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EFFICIENT GRID INTEGRATED PV MODULE: A REVIEW

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Abstract

To tackle the challenges of global energy consumption and emission of CO2, integration of solar panels is really necessary. This calls a concept of interconnected grids or network grids. To enhance the reliability and efficiency of the rooftop, a comparative performance testing is important. Power output of solar panels is not only affected by its nominal power rating but also affected by cascading system and weather factors like irradiation and temperature. In this paper specifically analysis is based on Mono-Si solar panel, wafer based crystalline Si(c-Si), thin films, emerging and novel PV technologies(concentration and organic PV), solar panels(using CZTS, CZTSe and CZTSSe compounds), Mc-Si, Thin-Film—CdTe, Thin-Film—CIGS and others proofs to remain best for energy yields examining their performance ratios. Here, there will be comparison to Poly-Si less efficiency and more power production with micromorph as well as current technology and future trends of PV and thermal However, efficiency and performance ratio of the solar panel shows decreasing trend with the increase of solar panel's temperature.

Introduction

Currently, the reliability of energy systems are totally based on fossil fuels burning. However, fossil fuels are conventional and nonrenewable as well as directly emit greenhouse gases to the environment. This has been revoking serious environmental and health hazards. Whereas, Urban areas host more than 50% of the world population, and are responsible for $3/4^{th}$ of energy consumption all over the globe. This is not the end, the emission of 80% carbon dioxide come out from here only.

There is an urgent need of smart and efficient system which could help in the growth of green economy. These system includes the concept of Micro Grids, rooftop PV panels, micro turbines and this invokes the idea of thin films of Kesterite compounds Cu_2ZnSnS_4 (CZTS), $Cu_2ZnSnSe_4$ (CZTSe) and $Cu_2ZnSn(S_xSe_{1-x})_4$ (CZTSSe). This analysis is going to be informative because these compunds have optimal direct band gap (E_g = 1.0-1.5 eV) [5], p-type conductivity, high absorption coefficient ($\alpha > 10^4$ cm^{-1}) and most non-toxic elements in its composition. Due to the above characteristics of CZTS, CZTSe and CZTSSe, they have a significant advantage over CIGS and CdTe in necessity to increase production volumes and to reduce the PV modules cost in the future.

There are some other areas of improvements in the emitters of standard cells and with passivized emitter and rear cells (PERC) which enables it to mass production, bulk recombination increasingly limits cell efficiency [6], particularly when using p-type mc-Si wafers [7].

The three most important material quality metrics in mc-Si are first, the excess carrier bulk lifetime, for simplicity denoted lifetime hereafter, second, the dislocation density, and third, the resistivity. It should be stressed that all measurements of lifetime in this study relate to as-grown material and not to the effective or bulk lifetime after solar cell processing.

There are certain new moves for continued tracking of module efficiencies are summarized in the final section. Silicon-Thin-Film-CdTe, Thin-film—CIGS and Thin-film—other, about which we will analyze here. The main application of solar energy systems is to act as clean power source connected to the electrical grid [13]. However, there are many additional applications of solar energy such as solar water pumps in standalone and grid-interfaced systems [14]; solar feeding of the telecommunication base towers which is cost effective particularly for remote areas [15], [16]; solar energy in building managements systems [17]–[19]; solar energy in micro grids, smart grid, and distributed generation [20], [21]; charging infrastructures of electric vehicles [22]; and solar energy for marine, satellite, and many other applications.

The time evolution of the champion efficiencies is dis-cussed and the cell and module efficiency ratios are compared. Recommendations are made about how maintaining a "Best module efficiency chart" and related data can be most useful to the community in the future. The overall information is made observational in [1]-[9] and based on that, we will continue our future study to ensure the cost and efficiency of renewable energy sources specially PV cells.

Recent developments in PV cells

Recently the technology adapted in solar cells are crystalline silicon (mono-crystalline & poly-crystalline), amorphous, Cadmium Telluride, Copper Indium Gallium Selenide, Organic photovoltaic etc. The efficiency of all new devices, which are currently creating based on CZTGeS, CZTGeSe and CZTGeSSe absorbers improvises the capacity to absorb and be more productive. It is believed that the efficiency of SC based on CZTS, CZTSe and CZTSSe is limited by bulk recombination based on the temperature dependence on voltage measurements. However, the complexity of determining of the dominant recombination path and the overall sensitivity of the heterojunction contribute to recombination on the interfaces

To date, mainly as-cut wafer measurements have been used to predict cell performance using dislocation density metrics based on the defect fraction in the PL image [8]. This usually works particularly well for aluminum back surface field (Al-BSF) cells as they are commonly not limited by the bulk lifetime or the diffusion length within the larger grains [7], [14].For electricity generation, the concentrated solar power (CSP) is a promising technology indirectly generating electricity, which is adopted particularly in high power generation plants.

A. Solar Energy System

1. Concentrated Solar Power

Concentrated solar power (CSP) could be categorized as indirect. The first type of CSP converts the solar energy first to heat and then to electricity, which is the thermal CSP.

2. Solar PV Technology

The direct solar power or the solar PV power refers to a system that converts solar radiation directly to an electrical form of energy using PV cells [27]–[29]. This type of renewables gathers the highest global attention because of its numerous advantages.

3. Solar cells

The solar cell is made from solid-state material that converts the energy of light (photons) into the electric form using the PV effect. Capturing the maximum power in any condition (temperature and irradiation) is essential and is achieved by efficient MPPT algorithms.

There are different types of materials used for the design of PV cells. The crystalline materials used for cells design are single crystalline (sc-Si) with a Czochralski (CZ) float zone (FZ) technology; multi crystalline (mc-Si) with a cast, sheet, ribbon growth technology; polycrystalline (pc-Si) with a chemical-vapor deposition technology; and microcrystalline (mc-Si) with a plasma deposition.

Nevertheless, there are promising data on the available and foreseen technologies like mono and Poly-Crystalline silicon (c-Si, pc-Si) [13%-19% efficient], Amorphous silicon, Cadmium telluride and Copper Indium gallium Selenide [3%-12% efficient]. Nowadays, the obtaining of CZT(S, Se) $_2$ films doped with Ge atoms in kesterite compounds are carried out by thermal evaporation [3-5], magnetron sputtering [7-8], colloidal synthesis [2-3], sintering by the Bridgman method [31-32], thermal annealing in GeS_2 vapors [3-4] and the using of chemical precursors [5-6].

Cells produced from this experiment reached maximum efficiencies above 19%. The peak cell efficiencies are found in the lower-mid height position of the bricks for Dislocations wafer and Lifetime ingot & Dislocations wafer while Lifetime ingot exhibits only small changes through the height profile except at the very bottom and top. The efficiencies of Lifetime ingot are found approximately 3% lower than for both Dislocations wafer and Lifetime ingot & Dislocations wafer. Mean and peak efficiencies are similar for Dislocations wafer and Lifetime ingot & Dislocations wafer despite the differences in as-grown lifetimes and dislocation density.

B. GRID-Connected PV Systems

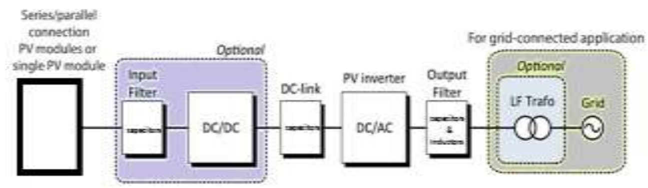

Figure 1. PV system with GRID Integration

Generally, the structure of a PV system can be derived from the nominal power of the system looking at highest efficiency with lowest costs [4].High power PV plants, residential and industrial PV installations, and low-power PV systems. High-power PV plants, the mainstream solution is to use a central three-phase inverter to connect the PV panels to the grid using a low-frequency transformer. With the current PV and power switches technology and grid codes, the maximum power of a PV central inverter is around 1 MW using a conventional two-level 1700 V insulated gate bipolar transistor (IGBT)-based three-phase inverter with a low frequency transformer.

C. Module Efficiency

A comparison of module efficiencies for all of the technologies, omitting data for modules <200 cm^2. The choice of the size range to include is challenging; the size of a commercial module today varies by technology and many champion efficiencies are reported for smaller modules. Even if a module is of a commercial size, champion specimens are not always taken from the production line, but fabricated to define what can be achieved, and record efficiencies are usually measured behind an aperture smaller than the physical module. Inclusion of “demonstration” and small modules allows us to track the technology development in a way that mirrors the Research-Cell Efficiencies Chart, providing value despite the lack of equivalence to commercial products. We chose to include modules >200 cm^2 in order to better track the OPV development in the 2008–2009 timeframe, but we suggest that a requirement of >300 cm^2 would be preferable by requiring a “module” to be bigger than the largest silicon cells.

D. Power Equations

It assumes that the converter output is inductive and the active (P) and reactive power (Q) is calculated as

$$P = (EV \sin\delta) / X. \quad (1)$$
$$Q = (EV \cos\delta - V^2)/X \quad (2)$$

Where *E* is the converter voltage amplitude, *V* is the filtered output voltage amplitude, X is the coupling impedance, and δ is the angle between E and V.

Table 1. Comparison of Characteristics in between Cells

Cell	Efficiency %)	Voc,(V)	Jsc, (mA/cm^2)	FF
CZTS[9]	9.4	0.700	21.3	63
CZTSe[10]	11.6	0.423	40.6	67.3
CZTSSe[8]	12.6	0.513	35.2	69.8
CZTGeS[44]	6.3	0.54	23.36	50
CZTGeSe[42]	12.3	0.527	32.3	72.7
CZTGeSSe[43]	11	0.583	33.6	55.9
CIGS[3]	22.3	0.722	39.4	78.2

Table 2. Performance Comparisons Using Bi-level Block Coding in the Two-stage Scheme

Data type	Sample size	LP order	Frame size	ABPS	CR
Audio	16 bits	10	1024 samples	4.58 bits	3.5
ECG data	16 bits	8	1000 samples	7.92 bits	2.02
Seismic	32 bits	8	835 samples	9.80 bits	3.27

Future Perspective of Solar Energy

Research trends are mainly focused on improving the reliability, efficiency, and power quality, reducing the cost, integrating with the grid at various scales and contributing to building micro-grid and smart grid paradigms. Environmental concerns have pushed up renewable energy sources revolution in the last decades, mainly wind and solar. Concentrated solar and solar photovoltaic technologies are now a mature solution to obtain energy from the sun irradiation which is a free and almost endless energy source. Both concentrated and photovoltaic systems have been developed extensively in the last 25 years, becoming today a supporting energy player in the energy sector. The future trend of solar energy is promising with the objective of it becoming one of the first energy producers of the world along with other renewable energy sources as regards the solar PV power converters, the focus will always be on maximizing the converter efficiency with minimum cost.

Reliability, fault-tolerant operation, easy maintenance and reduced transportation, and installation costs are also factors in developing new power converter topologies for PV systems, from low to high power. A vast use of multilevel converters for utility-scale PV systems will probably happen, if the voltage isolation regulation of the PV panels is to be revised in the future, achieving central multilevel PV inverters with direct medium-voltage connection avoiding the use of low-voltage transformers and associated switchgear costs.

Conclusion

The paper shows the possibility of the band gap controlling, the increasing of grain growth, the overcoming of the limitations of the recombination on interfaces and reducing of the V_{oc} deficit by incorporated of Ge atoms in kesterite compounds. Champion cell and module efficiencies for all photovoltaic technologies have continued to increase in recent years, with the ratio of the reported champion module efficiency to champion cell efficiency frequently exceeding 90% for crystalline silicon technologies, reaching 90% for CdTe and exceeding 80% for CIGS. Solar energy systems (photovoltaic and concentrated) have become a mature and promising technology worldwide. This paper has shown that the solar energy has been shaped to be an essential element of the present and future energy scenarios. Politically it needs to be encouraged and each and every nation should have enough solar panels to bridge their needs.

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