Solar Electric Refrigerator Truck Development Program

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Abstract- Photovoltaic based refrigeration vehicle is to use the energy derived from the solar power units installed in vehicle to support the power needed for the refrigeration function. It provides the renewable power for the power usage instead of the refrigerator is powered from the International Combustion engine that is not green. The technology include the development of photovoltaic for this application, the driver system for the refrigerator compressor and the battery system. The system prototype has been developed and performance is able to provide refrigeration to -24 deg C. It is ready for production.

Key words: Solar power, sea water solar power, floating solar system, Photovoltaics,

I. Introduction

The refrigerator truck is to transport perishable food at a controlled low temperature. It is like a large portable restaurant freezer. Most mostly seen is in form of truck. They are mainly for use in deliver the freeze food, fresh meal, ice cream and other needed temperature controlled foods. In order to maintain the temperature of the compartment, the engine should be turned on even during idling. For example, a refrigerator truck is needed to be turned on one hour before the operation or the food is filled into the compartment. During the idling when the food is delivering, the engine is maintained on to ensure the power to drive the freezer compressor. Therefore this type of vessel has a very large of emissions when the vehicle is in standstill. The idling fuel usage is also large. During the idling, the fuel is not only o drive the compressor, the other overhead torque by the engine is wasted. Therefore the photovoltaic version of refrigerator truck is proposed.

The PV allows renewable energy that to be installed on the top or side of a truck. The PV energy can power the refrigerator compressor or charged to the battery. Using PV also allows a better thermal insulation of the vehicle so that the efficiency of the refrigerator is improved. Because the idling duration is long, PV will have sufficient time to capture solar energy and store in the battery. PV usualy has an illumination time of 4-5 hours in a day that will provide sufficient power for PV to battery energy storage.

Solar vehicle is not new, [1-3] has reported the similar application. [2] describes the solar refrigerator vehicle application. However, the application in the area is not much. There is also no commercialization in this area.

II. The Key Technology

There are a number of important technologies needed for the project. They are listed below:

A. Maximum power point tracking

The solar power installed on the top of the roof is limited in surface area. Therefore the power is needed to be utilized properly. One of the techniques is called MPPT (Maximum power point tracking) that is to make use of the maximum power point to deliver the power at a given sunlight. The method is required a power converter the convert the electrical power from PV to the inverter to drive the compressor. The converter is to adjust its voltage and current profile in order to get a maximum power.

B. Circuit protection

Suitable diodes are needed to be inserted in the series path of the electrical power to ensure the protection from the reverse current flow. The solar panel is unidirectional, so that any reverse voltage or current will affect the safety, life time and power operation of the solar cells.

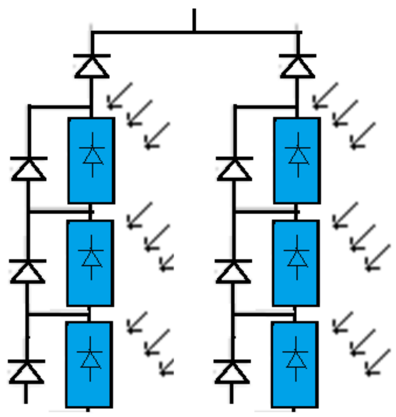

Fig 1 Diode protection to the solar panel system

C. Parallel diode

There are many cases of dead solar cells due to wiring, aging or other damage. A parallel diode is to bypass any dead cell so that the whole series connected path of PV cell is not affected. The method can also bypass the partial shaded for the solar panel. The method is not new, bit t is the necessary installation for safety and higher power design.

IV. The Project

The solar power supply system schematic diagram is follow in Figure 2.

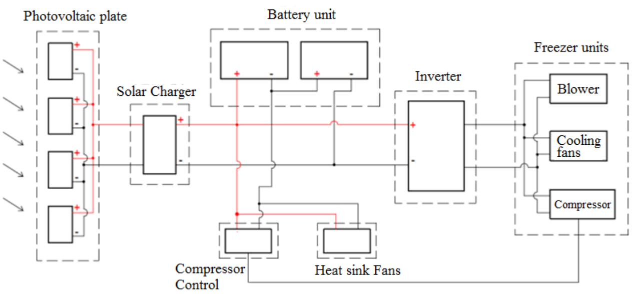

Fig 2: The schematic of the solar refrigerator truck

It consists of the solar power sources, it is then connected to a connection box for power connection and the associated protection system. The DC output connects to battery sets for energy storage. The DC is also connected to an inverter for conversion from DC to AC power signal to the refrigerator units.

The refrigerator consists of the blower, compressor and the thermal dissipation units. One of the key technology is the insulation. The chamber's wall is isolated with highly thermal insulation materials. The interior wall is also pasted with reflector.

B. The specification

The specification of the whole system is :

1. The solar power supply system consists of four solar panels in parallel and the peak power is of two 125W panels and two 150W panels, the solar panels output voltage is turned to 22.5V.
2. Two lead-acid batteries in series, the voltage 24V, capacity 150AH.
3. The dc-to-ac inverter is dc 24V to ac 96V, the power is 4000W.
4. The refrigeration system power is 700W and rated voltage 96V.
5. The compressor controller voltage is 12V.

C. The control unit

The refrigeration controller operation panel is shown in figure 3:

Figure 3 refrigeration controller operation panel

The description of each of the panel design is as follows:

 Master switch: Road switch, standby switch, the engine start and stop.

 Wind speed setting switch: Automatic, high, medium and low.

 Reduce key: Temperature setting, defrost time setting, parameter reference, etc.

 Plus key: Temperature setting, defrost time setting, parameter reference, etc.

 Defrost setting switch: Automatic, manual turn on, turn off, regular turn on, turn off.

Mode selection key: Automatic, cooling, ventilation, heating.

III. LABORATORY TEST

The refrigeration system and power system test have been conducted in the laboratory.

A. Refrigeration system test

1) Refrigeration with small bottle water

When a bottle of 500ml water was put in the refrigeration compartment, the power was then turned on, the water temperature of the water began to decrease from room temperature to all the ice 0°C takes 50 minutes.

2) Refrigeration with large bottle water

Figure 4 Test setup in the refrigeration chamber

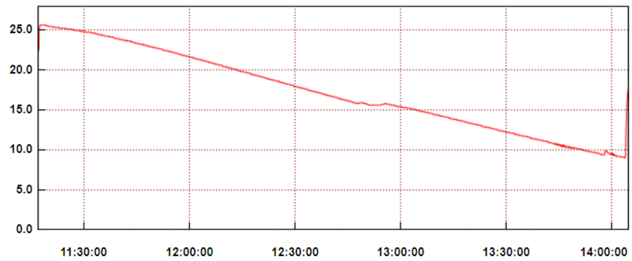

Figure 5 Temperature change curve

Put two barrels of water in the freezer like Figure 4. The test procedure is as follow: Firstly turn on the power, the water temperature began to decrease, and continuously work for 3 hours. From Figure 5 and Figure 6 the refrigeration system worked for different time periods of measurement. When the refrigeration system does not reach the set temperature it will keep on performing cooling. Whenever the temperature reaches the set temperature it will stop cooling. When the temperature rises beyond 5 degrees it will start cooling again. This mechanism is a thermal stat control. The system startup current is much larger than the operating current, so keeping the set temperature will cause temperatures control in a continuous manner and that the system startup time will be eliminate.

If more goods (load) is placed inside the chamber, or the chamber is kept in a hot outdoor environment, the system could not reach the minimum temperature set or it will get a longer working hours. The overall cooling settler time increases.

When the refrigeration system powered by the batteries and solar system only, the working hours under light load could work more than 3.5 hours.

3) Maintaining of the set-temperature

The system has been tested for the temperature maintained at -24 °C. It can maintain the temperature until the battery is flat. This is measured to be 1.5 hours.

When the solar system does not work, just powered by the batteries and without anything in the refrigeration chamber, the cooling effect is shown below.

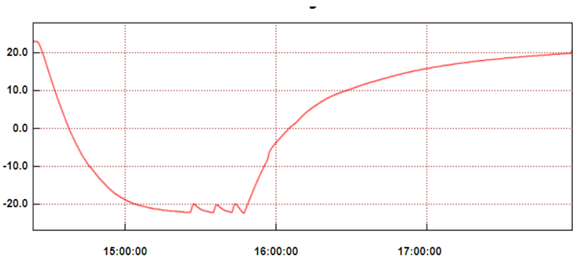

Figure 6 Temperature change curve

From figure 6 it could be seen that the temperature from room temperature 23 degrees to the minimum temperature -24 degrees needs 40 minutes. It has been tested that it can maintain the temperature until the battery is fully discharged. This is measured to be 50 minutes. After that the temperature rises slowly.

4) Maintaining of the set-temperature with leakage

The system has been tested for the temperature maintained at -20 degrees. However, a leakage of the freezer was emulated by allowing the door open with a gap of 0.5 mm. It has been tested that it can maintain the temperature until the battery is fully discharged. This is measured to be 3 hours.

B. Battery capacity test

Another test is to examine the battery charging profile. The status of refrigeration system stops when the battery voltage is charged below a set point. The battery is then re-charged again using a current of 0.2C that is a standard charging current for Lead-acid battery. The charging voltage and current curves are as follows in Fig 7:

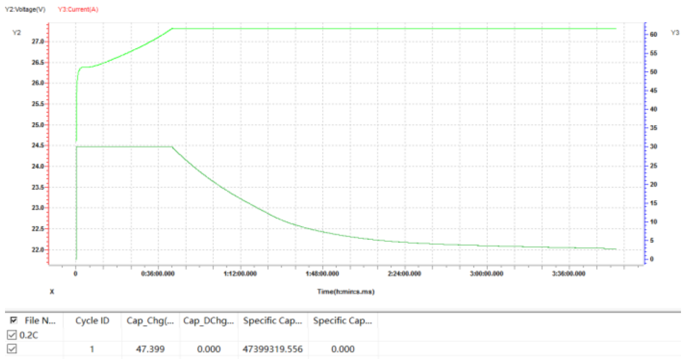

Fig 7 Charging profile of the battery

From the picture: Charging voltage is 27.3V during constant voltage (CV) mode, the Capacity is 47.4Ah and Charging time is 3.5 hours.

The beginning of the curve, as seen in Fig 7, shows the charging is under CC (constant current) mode during the first 36 min, and then changed to CV (constant voltage) mode

C. Solar power generation system test

Solar power generation systems are tested outside direct sunlight as shown in Fig 8. The measurement of the output current and voltage of the solar power system was conducted by current amplifier probe and differential probe. The test results are recorded and as shown in Fig 9.

Fig 8: The system under sunlight test

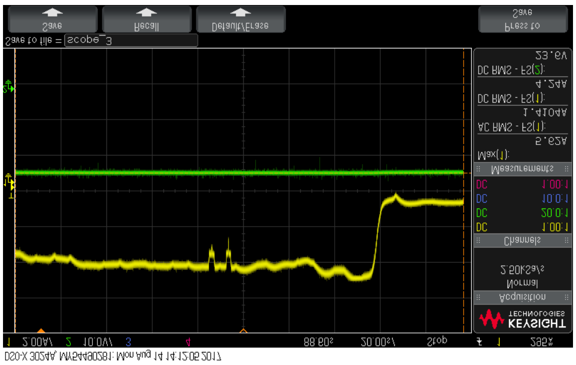

Fig 9: Oscilloscope showing the Current and voltage to the battery of the 4 solar panels connected in series.
(top: current 2A/div, bottom 10V/div)

The system has four solar panels with a total area of 3.3 square meters, there are two in the top area is $1.54m^2$, two in the side area is $1.76m^2$. From the oscilloscope figure shown in Fig 8, it could be seen that the solar system output voltage and current changes followed the intensity of sunlight changes. The maximum output current is 7.82A and the maximum received power is 188W. From the Solar Power Meter, it could be seen that the Solar power per square meter is $324.7W/m^2$. Received power is $56.97\ W/m^2$, conversion efficiency is 17.5%. This represents a good conversion efficiency.

VI. Discussion

This project is to develop a refrigeration system for the vehicles. The system consists of the refrigeration system and the associated power conditioning system. The solar power supply, power charger and the energy storage will be parts of the design and research. The product is to be the self-contained refrigeration transportation unit with renewable energy source in a scaled down model. A refrigeration system has been then developed. It consists of a solar panel system of 550W with 2 x125W and 2x 150W . The battery is 12V+12V with 150Ah. The initial test has confirmed that the system works well. It can provide down to -24deg C of temperature inside the chamber with light load. Thermal stat has been installed that allows the system to trace the temperature continuously. For heavy load or leakage condition, the temperature cannot reaches -24 degC. Finally the system prototype is shown in Fig 9. The whole use design and configuration is shown in Fig 10 with annotation.

Fig 9: The prototype of the refrigerator used in truck

Fig 10: The label of the whole unit

V. Conclusion

A battery and solar powered refrigeration system has been developed. This system consists of energy storage battery, solar power system, solar charger, refrigeration compressor system. The system is installed in a chamber to represent the refrigeration vehicle. The rating of the compressor is 1hp. The battery system is 24V 150Ah. The system is initially set at minimum 24V for the operation. When the battery voltage is lower than 24V, the control system will stop the refrigeration compressor in order to protection the system form over current due to insufficient voltage.

With the solar system under the direct sun light, the refrigeration system working times is around 3.5 hours. During that time, the battery voltage can be maintained at or above 24V that is to maintain the suitable voltage for the inverter to the refrigeration compressor. A thermal stat has been implanted such that the compressor for the refrigeration will continue to operate until the setpoint of temperature is reached.

Of course, the best working condition is when the solar panel under the direct sunlight so that higher input energy is achieved to power the battery and the compressor. The project is one of the first development in the region of a refrigerator truck. Its reduction in emission is the target for reducing of road side emission. In many delivery sites, zero-emission is needed during food deliver, therefore such vehicle is a very important development for the market

Acknowledgement

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