 was established with the aim of ensuring affordable, reliable, sustainable, and modern energy access for all. [4] This goal emphasizes the importance of improving access to clean and safe cooking fuels and technologies, enhancing energy efficiency, increasing the use of renewable energy sources, and promoting sustainable energy for everyone. Energy derived from renewable resources, such as wind, water, solar, biomass, and geothermal energy, is inexhaustible and environmentally friendly.

One objective of the Sustainable Development Goals aims to deliver affordable, dependable, and advanced energy to every global citizen. To achieve this, India emphasizes providing electrical accessibility to all residents within the nation. Globally, the proportion of people with electricity access rise from 87% in 2015 to 91% in 2021, benefiting approximately 800 million extra individuals. Nevertheless, 675 million people remained devoid of electricity in 2021, primarily residing in Least Developed Countries (LDCs). Although there has been consistent progress over the past six years, the annual growth rate of access (0.6 percentage points) between 2019 and 2021 is slower than the 0.8 percentage points recorded from 2015 to 2019. In sub-Saharan Africa, the number of people without electricity has persistently stayed at a high level since 2010, leaving 567 million individuals without access in 2021. Electrification can contribute to increased educational attainment, better healthcare, agriculture development support, reduced gender inequality, enhanced climate action, and business opportunities and job creation. However, if the current trend continues, about 660 million people will still be without electricity by 2030. To alter this trajectory and achieve universal access by 2030, the access rate must increase by 1 percentage point annually between 2021 and 2030. [5] The issue of economics arises when addressing the energy needs of small, dispersed communities. The high initial cost for constructing infrastructure, such as substations, transmission lines, and transformers, in these remote areas is difficult to justify. This makes it prohibitively expensive to implement traditional electrical grids in these regions. This situation presents an opportunity for engineers to explore new technologies to bridge the humanitarian gap in energy provision, despite globalization and advancements in technology.

To this day, the primary energy sources worldwide are derived from fossil fuels like petroleum, coal, and natural gas. These resources have been known to cause sustainability, national security, and global warming concerns. Fossil fuels

DOI: 10.17148/IJIREEICE.2025.13210

are finite resources, leading to unsustainability as they will eventually be depleted. Estimates suggest that oil, natural gas, and coal may last up to several years, respectively, at the current consumption rate. This is alarming, especially considering the increasing consumption due to industrialization in countries like China. This has driven the search for alternative, sustainable energy sources. Using Solar PV system and other renewable energy resources are advantageous because they are harmless to nature, easily accessible, and cost-effective. Harnessing natural energy contributes to our planet's well-being. The last two decades, people have prioritized clean energy for a more promising future. There are various factors contributing to this choice, with combating climate change being the most significant. Benefits from using these energy sources include improved living standards, stronger economies, safer energy provisions, reduced climate change, and healthier environments. Renewable energy sources offer potential long-term solutions to these problems. Many countries have invested in renewable energy to provide an alternative energy source, and they have been utilized in rural electrification projects in developing countries. Renewable resources are abundant, locally available, and evenly distributed globally. Even small amounts of energy can positively impact remote rural areas, justifying higher costs. Furthermore, utilizing local renewable resources can create jobs and counter urban migration trends. [6] Fig 1 and Fig 2 shows different kinds of energy resources available.

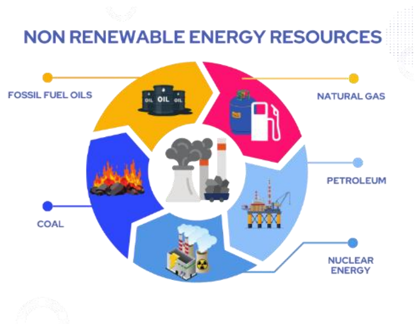


Fig 1: Non-Renewable Energy Resources

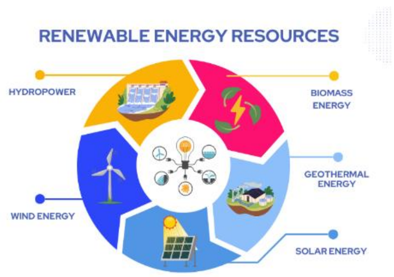


Fig. 2: Renewable Energy Resources

Current Scenario of Conventional existing power system and its different-different challenges are discussed in next section so that proper understanding about the problems associated with the conventional power system which needs a huge investment, different types of transmission systems used in India and a overview about that is explained in the next section of this paper.

II. CONVENTIONAL POWER SYSTEM AND ITS CHALLENGES

Remote generation and system interconnections have driven the search for efficient power transmission at large power levels. Increasing voltage levels is not always feasible. The challenges of alternating current (AC) transmission, particularly in long-distance transmission, have led to the development of direct current (DC) transmission. However, as energy generation and usage remain in alternating current, DC transmission requires conversion at both ends - from AC to DC at the sending end and back to AC at the receiving end. This conversion takes place at converter stations: rectifier stations at the sending end and inverter stations at the receiving end. These converters are static, utilizing high-power thyristors connected in series to provide the necessary voltage ratings. The physical conversion process allows the same station to switch from rectifier to inverter through simple control action, thereby facilitating power reversal.
.

The successful application of thyristors for power control in industrial devices encouraged their adoption in HVDC converters through the development of high-power semiconductor devices. India is progressively incorporating High-Voltage Direct Current (HVDC) transmission technology to cater to its escalating energy requirements and enhance the

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
Impact Factor 8.021 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 2, February 2025
DOI: 10.17148/IJIREEICE.2025.13210

efficiency of its power grid. [1] Currently, there are several HVDC projects either in operation or under development within the country. Below figure 3 and figure 4 shows basic structure of convention HVAC and HVDC system.

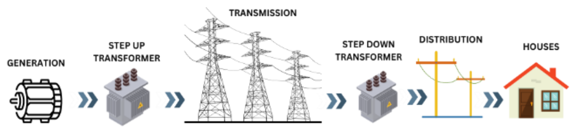


Fig 3: HVAC System

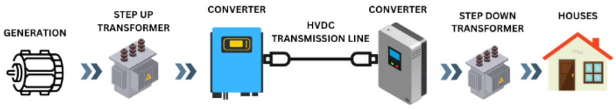


Fig 4: HVDC System

It is crucial to evaluate and contrast the advantages of two methods of transmission **(Alternating Current and Direct Current)** considering the following aspects:

1. **Financial Efficiency in Transmission*:*** Analyzing the costs and benefits associated with each approach.
2. **Technical Efficiency*:*** Examining the performance capabilities and limitations of AC and DC systems.
3. **Dependability:** Assessing the reliability and stability of both transmission types in various applications.

A. The Financial Aspects of Energy Transmission

In Direct Current (DC) transmission, the inductance and capacitance of the line do not influence the power transfer capacity or voltage drop. Furthermore, under stable circumstances, there is no leakage or charging current in the line. [1]. In contrast to Direct Current systems, which only need two conductors, Alternating Current (AC) systems, specifically three-phase ones, necessitate three conductors. The cost of the terminal apparatus is higher in DC lines than in AC lines. The "break-even" distance refers to the point where the costs of both systems are equivalent. The figure below suggests that DC lines are more cost-effective for distances longer than the break-even distance.

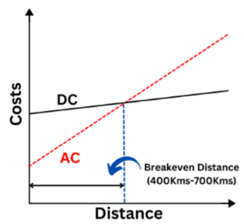


Fig. 5: Cost Versus Distance Diagram for AC and DC Transmissions

B. Technical Efficiency

On account of its rapid controllability, a Direct Current (DC) transmission possesses comprehensive authority over transmitted power. [2] It is capable of improving transient and dynamic stability in connected Alternating Current (AC) networks and can restrict fault currents in the DC lines. Additionally, DC transmission addresses certain issues related to AC transmission.

1. Stability Boundaries*:* The transfer of power in an Alternating Current (AC) line is influenced by the angle difference between voltage vectors at the two ends of the line. For a fixed power transfer level, this angle increases with the distance between the ends. The maximum power transfer is constrained by the factors of steady-state and transient stability. The ability of an AC line to carry power decreases inversely with the transmission distance, while the power-carrying capacity of Direct Current (DC) lines remains unaffected by the transmission distance. The land requirement and associated right of way for HVDC overhead transmission lines are less than that of an AC line.

2. Voltage Management*:* Managing voltage in AC lines can be complex due to line charging and voltage drops. The voltage profile along an AC line remains relatively flat only for a specific power transfer level, known as its Surge Impedance Loading (SIL). As the line loading varies, the voltage profile changes accordingly. To maintain constant voltages at both ends of the line, reactive power control is necessary as the line loading increases.

Impact Factor 8.021 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 2, February 2025

DOI: 10.17148/IJIREEICE.2025.13210

The requirement for reactive power increases with the length of the line. In AC cables, steady-state charging currents pose significant issues, making the break-even distance for cable transmission approximately 50 kilometers.

3. **Compensation in Transmission:** Compensation is vital for long-distance AC transmission to overcome issues related to line charging and stability limitations. This can be achieved through the use of shunt inductors, series capacitors, Static VAR Compensators (SVCs), and more recently, Static Compensators (STATCOMs). In contrast, DC lines do not require such compensation.

4. **Challenges in AC Interconnection:** Interconnecting two power systems through AC ties necessitates the coordination of automatic generation controllers using tie-line power and frequency signals. Even with coordinated control, issues may arise in the operation of AC ties due to large power oscillations, increased fault levels, and transmission of disturbances between systems. These problems are eliminated in DC lines due to their fast controllability of power flow, and asynchronous interconnection of power systems can only be achieved with the use of DC links.

5. **Ground Impedance:** In AC transmission, ground (zero-sequence) current must be prevented in steady-state due to the high magnitude of ground impedance, which affects efficient power transfer and causes telephonic interference. Ground impedance is negligible for DC currents, allowing DC links to operate using a single conductor with ground return (monopolar operation). However, ground return is undesirable when buried metallic structures, like pipes, are present and are susceptible to corrosion due to DC current flow. While operating in monopolar mode, the AC network feeding the DC converter station maintains balanced voltages and currents, enabling single-pole operation of DC transmission systems for extended periods, while this is not feasible in AC transmission.

C. Dependability:

The dependability of Direct Current (DC) transmission systems is satisfactory and on par with those of Alternating Current (AC) systems. The dependability of DC connections has also been quite commendable. There are two key aspects of overall system dependability - energy availability and transient reliability. Both energy availability and transient reliability of existing DC systems with thyristor valves is 95% or more.

Weather HVAC or HVDC we have discussed a lot about it but as the source of generation is nothing but conventional fossil fuel-based generation which has finite availability in this world. The reliance on fossil fuels brings up safety issues at a national level. Research has demonstrated that the use of these fuels has a substantial impact on the increase of global warming, an occurrence in which the Earth's temperature rises due to greenhouse gases emitted from burning fossil fuels, leading to adverse environmental consequences. This encourages for search and adoption of new alternative source of energy and renewable sources of energy is the best option for that. Among all the renewable energy resources solar energy has the greatest potential as the Sun has been as a life-giver to our planet since ancient times. The industrial ages gave us the understanding of sunlight as an energy source. Geographical and climatic condition of India is endowed with vast solar energy potential. About 5,000 trillion kWh per year energy is incident over India's land all these thin makes solar energy one of the best renewable sources of energy to use. [3]

D. Solar PV System

A solar photovoltaic (PV) system is an eco-friendly and renewable power setup that captures sunlight energy and transforms it into electricity. This sustainable energy source can supply power to homes, businesses, and entire communities. The solar PV system consists of various components working in harmony to produce, store, and distribute electricity. Fig 6 shows Conventional Solar PV System and Its Components.

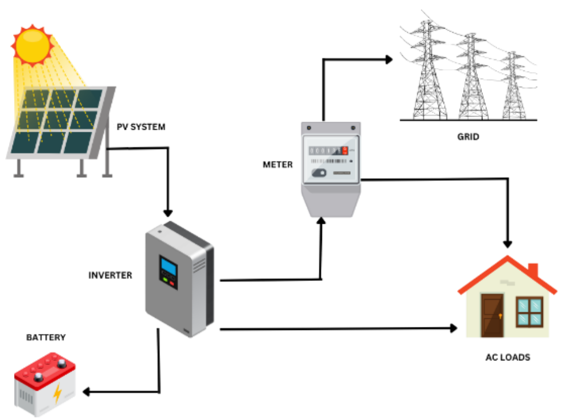


Fig. 6: Conventional Solar PV System and Its Components

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 8.021 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 2, February 2025

DOI: 10.17148/IJIREEICE.2025.13210

Solar PV system also has many problems like energy losses during conversion stages by the power electronics converters etc. The conversion losses range between 17% to 35% by the converters while dealing with the AC-DC-DC-AC Conversions [7]. Introducing a direct current (DC) electrical system can help eradicate the inefficient conversion of alternating current (AC) to DC and, in several instances, DC to AC before entering the house. By adopting the DC House system, it is estimated that an overall 15% efficiency enhancement might be achieved compared to its AC system counterpart. A significant issue with utilizing inverters is their lifespan, primarily due to the electrolytic capacitors extensively employed in them. These capacitors typically have a short lifespan of 5 to 8 years [8]. This necessitates the implementation of costly maintenance plans and power shutdowns during replacements. The DC system can avoid the heavy reliance on electrolytic capacitor banks, resulting in more efficient, dependable, and economical residential electrical systems.

E. Application of Solar PV in domestic (DC Homes)

In last few years, many efforts have been made to incorporate direct current (DC) systems in distribution networks along with the traditionally used alternating current (AC) systems. DC systems in microgrids with renewable energy sources, data centers, electric vehicle charging stations, and residential electricity systems are the few examples of it. The DC House project aims in proper electrification of the particularly rural area of developing countries that have difficult geographical locations. It aims in helping the electrification efforts of government. Even though the globe has found many ways to meet energy demands—such as HVAC systems and HVDC—there are still many obstacles in the way of bringing electricity to rural areas in developing nations like India and many other developing and under developed countries. The geographical location often makes electrification difficult and extremely costly, if not nearly impossible and because of this the rural population faces energy scarcity as many villages remain unelectrified in the 21st century. One possible solution to address this problem involves introducing DC homes and alternative sustainable energy options, such as solar or wind power, into off-grid systems. Through focusing on hard-to-reach geographical regions, the DC House initiative intends to present a substitute to rural electrification. In contrast to community-driven rural electrification, the DC House offers choices for individual residents or families. This approach makes the DC House system adaptable, cost-effective, and expandable. It achieves this by employing a low-power, low-voltage DC electrical setup to operate both its individual components and the entire system, enabling direct operation of DC loads. Consequently, it reduces the usual losses linked to the conventional AC system. DC homes are designed to operate on direct current (DC) instead of the conventional alternating current (AC) systems used in most urban areas. This use of DC offers several advantages, including improved energy efficiency, reduced energy losses and the ability to integrate various renewable energy sources more effectively.

Solar PV-based DC homes harness photovoltaic panels to convert sunlight into electricity, providing a clean and sustainable power supply to remote villages without centralized grid connections. Complementary renewable sources like wind, micro-hydro, and biomass can be integrated to create diversified and reliable power systems. These decentralized solutions decrease reliance on fossil fuels, promoting a more eco-friendly future for rural areas while addressing energy scarcity and fostering sustainable development. Solar photovoltaic systems generate direct current (DC), but most appliances require alternating current (AC). Thus, a DC-AC converter is needed to convert DC to AC. When incorporating a battery, an AC-DC converter is used for charging, while a DC-AC converter supplies AC power during discharge. However, these converters can lead to energy losses of 10-15%, and combining solar and battery systems may incur up to 45% conversion loss, along with additional battery inefficiencies. Fig. 7 shows Block Diagram of Solar PV Systems including converters and AC loads.

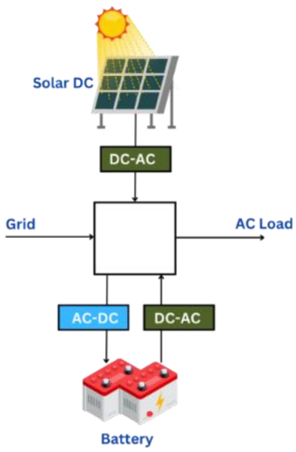


Fig. 7: Block Diagram of Solar PV Systems including converters and AC loads.

DOI: 10.17148/IJIREEICE.2025.13210

As people become aware that household appliances are shifting towards direct current (DC). A comparative table is shown below, which shows how DC appliances can save our electric consumption.

TABLE I RATINGS OF EQUIPMENT IN AC AS WELL AS DC

Fans	AC Fan	BLDC Fan	Lighting	CFL Tube Light	LED Light
At full Speed	**72.00 Watts**	**30.00 Watts**	At Maximum Intensity	36. 00 Watts	15.00 Watts
At speed 1	**60.00 Watts**	**9.00 Watts**	At Minimum Intensity	NA	4.00 Watts

- All electronic gadgets operate on low-voltage DC, such as LED/LCD TVs, laptops, cellphones, speaker-phones, tablets, and speakers.
- Converting AC to DC in each device results in energy losses.
- In the future, even appliances like refrigerators, air conditioners, and washing machines will be built with Brushless DC (BLDC) motors.
- Adopting DC-powered and energy-efficient devices can lead to a reduction in energy consumption by approximately 50%.

So best solution to avoid such low efficient systems (because of the problems associated with which is stated above) is to move to Solar-DC at Home Premises.

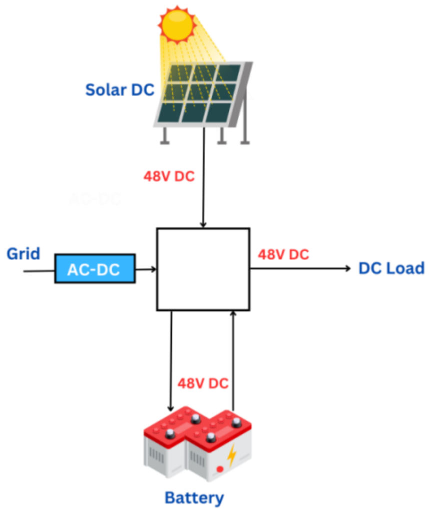


Fig. 8: Block Diagram Solar-DC at Home Premises

The home micro-grid consists of:

1. **Solar Panel:** This component helps in capturing solar energy and converting it into usable power.
2. **Battery:** This element stores excess energy from the solar panel and provides backup power during times of low solar energy production.
3. **DC Appliances:** These devices operate on direct current, making them energy-efficient and compatible with the micro-grid system.

F. Efficient power usage

The micro-grid design emphasizes highly efficient power utilization to reduce energy waste, while also converting low power from the grid to direct current, minimizing losses during the process; the selection of 48V DC was made for safety reasons and to achieve lower cable losses compared to 12V or 24V DC systems. The setup of a micro-grid is complex due to various factors, including the variable maximum power point tracking (MPPT) voltage of solar panels, the independent charging voltage requirements of batteries, the fixed voltage of the load, and the use of DC-DC converters, which can introduce additional losses.

ISSN (O) 2321-2004, ISSN (P) 2321-5526
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
Impact Factor 8.021 ⁒ Peer-reviewed & Refereed journal ⁒ Vol. 13, Issue 2, February 2025
DOI: 10.17148/IJIREEICE.2025.13210

G. Inverter less Solar DC system

Having discussed the major issues related to electrification in areas with challenging terrains and the losses occurring at conversion stages during solar energy utilization in PV systems, it is evident that our basic needs, whether for rural or urban individuals, involve light, fan, and charging points. These are all DC loads. We can directly use solar PV-generated DC power to supply DC loads in areas with difficult terrains. So in this context a excellent method addressing the electrification crisis for off-grid and near off-grid residences is by using the innovative inverterless Solar DC system. With fewer expenses, durable structure and improved efficiency the inverterless Solar DC System is the highly appealing solution for this. Figure 9 shows Solar DC inverterless system. The inverterless system is not only cost-effective for powering off-grid homes but can also be effortlessly integrated into the grid when available. For homes connected to the grid but experiencing power outages, this system ensures continuous energy supply. Many researches had already done in this area and many such systems have already deployed in areas having difficult terrains. As the global population continues to grow and technological advancements evolve at a rapid pace, there will always be opportunities to develop more efficient and sustainable solutions for our world. Energy conservation, a crucial aspect of addressing the challenges we face, is already a primary goal within the United Nation's Sustainable Development Goals. This further emphasizes the importance of continually seeking innovative approaches to improve our energy management systems and contribute positively to the well-being of our planet [10].

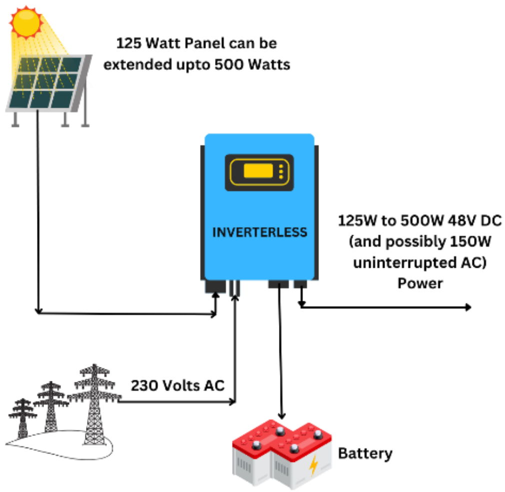
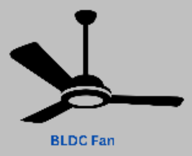
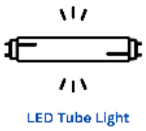


Fig.9 Solar DC Inverterless

In the context of Inverter less systems, the appliances utilized are primarily Direct Current (DC) devices. Many DC appliances are currently available in the market, and as we continue to focus on energy-efficient solutions for the future, the development of additional DC appliances can be further encouraged. These DC appliances generally consume less power compared to their conventional Alternating Current (AC) counterparts, making them more efficient and contributing to overall energy savings. As a proof of concept electrifying 4,000 secluded residences with assistance from the Ministry of Power (Government of India), Rural Electrification Corporation (REC), and Jodhpur Power Distribution Company Limited (JDVVNL) has been initiated. This project began in Bhoom Ji Ka Gaon, December 2015, characterized by challenging landscapes, no road access, frequent sandstorms, and scarce local resources. The success of this end eavor serves as a testament to the efficacy of inverter less systems in overcoming the obstacles of Rajasthan's difficult terrains, all made possible with government support. The positive feedback received further validates the effectiveness of these systems, as per the findings in the published paper. The table presented below delineates the distinctive characteristics and benefits associated with the appliances employed in inverter less systems [10].

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
Impact Factor 8.021 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 2, February 2025
DOI: 10.17148/IJIREEICE.2025.13210

TABLE III CHARACTERISTICS AND BENEFITS OF DC APPLIANCES

Appliances	Advantages	
BLDC Fan	Consumes 30W instead of 72W AC fan and 9W at lowest speed	
LED Tube Lights	15W - dimmable to 4W, instead of 36W Fluorescent tube	
Mobile phone charging points	DC Charger with USB Support for all mother DC appliances which needs charging	
LED Bulbs	Consumes 5W instead of 30W	
DC Powered Colour TV	Consumes 30W along with set-top box at 48V DC	
DC Cooler	Consumes 60W instead of 180W AC cooler	
Solar Water Stove and DC Refrigerator etc.	Under Designing process.	

DOI: 10.17148/IJIREEICE.2025.13210

H. Grid Connected DC Homes

As Discussed earlier even for urban, grid-connected homes, combined with Solar-DC Inverterless systems, DC power lines within the household, and DC appliances, can lead to substantial cost savings. Moreover, a 500-watt solar power system with DC appliances can efficiently handle most of the essential requirements for middle-class households. Exceptions include washing machines, mixer/grinders, and air-conditioners which are not basic needs of middle class families whose weightage are most in the society. This setup results in a minimal power demand from the grid, consequently reducing electricity bills. With approximately 240 million homes in India, each equipped with a 500-watt solar panel (covering around 50 square feet) and generating power for 1600 solar hours annually, the total energy produced would be roughly 190,000 GWh per year. This amount of energy is nearly equivalent to the entire domestic consumption in the country. By embracing this approach, India can strive to become the world's most environmentally conscious nation [11]. DC inverterless system, comprising DC appliances for grid-connected homes, can be further expanded as a Solar-DC microgrid for a 4-home cluster. This setup allows for the sharing of solar and battery resources among multiple residences, fostering collaboration and energy efficiency. Furthermore, the Solar-DC microgrid can be extended to accommodate 12/24 home apartment complexes, acting as a replacement for generators and offering significant energy conservation and savings [27]. This setup enables individual management of each home, maximizing benefits.

By implementing this system, we can achieve the following:

1. Lower and middle-income households, even those receiving subsidized rates, can access affordable
2. Power during load-shedding situations.
3. The DISCOM (Distribution Company) will face less strain due to subsidies, as solar-DC Inverterless systems at homes contribute to reducing their power requirements.
4. Homes utilizing solar power during peak hours will help DISCOM avoid purchasing electricity at high rates, benefiting both the consumers and the power distribution company.
5. By 2030, aiming for 50% of power production to be derived from solar energy, decentralized solar and DC microgrids will play a crucial role in shaping the energy landscape.
6. The climate change debate will experience a shift, as increased solar adoption contributes to a greener future.
7. The "Make in India" initiative will benefit from this technological advancement, fostering domestic manufacturing growth.
8. This innovative approach sets a benchmark for the global community, showcasing India's commitment to sustainable energy solutions.

The Indian government, in its pursuit of promoting green energy and reducing carbon emissions, aligning with the United Nations Sustainable Development Goals, has launched several solar mission schemes. These initiatives aim to encourage the use of solar energy, foster sustainable development, and create a cleaner environment for the nation.

I. Role of AI in Energy Saving

The projected area of the buildings we inhabit is anticipated to double by 2060, primarily due to growth in residential construction. This expansion will be driven by population growth and urbanization in emerging markets, leading to more extensive cities and a heightened demand for new housing in urban regions worldwide. These tendencies present an enormous prospect to innovate, new technologies, utilize the already available technologies and manage the homes of the future in a smart manner that conserves energy and minimizes carbon emissions, while also reducing costs. Artificial intelligence (AI) and IoT will play a crucial role in this end eavor by utilizing data, such as grid data, smart meter data, weather data, and energy usage information, to analyse and enhance the performance, optimize resource consumption, and enhance comfort and cost efficiency for residents. Furthermore, AI will analyse data from various urban DC buildings to refine the device design, building desgins and construction and guide future research and developments and policy-making related to energy efficient planning [15]. The birth of Solar Smart Homes (DC inverter less, DC appliances and also Grid connected) in urban and even for rural areas having connectivity which is very common this days as everyone is using smart phones in present era Incorporated with AI Technologies marks a significant milestone in the evolution of modern living.

These innovative homes combine renewable energy, specifically solar power, with advanced artificial intelligence (AI) systems to create a more sustainable, efficient, and comfortable living environment. Solar Smart Homes utilize solar panels to generate clean, renewable energy from the sun. The energy generated is saved in batteries, decreasing dependence on conventional energy sources and minimizing carbon emissions. The incorporation of AI advancements improves the efficiency of these homes by optimizing energy usage, supervising systems, and even anticipating maintenance requirements.

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
Impact Factor 8.021 ∺ Peer-reviewed & Refereed journal ∺ Vol. 13, Issue 2, February 2025
DOI: 10.17148/IJIREEICE.2025.13210

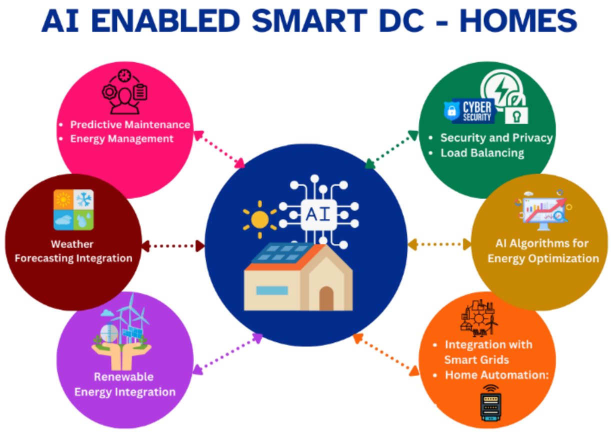


Fig. 10 Features of Enabled Smart DC Homes

Smart DC homes, empowered by AI technology, presents wonderful solution for residential energy management and automation. By integrating AI into Solar Photovoltaic (PV) systems, various enhancements can be achieved, including improved efficiency and performance optimization. This innovative combination of AI and solar PV systems significantly contributes to the advancement of sustainable living and energy management in homes. Important features of Smart DC Homes is shown in fig. 10. Below mentions are important aspects, thoughts, novel concepts, in this domain:

1. **Predictive Maintenance:** AI-driven algorithms can analyze data from sensors and monitoring systems in solar PV systems to detect potential issues and forecast maintenance needs. This forward-thinking method prevents expensive system failures and maintains optimal efficiency. By employing this proactive approach, solar PV systems can operate at their best capacity, reducing costs and ensuring their longevity.
2. **Energy Management:** Artificial intelligence can efficiently manage energy usage and generation by analyzing live data on solar energy production, energy storage, and grid requirements. This enables intelligent load control, minimizing energy waste and optimizing the utilization of solar power.
3. **Weather Forecasting Integration:** Combining AI with weather forecasting technologies can enhance solar photovoltaic systems efficiency by adjusting energy production according to weather predictions. This adaptation allows for increased solar energy generation during sunny periods and reduces the risk of damage caused by unfavorable weather conditions [17].
4. **Smart Energy Trading:** Artificial intelligence can enhance solar photovoltaic (PV) systems by forecasting energy prices and optimizing the sale of surplus energy to the grid. This integration can boost the financial advantages of solar PV systems for their owners, making them more profitable and beneficial in energy trading markets.
5. **Enhanced System Design:** Artificial intelligence can play a significant role in designing solar photovoltaic (PV) systems by considering multiple factors, including location, orientation, and shading. This helps in creating optimized and economical layouts for solar PV systems.
6. **Customer Engagement:** AI can be employed to create intelligent home energy management systems, offering users customized energy consumption information and suggestions. These systems motivate individuals to adopt eco-friendly habits and optimize their solar photovoltaic (PV) system utilization, promoting sustainable living. By incorporating AI in home energy management, users can gain valuable insights and make informed decisions to enhance their solar PV system efficiency and contribute to a greener environment.
7. **Self-Learning Optimization:** AI algorithms have the capability to continually learn from system data, enabling them to adapt settings for enhanced efficiency and performance. This dynamic process ensures that the solar photovoltaic system consistently operates at its optimal level. As a result, the overall efficiency and effectiveness of the solar PV system are consistently improved over time.
8. **Renewable Energy Integration:** Artificial Intelligence (AI) has the capability to forecast solar energy generation trends and adjust energy consumption accordingly. Likewise, AI can effectively manage and optimize energy consumption based on the availability of wind power.
9. **Home Automation:** Smart Appliances, Combining Artificial Intelligence with Smart Appliances for Intelligent Scheduling and Energy-Efficient Functioning. Occupancy Sensing, Employing AI-assisted occupancy sensors to regulate heating, cooling, and lighting systems according to room occupancy.

10. **Load Balancing:** Dynamic Load Management: Artificial Intelligence (AI) has the capability to dynamically manage energy loads, distributing power according to the present requirements of various devices and appliances. Peak Load Prediction, Forecasting peak energy consumption periods to prevent overwhelming the DC system.
11. **Security and Privacy:** Establishing strong cybersecurity safeguards to shield AI-driven systems from potential cyber risks. Privacy Concerns, Dealings with data privacy issues and guaranteeing the safe management of user data gathered by AI systems is crucial.
12. **Integration with Smart Grids:** Artificial Intelligence (AI) can facilitate the integration of smart homes into the larger power grid system, thereby enhancing grid stability and efficiency. Demand Response, AI can facilitate demand response programs by adjusting home energy usage based on grid conditions.

By incorporating AI into solar PV systems, their overall performance, efficiency, and user experience can be significantly enhanced, contributing to a more sustainable and efficient energy future.

III. CONCLUSION

The government's initiatives to adopt solar energy and become carbon-neutral align perfectly with the United Nations' Sustainable Development Goals. Integrating AI with solar power resources, particularly photovoltaic systems, significantly contributes to our journey towards a sustainable future. Adopting DC Solar rooftop systems along with DC appliances offers a promising solution for providing clean electricity to homes in India. The inverterless approach, which efficiently harnesses solar DC power, has revolutionized the energy sector. This innovative mechanism not only enables off-grid connectivity but also addresses the load shedding issues faced by urban areas connected to the grid. By combining AI and solar energy potential, India can effectively combat climate change, ensure energy security, and enhance the overall quality of life for its citizens. The successful implementation of these technologies will not only contribute to a greener planet but also create numerous job opportunities and stimulate economic growth. As we continue to embrace these revolutionary advancements, we can confidently move towards a brighter, more sustainable future for our nation.

REFERENCES

[1]. HVDC Power Transmission Systems, Technology and System Interactions, KR Padiyar
[2]. Kamalapur, G &Sheelavant, Vishwakumar& Hyderabad, Sabeena&Pujar, Ankita&Baksi, Saptarshi&Patil, Amruta. (2014). HVDC transmission in India. Potentials, IEEE. 33. 22-27. 10.1109/MPOT.2012.2220870.
[3]. Mitra, S., Pandaraboyana, D. K., Arulvendhan, K., & Srinivasan, J. D. (2019). HVDC in Indian Power Sector. International Journal of Recent Technology and Engineering (IJRTE), 8(1S4).
[4]. https://www.mospi.gov.in/publication/energy-statistics-india-2023 https://unstats.un.org/sdgs/report/2023/Goal-07/#:~:text=Affordable%20and%20clean%20energy,technologies%20for%20cooking%20by%202030.
[5]. Taufik, T. (2014, October). The DC House project: An alternate solution for rural electrification. In IEEE Global Humanitarian Technology Conference (GHTC 2014) (pp. 174-179). IEEE.
[6]. IEEE Plan for DC in the Home, IEEE Standards Association, retrieved from http://standards.ieee.org/email/2013_10_cfp_dchome_web.html
[7]. P. Wallich, "The lightbulb that really is a better idea", IEEE Spectrum, Volume: 48, Issue: 1, 2011.
[8]. https://mnre.gov.in/solar-overview/#:~:text=National%20Institute%20of%20Solar%20Energy,covered%20by%20Solar%20PV%20modules
[9]. Ramachandran, A., Mannar, S., & Jhunjhunwala, A. (2016, December). Inverterless Solar-DC system design for off-grid and near off-grid Indian homes. In 2016 First International Conference on Sustainable Green Buildings and Communities (SGBC) (pp. 1-5). IEEE.
[10]. Ashok Jhunjhunwala, Prabjhot Kaur, Aditya Lolla " Solar-DC Microgrid for Indian Homes: Transforming Power Scenario", IEEE Electrification Magazine, Vol 4, Issue 2, pp: 10-19. June 2016
[11]. https://mnre.gov.in/document/off-grid-and-decentralised-solar-pv-applications-program-phase-3-guidelines-and-amendments/
[12]. https://pmsuryagharyojana.in/
[13]. https://pmkusum.mnre.gov.in/landing.html
[14]. Likhachova, Irina, Aditi Maheshwari, and Ayesha Malik. 2019. "Green Buildings—A Finance and Policy Blueprint for Emerging Markets." IFC
[15]. https://books.google.co.in/books?id=gSoDaumDrjoC&printsec=copyright&redir_esc=y#v=onepage&q&f=false

DOI: 10.17148/IJIREEICE.2025.13210

[16]. Y.Z. Li, R. Luan, J.C. Niu, Forecast of power generation for grid-connected photovoltaic system based on grey model and Markov chain. In Proc. of 3rd IEEE Conference on Industrial Electronics and Applications. 2008, pp. 1729-1733.
[17]. https://pmsuryagharyojana.in/
[18]. https://pmkusum.mnre.gov.in/landing.html
[19]. D. Salomonsson, L. Soder, A. Sannino, "An adaptive control system for a DC microgrid for data centers", IEEE Transactions on Industry Applications, Vol. 44, Issue 6, 2008, pp. 1910-1917.
[20]. B.E. Noriega, R.T. Pinto, P. Bauer, "Sustainable DC-microgrid control system for electric-vehicle charging stations", 15th European Conference on Power Electronics and Applications, 2013, pp. 1-10.
[21]. W. Li, X. Mou, Y. Zhou, C. Marnay, "On voltage standards for DC home microgrids energized by distributed sources", 7th International Power Electronics and Motion Control Conference, 2012.
[22]. T. Shibata, K. Sakai, Y. Okabe, "The design and implementation of an on-demand DC Grid in Home", IEEE/IPSJ 11th International Symposium on Applications and the Internet, 2011, pp. 152-159.
[23]. IEEE Plan for DC in the Home, IEEE Standards Association, retrieved from http://standards.ieee.org/email/2013_10_cfp_dchome_web.html
[24]. P. Wallich, "The lightbulb that really is a better idea", IEEE Spectrum, Volume: 48, Issue: 1, 2011.
[25]. Taufik, The DC House Project, EEWeb Pulse, Issue 10, 2011.
[26]. Taufik, "Rural electrification: The DC House solution", The Economist, Powering Up: Perspectives on Indonesia's Energy Future, Jan 2014.