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A Systematic Review of Renewable Energy Trend

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ABSTRACT

This paper systematically and successfully reviewed the renewable energy trend from 2010 to 2023. This review detailed the difference renewable energy and conclusion was drawn that solar photovoltaic (PV) energy has the leading trend in power generation growth and innovation. This research work explained in detail the most recent solar photovoltaic optimization techniques and it was observed from the review that hybridization of intelligent and non-intelligent maximum power point tracking technique has the best tracking power conversion efficiency. The advantages and disadvantage of solar PV together with the solar optimization and innovational growth trends were examined. This research showed that clean and renewable energy sources will continue to grow and the solar energy industry is expected to experience significant growth and rapid innovation in the next 10 years. From the observed rapid growth and innovation trend in solar energy, the world will have a very cheap, abundant and clean energy before 2050.

Keywords: Renewable, Energy, Trend and fossil fuels

INTRODUCTION

The largest contributing sectors for the increase of emissions are electricity, transportation, manufacturing industries and agriculture. With a share of 31% of global emissions, the eagerness to control such through transportation and electricity cannot be underestimated. Their emissions are mainly resulting from the burning of fossil fuels such as coal and gas which need to be replaced by cleaner source of energy (Renewable energy). Therefore, as part of the available solutions, renewable power technologies will play a key part in the transition toward a net-zero emission economy [1]. Renewable energy covers all forms of energy generated from natural resources such as sunlight, wind, water (or hydro power), tide, geothermal heat, biomass and biofuels. They are derived from natural processes that are constantly replenished and each of them has characteristics that determine where and how they are being used [2]. The unit cost of the low-emission technologies has fallen continuously since 2010 due to

innovations and policy packages that have enable their deployment. Within the range of renewables, solar photovoltaics' (PV) cost has experienced a 90% reduction in the last 13 years, which has allowed for exponential growth and a global cumulative capacity reaching 920 GW in 2021. Driven by a technological and financial maturity, solar PV is now a leading actor in the decarburization plan of most countries [1]. It has been predicted that PV cells will deliver about 1081GW by the year 2030 [2]. The quest to urgently reduce the global emissions has been the trending research channel for researchers of the 21st century. The 2021 Intergovernmental Panel on Climate Change (IPCC) warned that the global greenhouse gas emission (GHG) in 2019 were 12% higher than in 2010 and 54% higher than in 2019. The panel also highlighted that the average global temperature is expected to reach or exceed 1.5°C warming by 2040. The consequences are increasingly visible with more frequent heat waves, floods, forest fires and others natural disasters with drastic impacts on populations [1]. This paper will systematically review the solar PV technologies and its optimization techniques from 2010 to 2023. The paper will be subdivided into four section; section two will review the solar PV technologies and optimizations techniques, section three will detail the Solar Energy Trends and Its Prospects and it will finally end with conclusion

Solar Photovoltaic Technologies and Optimization Techniques

In this paper, the mathematical modelling of a solar PV cell has been discussed along with the governing equations behind the characteristic curves. Here the single diode model of the solar PV cell has been used for modelling purpose. The advantage of the double diode model is that it takes into consideration the space charge distribution of the PV cell. But the single diode model gives fairly accurate results. The advantage of modelling a solar cell in computer based software is that the model can further be used in solar panel implementation of other models by varying the simulation parameters. As a result, a prior knowledge can be attained before the practical implementation of the same. The point of interest of the characteristic curves of a solar PV cell is the Maximum Power Point (MPP). Different algorithms for tracking the MPP require the model of the solar PV cell for simulation. The model used for simulation can be very useful for designing controllers/compensators to track the MPP and for larger power system [3]. This research paper in [4] classified solar energy based on technology and optimizations. This paper discussed solar energy based Polycrystalline Solar Cell (Multi-Si), Polycrystalline Solar Cell (Multi-Si), Amorphous Silicon Solar Cells (a-Si), Multi-Junction Solar Cell (M-J), Quantum Dot Solar Cells (QDSC), Dye-Sensitized Solar Cells (DSSC), Perovskite Solar Cells (PSC). This paper also categorized optimization into intelligent, non-intelligent and hybrid type of maximum power point tracking [4]. The paper reviewed Smart Grid data center topologies and identified prospects in spine-leaf architecture as a promising architecture that can be adapted in a smart grid ecosystem data center design. This paper concluded that based on the evaluated literature, the need for more built-in predictive learning curves in smart grid systems and robust Smart grid architecture with enhanced data Centre design for Smart grid systems is observed and recommended [5]. Another researcher in [6] predicted that a lower load in grid results in utilities not transmitting the actual generated units and therefore incurring higher costs due to the use of peak power plants. Furthermore, predicting a higher load than actual load will result in higher costs because unnecessary baseline units are stated and not used. This research work designed an Artificial Neural Networks (ANNs) which provides an accurate approach to the problem of energy forecasting and have the advantage of not requiring the user to have a clear understanding of the underlying mathematical relationship between input and output [6].

A solar photovoltaic material for fabrications and optimizations were developed and effectively discussed in this papers. A non-toxic materials that can substitute lead in solar perovskites fabrication which many materials such as Tin-based Perovskites (MASnX3), Bismuth-based perovskite $(MA)_3Bi_2I_9$, Germanium-based perovskites ($AGeI_3$), Bismuth-based double perovskite ($Cs2AgBiBr_6$) and Copper-based perovskites ($(MA)_2CuCl2\ Br_2$) were suggested as a potential replacement was discussed in [7]. Methods and ways of improving the efficiency and stability of in-air fabricated perovskite solar cells using the mixed anti-solvent of methyl acetate and chloroform was reviewed in [8] and finally Optimum silver contact sputtering parameters for efficient perovskite solar cell fabrication was extensively discussed in [9]. The sun has the most abundant sources of energy which can be utilized for its thermal properties which can be converted to more versatile electrical energy. This research paper in [10] presented theoretical research on the nature of solar energy and its uses, future methods of harnessing and limitations. It showed different ways at which solar energy can be harnessed practically and as well proposed likely the emerging technology and their limitations. This research work reviewed various solar thermal power plants and compared them according to performance and technology and from the thermal review it was concluded that parabolic trough concentrator is more efficient when compared with linear Fresnel reflectors. In addition to solar thermal power plants, solar energy can be directly converted to electricity using PV modules. From this research work in [11] it concluded that PV systems are more applicable for small- scale power generation and have higher output electricity compared with CSP plants in the same area of installation. However, CSP plants have some advantages such as

better economic return and lower CO2 emission [12]. The usage of renewable energy sources has reduced the high rate of pollutant emissions into the atmosphere. The sun is about 1.4 million km in diameter and 150 million km from the earth. It is close to 5500°C at its surface and emits radiation at a rate of 3.8×1023kW. This power is due to nuclear fusion reactions near its core going to continue for several billion years. Exploration of solar energy plays a vital role in developed and developing countries like Nigeria, Uganda (Africa) where the energy problem is very serious, despite of discoveries and abundantness of oil and gas off the west coast [13] [14].

The sequential evolution of solar photovoltaic maximum power point tracking (MPPT) techniques were reviewed, developed and discussed by [15]–[17]. Many tracking techniques were discussed based on intelligent (Particle swarm optimization (PSO), Artificial Neural Network (ANN) etc), non-intelligent (Incremental Conductance (IC), Perturb and Observe (P&O), Optimized Adaptive Differential conductance (OADC)) and hybrid (Perturb and Observe and Balanced Optimized PSO [16], Optimized Adaptive Differential Conductance and Particle Swarm Optimization)). These optimization techniques serve as guide for solar photovoltaic designers and developers on the latest optimization technique and the appropriate one to be adopted during design and installation.

In [2] The paper discusses the solar energy potential for sustainable energy generation in Nigeria, the numerous issues involved in harnessing solar energy and clearly articulates a road map to enable Nigeria tap into this huge potential. Research indicate that, Nigeria lying in the tropics, receives abundant sunshine where about 1500PJ could be available to Nigeria annually from solar energy. Due to the numerous disadvantages of conventional fuel sources when compared with solar energy and the recent giant strides in improving solar cell efficiency using a photovoltaic (PV) device that converts 40.8% of light that hits it into electricity, Nigeria needs to reposition herself by investing in this invaluable resource to secure the energy future of our economy [18].

Table1: Summary of the MPPT Techniques from 2010-2023

MPP Technique	Efficiency	Convergence speed	Oscillation	Cost	Implementation complexity	Sensed parameters	Track real MPP	Reliability
FSCC	Poor	Medium	Yes	Inexpensive	Medium	Current	No	Low
FOCV	Poor	Medium	Yes	Inexpensive	Low	Voltage	No	Low
P&O	Medium	Varies	No	Relatively lower	Low	Voltage	Yes	Low
AP&O	Medium	Fast	No	Expensive	High (Digital)	Current	Yes	High
INC	Max	Varies	No	Expensive	Medium	Voltage, Current	Yes	Medium
IINC	Max	Varies	No	Expensive	Medium (Digital)	Voltage, Current	Yes	High
RSM	Medium	Varies	No	Inexpensive	Digital	Multi-variable	Yes	Medium
DIRECT SA	Medium	fast	yes	moderate	Medium (digital)	Multi-variable	Yes	High
OADC	max	Very fast	No	Moderate	Digital	Vmpp, Impp	Yes	High
HGCMPC	Max	Fast	No	Expensive	Digital	Current Voltage	Yes	Medium
SCOU	Max	Varies	Yes	Inexpensive	Digital	Multi-variable	Yes	High
EAESC	Max	Very fast	No	Expensive	Digital	Multi-variable	Yes	High
FLC	Max	Fast	Yes	Expensive	High (Digital)	Varies	Yes	Medium
T-S fuzzy	Max	Fast	Yes	Expensive	High (Digital)	Varies	Yes	Low
ANN	Max	Fast	Yes	Expensive	High (Digital)	Varies	Yes	Medium
PSO	Max	Fast	No	Expensive	Medium (Digital)	Multi-variable	Yes	High
IPSO	Max	Fast	No	Expensive	High (Digital)	Multi-variable	Yes	Medium
MAPSO	Max	Fast	No	Expensive	High (Digital)	Multi-variable	Yes	Low
SPSO	max	fast	No	Expensive	High (Digital)	Multi-variable	Yes	Medium
PSO & PO	Max	Fast	No	Expensive	Digital	Multi-variable	Yes	High
PSO & AGO	Medium	Fast	Yes	Expensive	Digital	Multi-variable	Yes	Medium
APSO & ANN	Max	Medium	No	Moderate	Digital	Multi-variable	Yes	Low

Table 1 summarized the solar photovoltaic optimization techniques and from the summary it was observed that the best technique for solar photovoltaic optimization is hybridization of intelligent and non-intelligent techniques with very simple circuit.

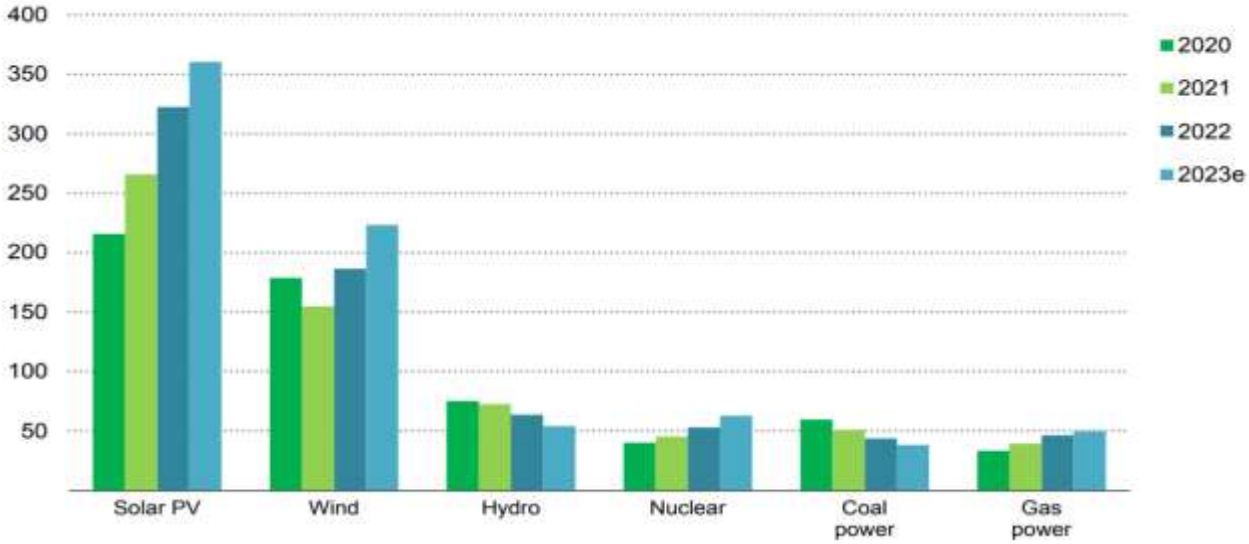

Figure 1. Renewable Sources of Energy and their Generated Power from 2020-2023 [19]

Figure 1 showed the energy generated by difference renewable energy sources, it was clearly observed that solar has the leading trend. It was observed from figure 1 that the most leading renewable energy in 2023 are solar, wind, nuclear and gas whereas hydro and coal are diminishing with respect to the years. Solar photovoltaic has the brightest prospect among all the renewable sources of energy and with this rapid increase will make a very great history in energy sector before 2050. The second is wind which is still in the performance level of solar in the year 2020 and with this it may still be among the trending one as it decreased in 2021 and picked up in 2022 and 2023.

Solar Photovoltaic Components and Its Classifications

The Photovoltaic system can be classified into two parts which are the PV array (PV panels and support structures) and the Balance-of-System (BoS) components (storage batteries, Charge controllers, inverters and wirings). There are four basic components of a solar power system: Solar Panels, Charge Controller, Batteries, Power Inverter [20][21][22].

i. **Solar panels:** solar panel is made up of individual solar cells that are connected in series and parallels to form a solar module. Multiple connected solar modules forms solar array. Figure 2 is a typical example of cells connected to form modules and modules connected for form arrays.

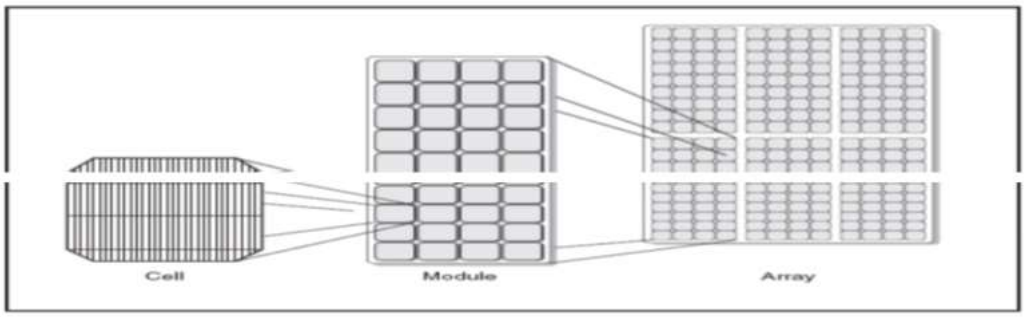

Figure 2: A connected PV Cells, Module and array [21]

ii. **Batteries:** Deep Cycle Batteries are needed for the storage of electricity, but more specialized batteries such as Tubular batteries are also gaining popularity for larger applications.

iii. **Charge Controllers**: Charge Controllers are used in preventing overcharge of the battery and high voltage which may damage the battery. There are many technologies used in battery charging such as Pulse Width Modulation (PWM) technique and the best charge controller makes use of optimization technique called Maximum Power Point Tracking (MPPT) technique [23]

iv. **Power Inverters:** The electricity produced by the PV panel is Direct Current (usually 12V, 24V, or 48V, etc.), which is then converted to Alternating Current (AC).

Advantages of Solar Energy

1. Low running cost
2. No Monthly Bills
3. It is renewable
4. Low Maintenance Cost
5. Environmental friendly
6. Source of Income
7. Value-Added Property
8. Improving Technology
9. Improves the Economy
10. Job provision

Disadvantages of Solar Energy

1. It is expensive to setup
2. Intermittent in a cloudy weather
3. Low Efficiency
4. Occupy more space
5. Dependency on Latitude

Solar Energy Trends and Its Prospects

As the quest for clean and renewable energy sources continues to grow, the solar energy industry is expected to experience significant growth and rapid innovation from 2023 upwards. The solar energy trends that are expected to shape the renewable energy industry in the future are as follow:

1. **Growth of large-scale solar farms:** The growth of large-scale solar farms is expected to continue in 2023 as more countries increased their investment in renewable energy. Solar farms can provide a cost-effective and scalable source of clean energy, helping to reduce reliance on fossil fuels and improve energy security.
2. **Expansion of rooftop solar panels:** The installation of rooftop solar panels is expected to continue to expand the more from 2023, particularly as more households and businesses look to reduce their energy costs and improve their environmental footprint. Rooftop solar panels can provide a cost-effective source of clean energy and can help to reduce dependence on the grid.
3. **Adoption of energy storage solutions:** Energy storage solutions, such as batteries, are expected to become increasingly widespread in 2023. Energy storage solutions can help to improve energy security and reduce dependence on the grid, while also enabling more effective use of renewable energy sources.
4. **Growth of community solar:** Community solar, which allows multiple households or businesses to share a single large-scale solar installation, is expected to continue to grow in 2023. Community solar can help to make solar energy more accessible and affordable, while also promoting community engagement and environmental awareness.
5. **Expansion of off-grid solar:** Off-grid solar, which provides electricity to communities and individuals that are not connected to the grid, is expected to continue to grow in 2023. Off-grid solar can help to bring electricity to remote or rural areas and support economic growth and development.
6. **Increased use of smart grid technology:** Smart grid technology, which allows for the intelligent management of energy supply and demand, is expected to become increasingly widespread in 2023. Smart grids can help to improve energy efficiency, reduce energy waste, and promote the integration of renewable energy sources into the grid.
7. **Development of new financing models:** New financing models, such as crowdfunding and micro-financing, are expected to emerge in 2023, helping to make solar energy more accessible and affordable for communities and individuals. These financing models can help to overcome the barriers to investment and support the growth of the solar energy sector.

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CONCLUSION

The rapid growth and innovation in solar photovoltaic/solar energy sector is quit overwarming as more households, businesses, and countries embrace this clean and renewable source of energy. This showed that solar photovoltaic and wind turbines have the highest trend of renewable energy growth and innovation. These trends are expected to help reduce dependence on fossil fuels, improve energy security and final support the transition to a more sustainable clean and cheap energy in future.

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