Use of Solar Energy in the Automotive Sector

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ABSTRACT

With the advent of more Plug-in Hybrid Electric Vehicles (PHEV) on the market, the use and integration of solar electric components in this sector is increasing. Two areas of providing electrical energy into a PHEV are now being exploited, photovoltaic (PV) systems on the vehicle themselves and common to the parking structures used by these vehicles.

Keywords: phev, solar roof, solar car port, solar parking structure, solar sun roof

1 PV POWER ON VEHICLES

The integration of solar components into traditional internal combustion power automotive platforms had already begun years earlier by various companies but with limited success. This was due to a number of reasons including the cost of the PV system, the power output of the system and simply what to do with the power once generated. Since these earlier years the price of silicon has come down, steady advancements in technology and manufacturing has increased the efficiency of solar cells, and the use of electrical power as the prime mover in an automotive platform has made the previous hurdles much smaller.

1.1 Cell Technology

Two commercial usable types of cell technology available for automotive solar roof applications are thin film and crystalline. While thin and/or bondable film solar cells have a number of positive characteristics, the negative characteristics tend to out weight them. Thin/bondable films provide properties of ease of application and/or attachment. This helps with respect to being able to bond them onto existing roof structures or being able to apply them to roof lines having strong curvature. The manufacturing cost using this method has traditionally resulted in lower cost per watt results compared to crystalline manufacturing technologies. These savings however will only be seen in this sector when the volume requirements required for this specialized application are realizes.

While the above positive attributes help with trying to determine what cell technology to use, the greatest negative attribute to this technology is the lower power density provided by thin film materials. When deciding on a technology to use when apply solar systems to conventional surfaces (i.e. roof tops and ground based systems) the biggest driving factor is cost vs. power density. On large scale systems where surface area is not an issue or the land cost is low then thin film becomes the most cost effective. However, as the amount of surface area goes down then transitions to crystalline panels are made. This is never truer than on a car roof. Unless the solar system is intended to be mostly cosmetic or along for the “green” ride, then power density will be the driving factor. The much higher conversion efficiencies of crystalline solar cells (>16%) cannot be met with thin/flexible film cells.

Crystalline solar cells however are not without its drawbacks as well. The two biggest challenges with this technology are substrate material and contour limitations.

Crystalline solar cells work by exposing the solar sensitive side of the cell to sunlight. Because of the fragile nature of the solar cell it is most commonly bonded to the underside of a glass panel. This means any roof structure wanting to have a pv solar collection system on it will require it to have a glass roof. While this will not be a problem for most applications it does limit it use in others. This problem also crosses the technology boundary when it comes to use thin film as well. If the roof structure cannot accommodate a glass roof element, such as a sun or moon roof, then the panel has to be placed on top of the existing structure adding additional complexity and weight to the vehicle. If the vehicle has this existing component or can be designed into the vehicle from the onset then the impact is small.

The second challenge to using crystalline solar cells comes again from the fragile nature of the cell. Crystalline solar cells are thin (<200μm thick) by design to for numerous physical and economical reasons. The cell is typically 125mm square or 156mm square in outside dimensions. Unless the designer is willing to go beyond these conventional cell sizes the maximum curvature the glass can have becomes a road block. Specialized manufacturing processes have been developed to help offset some of these issues.

Due to the above mentioned considerations the technology Quantum has adopted to use in the manufacture of solar roofs is crystalline solar cells.

1.2 Manufacturing Process

The manufacturing process used to make an automotive pv solar roof is very similar to conventional crystalline solar cell manufacturing. The benefits of this are a well understood manufacturing process, availability of large scale commodity items and high assurances of product longevity.

A typical automotive solar panel structure can be seen in Figure 1.

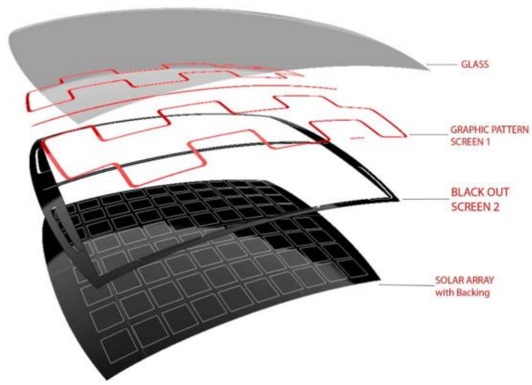

Figure 1: Solar roof assembly

The layers are typically the tempered clear solar glass roof on the outer surface, one or more graphic layers for cosmetic looks and then the solar array. The graphic layers are typical on automotive glass and are usually seen around the outside of the glass panel. The graphic layer is fused to the glass using conventional techniques, and is used to provide a “look” and to hide the adhesives used to attach the panel to the vehicle frame. The solar array itself consisting of layers of EVA, solar cells and a solid back plastic membrane laminated onto the underside of the glass panel.

This buildup philosophy brings with it the advantages seen by conventional solar panels. This sandwiching technique protects the solar cells from typical automotive environmental attacks, provides electrical isolation and the solar cells are protected from mechanical abuse such as car washes, snow scrapers, roof racks etc. Like the commercial world, life expectancies of automotive pv solar systems are well beyond 20 years.

Like conventional panels the solar cells are first strung together with flat copper wire into an array using automated equipment. The cell arrays are then laid up on the glass surface, bused into one or more arrays and brought to common terminating points.

The solar panel is manufactured using the same laminating process as conventional panels. The difference lies in the need for modifications to the laminator to accommodate the curved surface of the glass substrate.

Upon completion of the laminating process the panel is removed from the laminating oven, it is cleaned, visually inspected and the wire harness is attached and routed to a multi pin connector plug.

Once these final manufacturing steps are completed the panel is visually inspected with an attention to detail for defects and pv power tested to ensure the proper performance of the arrays in the solar roof are seen and documented.

The completed solar panel is typically installed in an automobile the same way conventional glass is installed. A urethane bead of adhesive is applied to the underside of the panel and it is the placed in the car opening. In some cases additional plastic trim pieces are also attached to the outer perimeter of the glass panel for the purposes of water flow control and visual aesthetics. On the underside the wire harness is then plug into the vehicle harness, the installation is complete.

1.3 Conversion of Power

How the dc power generated by the solar panel is used is purely up to the original equipment manufacturer (OEM). In all cases the DC power coming from the panel is first sent through a DC-DC converter. This is done to change the varying DC voltage output of the solar panel to a known DC voltage so proper control of the system is attained. What the power is used for is generally dependant on how much power is being created. If a low power thin film system is used then the little power produced is used for menial tasks such as trickle charging the battery or running a simple fan system to provide air circulation in the cabin when the vehicle is off. When more powerful or larger systems are installed then a mort intelligent power controller is used. These controllers typically are interfaced into the communication backbone of the vehicle and provide power to the AC circulating system when the vehicle is off, can provide true recharging power to the low or high voltage battery and can power ancillary systems both when the vehicle is in motion or at rest.

2 PV PARKING STRUCTURES

The second area of influence of solar power in the automotive environment is providing green recharging capabilities for the vehicle while it is parked. With the introduction of PHEV’s on the consumer market, the dramatic reduction in cost of PV systems and the culture of using green power to recharge a green vehicle the desire and economical sense of a solar powered car port is inevitable.

With the ability to recharge the prime moving battery of a PHEV from consumer accessible electrical power, it makes sense from both an environmental as well as economical sense to make this power as green as possible. There is also the secondary effect of minimizing the additional load on our electrical grid and providing decentralized distribution. Economical metal structures are now available that can be installed at residential, commercial, retail and industrial locations that can provide sufficient power to fully recharge a PHEV vehicle in a

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modular way. With these modular structures a consumer or business can slowly buildup the number of arrays to recharge these vehicles as their popularity and numbers increase. Additional benefits from this approach are the image portrayed and the ability to net meter the power produced by these arrays when vehicles are not attached to them.

2.1 Structure types

The three most common types of structures are corner supported, single center post and cantilevered. Each type has its advantages and disadvantages.

The decision as to what type of structure to use is highly dependent on the end users requirements, there really is no right or wrong type. Traits or characteristics brought into consideration include overall cost, vehicle size, number of vehicles, city codes, environmental conditions, subterranean conditions, amount of PV power needed and visual appearance. Some elements that may lean a person in one direction or another are, can any part of the structure be damaged by a vehicle because of where it will be located, how deep can the foundation be sunk without interfering with existing underground structures, what will the overall cost be, will a city planner reject this project for appearance reasons. Some of the more trivial or mundane ones can sometime surprise you.

With respect to the three structure types the corner supported is the most common, Figure 2.

Figure 2: Corner support carport

This is due in part to the carryover of common existing designs to include solar on top. This design also tends to be cost effective but results in numerous parts of the support structure being exposed to vehicles and therefore subject to damage or damaging the vehicle. An added benefit is that although more foundation supports are required for this design, the depth and size of each one is small when compared to the later types.

The center post design offers a cleaner look and reduces the number of potential contact points with vehicles, see Figure 3.

Figure 3: Center post carport

The center post carport optimizes material usage by having a structurally balanced system with even load distribution. With this design there is also only one ground penetration per structure. An additional added benefit of the center post is a convenient location to place a charge port that can be accessed by either vehicle under the stall.

The cantilevered carport provides the cleanest solution, Figure 4.

Figure 4: Cantilevered Carport

This design provides the most protection to both the carport structure and the vehicles under it with respect to contact or collisions. There is very little danger of vehicles clipping the structure as the drive down the center lane or having to “shoe” into a parking spot due to width constraints. The drawback to this design is the need for a heavier structure and two sizable foundations in the ground to counter the moment loads.

2.2 Conversion of Power

As already mentioned the benefits of this concept are immediately attainable. Having a PHEV parked under this structure provides shade, power and a real green statement.

A pv system over a car port can provide many kW’s of power, obviously depending on the surface area made available. Like pv systems on cars here the option of thin film vs. crystalline solar panels is available again. But due to space limitations and the desire to maximize power production the most common option chosen is crystalline. The carport shown in Figure 2 for example produces 5.5kW DC_p. Over a day this can provide >20kWhrs of PHEV recharging power. This is more than enough to recharge most PHEV's on the market today. Like the vehicle the DC power coming out of the pv system has to be converted into something stable and usable. In this application the power is changed from DC to AC. One of the side benefits is that even if a vehicle is not parked under and plugged into the pv array the power produced can be put back on the electrical grid effectively slowing down or in some cases turning your power meter backwards.

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