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Organic Photovoltaics

Ran Cheng

Organic photovoltaic (OPV) is a rapidly emerging PV technology with great potential for extremely high-throughput manufacturing at very low cost. It's made from non-toxic, earth-abundant materials with low energy inputs. They have the potential to serve as lightweight, flexible, conformal, and low-cost solid-state power sources. Unlike most inorganic solar cells, OPV cells use molecular or polymeric absorbers, which results in a localized exciton. However, the main disadvantages of OPV are low efficiency and short lifetime.

Current state-of-the-art OPVs exhibit power conversion efficiency (PCE) of ~9 % in small size (20% for single cells and even higher for tandem cells by tuning material properties, such as bandgap, charge mobility, and energy levels to optimize the light absorption, charge transport, and photovoltage. Developing these optimal materials remains challenging and continuous improvements in material design and chemical synthesis are urgently needed. Research was done on how to develop a new flexible transparent electrode with high transparency, low sheet resistance and mechanical robustness. In addition to that, optimizing interfacial properties and developing new device architecture is also a way of improvement.

In this work, more details about single layer OPV cell, Bilayer OPV cells and bulk heterojunction OPV cells will be presented. Fundamental knowledge of device physics and strategies to improve OPV cell performance are also introduced.

Photovoltaics Grid Integration and Problems

Andrew Foote

The onset of more and more photovoltaics connected to the power distribution system has become a hot-topic for debate and research. Although a markedly high proportion of the concerns seem to come from utility companies, whose business is to generate and sell energy, their issues are valid in most cases. Most of the problems with grid connected photovoltaics come from the fact that they generate energy intermittently and only when the sun is clear of weather and landscape. Most of the time, PV generation takes the form of a diurnal power generation spike that peaks at solar noon. This generation doesn't match the typical load curve that consumers usually follow. Because of this, it has been theorized that conventional load following plants will be forced to follow an increasingly dramatic ramping curve as the effect of solar energy becomes more pronounced. This sort of curve has been named the "duck curve" and represents a worst-case possibility for power networks with a high penetration of solar energy. Real-world examples of this curve have begun to be seen in California, where the "duck curve" idea comes from, and Hawaii. Other problems, especially in Hawaii, arise from "rooftop" units that homeowners install that try to offset their power costs through net metering. These can cause reverse power flow through distribution transformers or throughout the whole system, which can cause problems such as overvoltage and frequency fluctuations if the system is not adjusted with this in mind. The forthcoming solution to these problems is to have enough energy storage to flatten the generation curves, but many times energy storage technology is expensive or underdeveloped. With grid-scale problems such as these, it is difficult to conduct research empirically, but much work has been done on this area, such as the hardware-based emulation of power grids with renewables present and extensive research into utility-scale energy storage (sometimes with real systems connected to the grid). The debate around solar is heated at times, and the "naysayers" or "renewables deniers" have many valid arguments into why photovoltaics are a giant waste of money. Economically, there are real concerns, especially when many of the "rooftop" solar cells have been installed with significant financial subsidies from governments. And, as mentioned before, solar power can cause very real technical problems for utilities that do not modify their systems to account for distributed generation and overgeneration. However, it is important to note that very few of these discussions dare attack the functionality of the technology as a whole (other than the ones mentioned in this abstract), but rather deal with the economics, policy, and the implementation of photovoltaics. It is a developing technology, but if storage becomes good enough to discard the time-dependency problem of solar power, it seems hopeful that solar will continue become more viable as a "standard" energy generation means.

Near Earth Orbit (NEO) Space Weather Effects on Si and GaAs Solar Cell Degradation

Steven D. Gardner

The space environment is hostile to satellites due to coronal mass ejections (CME), solar flares, solar wind, solar energetic particles (SEP) and extremely cold temperatures. While damaging space weather events are not very common occurrences, they must be considered when developing a satellite. The effects of space weather on solar cell degradation is the primary focus of this project. The thickness of the solar cell correlates to the magnitude of degradation caused by solar radiation. High-energy protons will have a lower chance of being absorbed by a thinner cell since there is less material to decelerate the particle. Germanium-Arsenide cells are more preferred than Silicon cells because of how thin they are in comparison. The result of GaAs cells having a thin profile is that radiation tolerance is better than with Si cells. Detecting solar cell degradation does not depend on the efficiency of the cells but rather on short-circuit current (I_{SC}), open-circuit voltage (V_{OC}), and maximum power output (P_{MP}). V_{OC} degrades as a result of the charged particles developing carriers in the lattice of the semiconductor. Those particles also generate recombination centers which shortens minority carrier diffusion length and degrades I_{SC}. Recombination is the leading factor for Si and GaAs cell radiation degradation. The minority carrier diffusion length ratio is less in Si than GaAs cells, thus the efficiency of the GaAs is higher and preferred over the Si cells. Maximum cell degradation of Silicon cells over 10 years is about 10% while GaAs cells is at about 9.3%. Additionally, a single SEP event can degrade GaAs cells at about half a percent while closer to one percent for Si cells. It is clear that GaAs cells have better abilities to handle space weather than Si cells.

Photovoltaics for Satellite Applications

Haley Harrell

Since the launch of Sputnik, the world's first artificial satellite, in 1957, scientists and engineers have been looking for ways to more reliably and efficiently power satellites and other technologies in space. Advancements in these technologies has led to many exciting applications such as the famous Hubble telescope, as well as communication satellites and small cube satellites. Photovoltaic (PV) cells have been used to power these satellites through the years, as the cost of PV cells is low in comparison to the high cost of launching a satellite into space.

However, due to the extremely harsh environment of space, advancement has not been easy. Solar cells are susceptible the radiation damage, as they are outside the protection of earth's atmosphere. Along that line, sunlight in space therefore has a different spectrum from sunlight received by cells on earth's surface. Satellites also experience dramatic changes in sunlight intensity and temperature as they move in and out of the earth's shadow, causing high thermal stress. Since it is nearly impossible to repair satellites once they are in earth orbit, sustained performance and reliability are absolutely critical for long missions. Yet another requirement of space travel is that photovoltaic modules must be kept small and light, otherwise they add unnecessary weight to the launch payload.

Despite the unique challenges of space, scientists and engineers have developed innovated solutions to meet those needs. The market has moved on from silicon PV cells, which were once the main source of power for spacecraft. The current trend is to use triple junction gallium arsenide cells, as it has a higher bandgap energy which allows a greater efficiency outside of the earth's atmosphere. In addition, triple junction GaAs cells are extremely reliable and lightweight. The greater cost of GaAs cells as mitigated by the fact that space travel is already so expensive. Compared to the price of a rocket launch, the price of PV cells is insignificant.

Rechargeable Batteries and Systems for Photovoltaic Applications

Remington Chase Harrison

Rechargeable batteries are an integral part to an economical photovoltaic system; without batteries, the user is reliant on the electricity grid to provide power that exceeds the current demands of the user and to sink extra power that the user does not currently need. This access to and dependence on the grid usually comes at a larger cost than the cost of storing the energy locally in a battery system. However, rechargeable batteries do have various downsides, including maintenance, charge controlling, and safety. This presentation will show an overview of the different battery technologies currently available for photovoltaic applications, including nickel cadmium, nickel metal hydride, lead acid, and lithium polymer, as well as a test use case in the Auburn Solar House.

While NiCd batteries have been used for the longest time historically, their energy density is low and the toxic cadmium has caused this technology to be relegated to a few specific low power applications. They are much more tolerant of mischarging and environmental extremes, however. NiMH is less dangerous and has a higher energy density than NiCd, but the nominal cell voltage requires that a large amount of them be connected in series for integration in a photovoltaic system, which raises the equivalent series resistance and lowers the effective power output. The main battery technology in use today is lead acid, which has a very well-developed market from their use in automobiles and marine vessels. While lead is very toxic, the safety features that come with these batteries today have almost negated this portion of risk. Care must be taken, however, in charging these batteries to prevent gaseous H2 from building up and breaking the pressure seal within the battery case. Lithium polymer batteries have the highest energy density and cell voltage and are slated to become the main battery used in the future, but they are very prone to hazardous fires and leaks if charged or discharged incorrectly.

Power electronics for PV for AC-grid

Tiancheng Huang

While the world's power demand is increasing, grid-connected PV system is a great application of PV technology, which improves the general use of photovoltaic power. The power electronics inverter plays the most important role in this system, because it is the enabling technology for converting PV produced DC output into AC signal which can connect to grid for residential use. The presentation focuses on four main aspects of inverter of grid-connected PV system: basic technical theory, design method, relevant scientific research of inverter, and current products situation. The evolution of PV inverter starts from centralized inverter, to string inverter, and multi-string inverters. It is categorized into four classifications: the number of power processing stages in cascade; the type of power decoupling between the PV module and the grid; whether they utilizes a transformer (either line or high frequency) or not; and the type of grid-connected power stage. There are two inverter architectures: self-commutated and line-commutated. In the inverter design process, several aspects are essential to be focus on: inverter sizing and selection; the efficiency and minimum voltage of inverter; how many modules can be fit on the roof; how to size the strings; how to size conductors. Scholars are still doing research to improve performance and function of PV inverter, like optimizing the control strategy, increasing efficiency, and reducing low frequency current ripple of PV output. At last, in power electronics manufacturing industry, there are six main companies making grid-connected PV inverter. The pure sine wave inverters are a little more expensive, but compatible with alternating current waveform and appliances. Also, there are sorts of micro-inverter. The price for a single inverter varies from one thousand to five thousand dollar.

Algorithms Used For MPPT

Yatish Kaveti

The growing energy demand and decrease of conventional energy sources have intrigued scientists to research on renewable sources of energy .One choice is Solar energy, which on today is relatively expensive. Although solar energy is readily available everywhere ,its application is highly challenged by environmental and technological constraints. Photovoltaic (PV) offers an environmentally friendly source of electricity, but Solar panel efficiency of energy conversion is not high. The maximum power point tracking (MPPT) of the PV output for all variations in sun position is the vital factor to maximize the power output of PV system for given conditions of radiation and temperature. It is important to note that the output characteristic of a photovoltaic array is nonlinear and changes with solar irradiation and cell's temperature. MPPT technique maximizes the produced energy using widely-adopted MPPT algorithms. In particular, this study compares the behaviors of each technique in presence of solar irradiation variations with a common device with minimum hardware variations.

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Photovoltaic Laws and Policies for Grid Integration

William R. King

Photovoltaic (PV) grid integration requires that appropriate techniques are followed to ensure the quality and safety of the PV generated energy. Associations such as the Institute of Electrical and Electronics Engineers (IEEE) and Nation Fire Protection Association (NFPA) have developed sets of codes and standards that must be followed for PV grid integration systems. These codes and standards contain specification for all of the components used to build a PV system and assure that the system will not negatively affect the current power grid. The NFPA 70, also called the National Electric Code (NEC), establishes a PV system interconnection circuit that has limits on the components and safeguards in place to reduce the safety issues associated with power generation. Following these sets of codes and standards allows PV systems to be integrated to the grid with the sufficient protection for the grid and surrounding areas.

Introduction of Grid-connected technologies in Photovoltaic Power systems

LIU CE

Nowadays with the increasing costs and decreasing reserves of fossil-fuels, as well as the global environmental concerns like carbon dioxide emissions, renewable energy is becoming a significant fraction of the total energy generation. In the past, Photovoltaic (PV)generation systems were more likely for sole home or factory use, but as the demand for load increasing rapidly, the worldwide-installed Photovoltaic systems are used to supply the generated energy into the electric grid.The key point is that PV array may generate significantly unstable DC output contrast to the requirement of stable sinusoidal wave of the power grid. So the topology of two stages PV system has been into implementation. The presentation will first introduce the two stage PV system consisting of a DC/DC converter direct coupled with PV array and a grid connected inverter. Besides there are still so many techniques requires to meet the condition of power grid like phase angle, frequency, amplitude and harmonics. The presentation will state the further struction of grid-connected PV systems including Control unit using maximum power point tracking (MPPT) ,some kinds of PWM strategies and Detectors. With the help of these elements, the output will finally meet standard specifications in terms of power quality and safety.

Economics of photovoltaic systems

Yumeng Liu

With the development of photovoltaic, the study of economics of photovoltaic becomes an essential issue. The price of photovoltaic system is a critical problem for its development. It is important to find a method to provide affordable photovoltaic system for individuals and small business. There have been major changes in the underlying costs, industry structure and market prices of solar photovoltaics technology, in recent years, and gaining a coherent picture of the shifts occurring across the industry value chain globally is a challenge. This thanks to the rapidity of cost and price changes, the complexity of the PV supply chain, which involves a large number of manufacturing processes, the balance of system and installation costs associated with complete PV systems, the choice of different distribution channels, and differences between regional markets within which PV is being deployed.[1] Since the price of the system decline dramatically, the growth of PV industry will be faster .

The research make a prediction that 2009 – 2030 trajectories of PV LCOE($/KWH)and electricity rates are somewhat different for utility residential compared to commercial and residential systems, with a projected LCOE decline of just over 2 1/3 times and average electricity rate increase of almost 30%. Similar to commercial systems, utility PV system costs (and LCOE) decline more sharply than residential systems in the early years but more modestly thereafter. Due to the larger project sizes and less fragmented market compared to residential PV, the utility PV market is expected to mature more rapidly but with less total headroom.[2] This shows that the PV are becoming more and more efficient and more cheap than ever before, It will not take long to make renewable energy become the major power resource in the future.

Besides, a compare of photovoltaic and traditional energy is presented. Including cost, install labor, and life time cost per KWH. This shows the advantage and disadvantages of both energy source. The paper discuss the economics of using PV to reduce oil consumption, as well as traditional electricity. To that end, storage costs need the biggest reductions; the energy price is already quite compelling.

Moreover, there are many photovoltaic companies all around the world, it is useful to learn how they perform in market and how they manage their companies, which is significance for investment. For example, Sun run (NASDAQ:RUN) is the largest dedicated residential solar company in the United States. In this paper, the operating model, the products and the finance of this company is discussed. In the presentation, information of this company will be showed.

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Hybrid Power Systems

Bonian Lu

The first purpose of this presentation is to introduce overall conception and characteristic of hybrid power system. The momentum to study hybrid power generation system is because alternative renewable sources like solar and wind energy are good to environment, but they are easily interfered by external environment change. The solution of this problem is to combine renewable source with fossil fuel source in a hybrid power system which may have high renewable energy penetration and also high reliability and effectivity. A standard solar-wind system should have photovoltaic generator, wind turbine, controller, and inverter. There are many alternate or additive options for most of parts so that generate different types of hybrid power systems. For example, hybrid system can either stand-alone or connect in grid, have storage or no storage, etc. Each kind of hybrid power system has its advantage and drawback, it may necessary to introduce difference between various systems.

Because of various components and resources in a hybrid power system, it become very complicated to sizing and analysis it. Therefore, the important content is how to design and analysis a hybrid power system. This presentation will focus on one mini-grid solar-wind- diesel hybrid power system like a mobile renewable house, specifically introduce the structure configuration of this system. For sizing system like this, needs to models each components first, calculate their input and output power, and optimize it to a good effectivity and reliability. There are some advanced techniques such like loss of power supply probability (LPSP) or genetic algorithm (GA) to complete that. I may just descript these mathematic methods, and not go deep to use them to simulation.

Analyzing a hybrid power system is also important. We have economic and environmental consideration about hybrid power system. There some useful characteristics like cost of electricity (COE), simple payback time (SPBT) for economic analysis; Amount of greenhouse gas emission for environmental analysis. To interpolate the results of hybrid power system in these two parts, this presentation will illustrate a wind-pv-diesel hybrid power system for a village in Saudi Arabia. There are some good data of this system and it may useful to compare with other systems.

Integrating PV to the power grid outside the USA

Gabriel S. Motunde

The qualitative benefits and the issues with integration of photovoltaic (PV) generators when it is integrating with Electricity Grids distribution and transmission in Nigeria. Renewable Solar energy technologies have an enormous potential in the Nigeria and only if the potentials can be realized at a reasonable cost. Market research shows that many customers will purchase renewable power even if it costs somewhat more than conventional power. Since the grid-tied Photovoltaic system does not use batteries, the inverter which converts the DC currents to AC currents must be dealt with.

Grid Inverters: These inverters operate coupled to the electric distribution network and therefore must be able to produce almost perfect sinusoidal voltages and currents. The operating requirements for these types of inverters are in most cases determined by the Nigeria's local utilities, yet most utilities rely on the existing standards required by the IEC.

PV technology is growing and very promising but the two commercialization barriers must be addressed to be viable against mature fossil fuel and nuclear technologies renewables must overcome three major barriers to commercialization: undeveloped infrastructure, lack of economies of scale and problems with Grid Distribution the magnitude and the phase angle.

Hence, with cost, law and other issues with integrating PV to the National Grid being dealt with, the PV solar cells as the alternative source of generating electricity in Nigeria is promising.

Cost Analysis of Personal Photovoltaic System

Craig Prather

Photovoltaics is a promising and popular venue for renewable energy generation. They are easily scalable, work well in many environments, and can be fairly inexpensive to operate. One issue with creating a system is the cost. A system can be expensive to install for a single family therefor the cost and payback details are very important to most consumers unless they have alternative motives for installing the system (such as they want to be environmentally friendly). For the average family, if the photovoltaic system is not cost effective, then it would not be a practical investment and the family or individual would probably not install the system. This presentation will address these concerns and focus on the economics of the implementation of a photovoltaics array that a single individual or family could implement on their private property. The presentation will address the costs of installation and maintenance associated with installing an array and report the amount of money saved and generated with a grid connected system. The system will be designed for the Auburn, Alabama area and will look at the rates and rebates associated with that locality. Quotes will be obtained from local experts in photovoltaic installation to ensure the accuracy of the installment estimates. Quotes will also be sourced from Alabama Power to see what the local buy-back prices are. The federal tax rebate of 30% for the system will be included in the economical analysis as well. As will be detailed in the presentation, Alabama has one of the worst incentive programs for the installment and operation of a photovoltaic system and Alabama Power does not have a high buyback rate for generated solar power. Costs that are not immediately evident (such as insurance premiums) will also be reported on as they can further increase the cost of a solar array. Additionally, as most residents of the Auburn area do not have more than $20,000 sitting in an account ready to invest in a solar array, the presentation will assume the family loans the funds needed to install the array so the interest of a low fixed rate loan will be included in the presentation's cost analysis. Finally, the payback period of the photovoltaic system will be shown to demonstrate the economic viability (or lack thereof) of a personal photovoltaic system in Auburn, Alabama.

Photovoltaic industry in China

ERYU SU

With its rapid development China has become one of the major players in the global photovoltaic. In the last decade the PV industry in China has developed rapidly. China's PV module production is ranked top in the world. PV industry seems to be a big problem after 2012. Because the global market recession in 2012 exposed the issue of overcapacity and other problems. In the presentation I will briefly discuss China's PV industry in two parts: market and new technology breakthrough.

In the first part, PV market. I will introduce the global market and PV market in China. In some reasons. The market in China and global have many different problems. After that I will focus on the market in China. In this section, I will also talk some advantages but it is not my major part. I will focus on the problems in China. I will list several problems in China such as technologies used by China manufactures are identical, China are only investing in solar cell production and solar modules assembling, Overcapacity issue. After that I want to introduce some method to solve the problems above. We can expand the supply chain not just two parts. We can also explore the global PV market. More than 80% of the PV products in China are exported to Europe and the US, the two most mature markets in the world. The truth is this two markets are going to weak. China should find other opportunities in developing markets.

After that I will go to the second part technology breakthrough. New technology can reduce cost. For now, PV industry is still suffering from the high cost of manufacture and low efficiency of PV conversion. In this part, I will introduce the technology in industry manufacture. List the advantages and disadvantages by using this technology. Then I will introduce some new technologies.

Photovoltaic systems and/or applications

Sunil Uprety

PV systems are mainly of two types, Grid Connected and Stand alone. A grid connected Photovoltaic Power Systems are particular as they work on the basis of energy exchange with the local power grid. In practice, in daylight hours the consumer uses the electrical energy produced by their own installation and feed any un-needed power to the AC grid for money, while when there is no light or it is insufficient, or when the consumer requires more energy than his installation is capable of providing, the electrical grid guarantees the supply of necessary electrical energy. Since 2000 grid connected PV had overtaken standalone PV and since 2009 more than 95% of PV cells were being used for grid connections applications. Whenever or wherever power grid is not or not at reasonable costs available, a Stand-alone PV system can be used to generate the needed electrical energy. The components of this system are PV modules; which converts sunlight into electrical energy, Batteries; the energy provided by the solar modules is accumulated in these, Regulators; regulates the charge and discharge of the batteries, which are the most important elements of the system. Regulators are the 'brains' of the installations, which manages the supply from the modules and regulates consumer use severing the consumption if the battery voltage goes below a certain minimum level beneath which the accumulator will be damaged. The last component of the system is the inverter that converts DC current and voltage into AC current and voltage. PV systems has numerous applications in various fields. Few are listed below.

Agriculture: Especially in the rural areas PV system is used for the irrigation and drinking water as it helps in the water pumping. The disadvantage of this type of pumping system is that it has high initial cost and it won't yield much water during cloudy days.

PV Refrigerators for rural health care: In many developing countries, malnutrition is prevalent with a high incidence of disease. Much of the disease could be eliminated or controlled through mass immunization and the vaccines require refrigeration during transportation and storage to remain effective. So, PV system provides a sustainable way to refrigerate vaccines.

Industry, Telecom and Public Services: Cathode protection of gas, oil pipelines and other types of piping use PV system. Radio, television relay stations, stations for data surveying and transmission and lightening of gardens and public transportation stops, street signaling also use PV systems.

Residential: PV system can be used for the household purposes especially for the lighting. Very significant of this type is prevalent in developing countries. It is also used for heating purpose. PV system are also used in charging boats and camper batteries.

Multijunction Solar Cells and Photovoltaics for Wearables

Armin Vahid Mohammadi

Multijunction solar cells are solar cells that consist of multiple stacks of different p-n junctions, typically made of different semiconductor materials and connected in series, where the band gap of each subcell is designed for a specific range of photon energy. Therefore, multiple stacking of various solar cells results in higher efficiency by absorption of a wider range of solar spectrum. Multijunction solar cells were first introduced in late 1970s were an AlGaAs junction was grown on top of a GaAs junction. Their high efficiency led to enormous research that later in 1990s, changing the thickness of the top layer for 2-junction and 3-junction solar cells with GaInP and GaAs both grown on top of an active Ge substrate resulted in record-breaking efficiencies of above 30%. This potential of multijunction solar cells and the high efficiency they could offer dramatically increased the ongoing research on them and in a short time testing GaInP/GaInAs/Ge 3-junction solar cell under concentrated spectrum, for the first time, resulted in efficiency of above 40% (40.7%) for a solar cell. Among different types of multijunction solar cells, III-V multijunction concentrator solar cells are the most attractive type as they offer very high conversion efficiencies. However, compared to single junction solar cells, design and fabrication of multijunction solar cells is more complex and costly as they are usually made of expensive III-V semiconductor materials on a group IV substrate. To overcome this higher manufacturing costs of multijunction solar cells in terrestrial applications there has been much interest in emerging Concentrator Photovoltaic Systems (CPVs), where a concentrating optic such as mirror or lens intensifies sunlight to around 500 times higher enabling reducing the device area and total cost. Other than CPV systems, high cost of the multijunction solar cells has limited their application mostly to aerospace where their high cost to efficiency is acceptable. The first part of this presentation focuses on background of multijunction solar cells, materials used in them, different types of them, and a brief survey of their efficiencies and applications. In continues and in the second part of this presentation, recent efforts in application of photovoltaics for wearables and energy storage devices with focus on materials criteria will be discussed. This field, which has recently attracted huge attention, mostly includes skin-wearable solar cells (stretchable solar cells) and solar-charging of wearable electronics like smartwatches and smartphones. First stretchable solar cells were reported in 2011 where an organic active layer was coated on a poly(dimethylsiloxane) substrate. However, their initial efficiency was dropping to around 30% lower after several cycles of compression. Therefore, the main research goal for this technology is to develop new materials that can stand more bending/compression cycles. As for the wearable electronics, the goal is to create a photo-rechargeable battery system for them, which can lead to dramatic change in wearable technologies such as smartwatches where their progress is very limited due to their poor battery life (usually limited just to 1-2 days). The second part of this presentation tries to explain the background and concept of such photovoltaics along discussing current challenges in them.

Photovoltaics for Space Exploration

Karen Vincent

Applications for Interplanetary Probes

Solar arrays are very common on interplanetary probes. In some instances the solar arrays play into the propulsion system. However, the primary uses of these arrays are for powering onboard electronics rather than propelling the probe. Lenses can be used to focus more concentrated light onto a smaller solar array, which is good for applications where drag is an issue.

One system that is being used for interplanetary solar arrays is Low Intensity Low Temperature (LILT) solar cells. These have been implemented on some of the newer probes such as Rosetta, Dawn, and Juno. These higher efficiency cells are beginning to replace some of the older nuclear power systems due to the shortage of plutonium and the ability to created smaller arrays. One of the reasons that probes need such a high efficiency is that the solar intensity drops off as the square of the distance to the sun. Arrays operating at lower sun intensity also operate at lower temperatures.

Some of the newer probes like the Dawn probe actually use solar arrays to power a solar electric propulsion system. These solar cells power an ion propulsion system, allowing for Dawn to use its solar cells to provide power for the system to thrust for 70% of its mission. Conventional propulsion systems primarily coast and only thrust to change speed and direction.

This presentation will present an overview of the types of solar cells used in interplanetary probes. It will also discuss the different uses of these arrays in the probes systems. The presentation will also include a very brief history of the solar array in interplanetary probes.

PV cost trends in US

Weichao Wang

The cost of photovoltaics (PV) has declined by a factor of nearly 100 since the 1950s, more than any other energy technology in that period. The price of photovoltaics systems in the United States has dropped precipitously in recent years, led by substantial reductions in global PV module prices. Markets for PV are expanding rapidly, recently growing at over 40% per year. Future scenarios that include stabilization of greenhouse-gas (GHG) concentrations assume widespread diffusion of PV. Unlike traditional energy-production technologies that have ongoing consumables costs, nearly all of the costs for photovoltaic (PV) systems must be paid at the beginning. Reducing those initial capital costs is crucial to reducing the cost of solar electricity. In addition to module price, many factors contribute to the price of a PV system, including installation labor, power electronics, permitting and other regulatory costs, and—in the case of ground-mount systems— site acquisition and preparation costs. The costs of PV can be divided into two parts, including rooftop and ground-mount. And rooftop consists of residential and commercial. All together these three costs are different and will be discussed individually. Also there will be cost trends in grid-connected PV systems. There are two different ways to analysis the cost in PV. Fair market value and Bottom-up analysis. We will explain the cost trends in these two different metrics. For the near future cost trends, most analysts project that PV price trends will maintain their downward trajectory in the near term as PV hardware costs continue to decline.

Optics for Photovoltaics

Frank Werner

Optical devices, such as mirrors or lenses, can be used in Photovoltaic (PV) arrays as solar concentrators. Concentrators provide a number of advantages to PV arrays. First, PV cells operate at higher efficiencies under higher solar concentrations. Second, replacing expensive PVs with cheap optical concentrators can decrease the cost of the system without decreasing the power output. Third, concentrators decrease the impact of the system on the environment by requiring less rare earth metals and by decreasing the albedo of the system. The main disadvantage of concentrators is the cost of high concentration systems can outweigh the saving. This cost comes from constructing and maintaining the tracking and cooling systems required.

The main types of concentrators for PV systems are reflective, refractive, and luminescent. Reflective concentrators are one of the earliest and most commonly used types of solar concentrator. They use a parabolic mirror to reflect light from the sun onto the PV array. There are multiple configurations for using a reflective concentrator, the most common being the parabolic trough. The concentration limit of a parabolic trough has been found to be around 200x. This limit can be improved with the addition of secondary optical systems, such as the compound parabolic concentrator.

Another common type of concentrator is refractive. Refractive concentrators use Fresnel lens to magnify image of the sun over the PV array. Fresnel lenses are based off conventional convex lenses; however, the undesired material inside the lens has been removed while the contour profile of the lens remains the same. Removing the excess material reduces the absorption loss and the cost of the lens. There are two types of Fresnel lenses: imaging and non-imaging. Imaging lenses are flat lenses that project a sharp image of the sun on the PV array. However, they require very precise tracking and can create hot spots on the PV array. Non-imaging Fresnel lenses, on the other hand, do not produce a sharp image of the sun. Non-imaging lens are cheaper to manufacture and do not require as precise tracking systems. They also have higher conversion efficiencies and larger acceptance angles. The concentration limit of Fresnel lenses has been found to be around 1000x. This limit can also be improved with the addition of secondary optical systems.

Luminescent solar concentrators, or LSCs, are another type of concentrator for PVs. LSCs consist of a transparent plate doped with a luminescent material. When a photon strikes the top of the plate, it is absorbed by the luminescent material. It will then be re-emitted at a longer wavelength. The re-emitted photon will be directed towards the narrow edges of the plate as it is reflected off the top and bottom of the plate. At the edges of the plate, photons are collected by solar cells optically coupled to the plate. The light is typically concentrated by a factor of 5 to 10. The advantage of LSCs is that, unlike other types of solar concentrators, they collect both direct and diffuse light, meaning sun tracking systems are not needed. This makes LSCs an attractive option for locations where there is a large amount of diffuse light, such as in the cloudy Northern Europe. There has also been research into using LSCs building integrated PVs.

Current research into PV concentrators is focused on new optical configurations and new materials. One large area of research is adapting structures found in nature for use in concentrators. For example, it has been discovered that the wings of the Pieridae butterfly are highly reflective and are used to concentrate light onto the butterfly's body. It is believed that the properties of the wings could be adapted to create lightweight concentrators.

Photovoltaic Technologies with binary III-V materials

Chungman Yang

As a one of the effective renewable energy resource, the solar energy has been considered as important energy to be utilized to replace our limited fossil fuel resource for the future. Researchers have investigated photovoltaic technologies with conventional semiconductor materials such as Si with different type of crystal structures.

Photovoltaic semiconductor development has been reached up to various applications from daily use purpose to special occasion such as space science. As the solar cell market has been grown and become bigger and bigger, however, photovoltaic devices made of silicon could not only satisfy certain level of efficiency demands of industry field, but also its limited chemical, mechanical, and electrical properties.

The binary III-V semiconductor compounds, GaAs and GaN, has been scrutinized to overcome restricted features of conventional PV semiconductor material. Due to unique and exceptional electrical properties of binary III-V semiconductor compound such as high mobility, higher efficiency, and stability under harsh conditions, they have been estimated as expectative candidates for advanced technologies.

In this presentation, based on physics concepts and the principle of how photovoltaic device works, I have pointed out specific III-V material characteristics for PV technique, which lead them to become competitive material compared to other conventional semiconductor materials in terms of efficiency and endurance under extreme condition for special needs. In addition, the electrical property and efficiency depending on various device structures will be discussed. Even though III-V compound has outstanding properties required, there are still limitations to overcome using GaN or GaAs compound materials for PV devices. At the end of the presentation, the advantage and disadvantage of III-V semiconductor materials will be addressed.

Maximum Power Point Tracking for Solar Energy System

Xingyu Yang

According to the output U-I (Voltage-Current) characteristics of a PV cell, the U-P (Voltage-Power) curve is the single peak curve, which means that the PV system must have a Maximum Power Point under a certain condition. Thus, Maximum Power Point Tracking (MPPT) methods and devices are widely discussed and researched, to optimize the energy yield. The MPPT algorithm will guarantee the maximum power output of photovoltaic under any conditions. I am going to simulate the whole system in Simulink.

In my view, the whole system should consist of four main subsystems, which are photovoltaic solar cell, MPPT device, PWM generator, and boost converter circuit. Photovoltaic solar cell is the source of the whole system. The output power of it will consistently change under different conditions, such as temperature and isolation. So, we need to consider the physical equivalent circuit and mathematical model of the photovoltaic solar cell, transforming all the environmental conditions into variable parameters.

Since the photovoltaic solar panels need to be connected to the power grid, and the minimum grid voltage in China is 220V, in the America is 110V. While, the output voltage of a photovoltaic solar panel is currently lower than the minimum grid voltage. So we must need a converter, which can raise the voltage, such as a boost converter, or a buck-boost converter. However, since the output voltage is always higher than the input voltage, I choose the boost converter.

PWM pulse generator should be capable of generating pulses at a certain width, according to the value of D. Should be noticed that the frequency of the pulse determines the frequency of the switch, which should be fast.

According to the MPPT algorithm, the MPPT device should be capable of tacking the maximum power point under different conditions, such as the change of temperature, isolation. And the response must be quick, besides the disturbance cannot be too big. The MPPT device will generate a value of D, and deliver it to the PWM pulse generator.

This is the whole system I am going to simulate in the Simulink. First of all, I will simulate different parts individually. And then connect them together. In the end, this system should be capable of responding to the different environmental inputs, tracking the maximum power point automatically.

The Cost Trends in Chinese PV Technology

KUAI YU

ABSTRACT: As we know, the cost of photovoltaic (PV) power generation has always been much higher than the cost of conventional power generation or the sales of electricity both at home and abroad. Under the enormous challenges of global energy conservation, emission reduction and energy security, the development of renewable energy becomes an important way for promoting economic transition in post-crisis era and developing low carbon economy. In order to realize the integration of the PV power with the power grid at a lower price, it is necessary to have a clear understanding of the possible measures to be taken to reduce the PV cost and the potential of the cost reduction. This study explores the cost reduction potential of the PV power generation in China to provide the decision-making basis for the businesses. I learn and introduce a bottom-up model based on the whole life cycle cost so as to identify the PV cost reduction potential in China before 2020 that will be realized by major driving factors. It is concluded that the PV power and the conventional power will reach parity in price in parts of China by 2020, while the cost of the PV power generation should be further reduced to realize large scale application and sustainable development. Technological innovations will play a key role in the cost reduction.

Reliability and Degradation Analysis of Photovoltaics

Di Zhang

Photovoltaics is the technology for converting solar energy into electricity. Because of increasing need for renewable energy sources. It has been the fastest growing energy technology recently. However, it is possible that some modules are failed when they are exposed to outside extreme environment such as heavy rain, high temperature, heavy snow and strong wind. In order to reduce the degradation and failure of PV modules, it is important to understand the failure mode and reliability performance of those modules under harsh environment. In this presentation, different failure modes and degradation of PV modules are discussed, including degradation of packaging materials, adhesion loss, degradation of interconnects, degradation due to moisture intrusion and semiconductor device degradation. In addition, modeling and simulation methods are also talked in this presentation to estimate the reliability performance of PV modules. One of the advantage of modeling and simulation is efficiency. We don't have to wait for lots of years to get results. With simulation, the reliability of PV modules can be estimated in very short amount of time based on prediction model. Thermal stress is one of the main concern of reliability of PV models. When converting solar energy to electricity, thermal stresses are imposed on PV packages due to different CTE of different materials. Fatigue may be happened when materials are subjected to cyclic stresses. Life can be predicted based on fatigue stress and strain analysis. Finally, from life prediction analysis, a better design is able to come out to increase the reliability performance of PV modules at harsh environment.

Photovoltaic Applications in China

Ziqi Zhou

Since the drive of environmental conscious awareness and economic interests, Photovoltaic is an uprising in industry all over the world especially in developing country like china. Photovoltaic can be widely used in the field of power, transportation, manufacturing, housing, agriculture fields, etc. Compared to other energy sources, photovoltaic has the following advantages: no traditional energy consumption, non-toxic and greenhouse gas emissions; low maintenance costs; quiet operation, no noise; good for remote areas, especially like island where lack of electricity grid. China has become the world's largest photovoltaic applications market, by the end of 2014 the national grid of China's PV cumulative installed capacity reach 28.05 million kilowatts, ranking second in the world, generating about 25 billion kwh every year, an increase of over 200%. In the thirteenth Five-year plans of China, indications that the National Energy Administration (NEA) of China will seek to increase the targeted solar PV installation figure from 100 GW by 2020 to a far higher figure, with some other sources suggesting 200 GW by that date. In this presentation I will illustrate the photovoltaic application in daily life, especially in mainland China. I also believe that with environmental problems have become more and more severely, with the development of photovoltaic technology, it will be more and more photovoltaic apply to everyday life, our lifestyle may also change by this new technology.