Smart Solar Powered Chiller

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***Abstract*—The Smart Solar Powered Chiller is basically a portable deep freezer which is used to preserve food and ice creams from spoiling at a temperature extremely below the atmospheric temperature. The system is independently and efficiently powered by solar energy consisting of a solar panel where the conversion of solar radiation to Electrical Energy takes place, also consisting of a set of smart charge controller, a Tubular Lead-Acid Battery which are basically used for reliable and uninterrupted Electric supply feeding to the Freezer unit (load) through the smart Inverter. The Freezer unit consists of a thermally insulated compartment and AC Compressor.**

***Keywords—Compressor, Deep Freezer, Inverter, R134A Refrigerant, Solar Charge Controller, MPPT, Solar PV Panels and Tubular Lead-Acid Battery*.**

I. INTRODUCTION

The Smart Solar Powered Freezer is a useful application in areas of the world having high isolation levels where there is a constant demand for cooling and there is not sufficient electricity to supply the conventional power for the system. The Smart Solar Powered Chiller is basically consists of a freezing compartment assembly which operates automatically based on the circuit logic provided to the assembly. The smart chiller consists of components viz the Solar PV Panels, Solar Charge Controller, Tubular Lead-Acid Battery, Smart Inverter, Deep Freezer and the well defined compressing unit. The features of the components along with their application have been provided. The project is also designed to reduce the stress on conventional power supply required for the chilling purpose in the developing areas of the nation. The project also provides protection against overvoltage surges and short circuit conditions. The Smart Solar Powered Chiller is a crossover between mature technologies. The project can be used for mobile chilling applications. Though solar cooling system is hardly classifies as a recent invention, the challenge has been to design and manufacture the product which would offer functionality and capacity at a really competitive cost to conventional products. It efficiently converts the solar energy radiation into usable electrical form of energy using MPPT charging algorithm. As opposed to market-available conventional power chillers, the Smart Solar Powered Chiller does not include an energy consuming compressor unit for generating cooling. Instead, the cooling cycle is simply based on thermal heating which is directly supplied from the sun or other low carbon conventional energy sources.

II. COMPONENTS AND FEATURES

A. *Solar PV Panel*

A Solar PV Monocrystalline Panel having high performance efficiency up to 15%-17.2% [1] is used for energy conversion from solar radiation to variable DC Supply. The universal format of solar PV panels and their comparatively light weight makes them well suitable for both rooftop application and portable projects. A photovoltaic (PV) module is a packaged; connect assembly of multiple solar cells which are connected to each other in both the series and parallel format in order to maximize the voltage output which constitute the solar array of a photovoltaic system that generates and supplies solar electricity . A photovoltaic system typically includes a panel or an array of solar modules, a solar inverter, and sometimes a battery and solar tracker and interconnection wiring. The Output power rating and the voltage rating of the panel used is 150 watts, 18V and the dimension of the panel is 666 x 1483 x 35 (B x L x T) [2] mentioned in mm. Also the Bypass diodes are incorporated, in case of partial shading of module, to maximize the output of module sections still illuminated and improve the overall efficiency of the solar panel.

B. *Solar Charge Controller*

The Solar Charge Controller or solar charge regulator is basically a voltage and/or current regulator to keep batteries from overcharging. It basically regulates the output voltage and output current coming from the solar panels before going directly to the battery assembly. The solar charge controller regulates this 16 to 20 volts output of the panel down to what the battery needs at the time, also as per the requirement of our refrigerator load at that period of time. This voltage would vary from about 10.5 volt to 14.6 volt [3], depending on the state of charge of the battery and the surrounding temperature at that given point of time. Secondarily, it also provides protection against Overvoltage surges which would enhance the project controllability. It also prevents completely draining (deep discharging) by discharging only to 70-80% of its total capacity, thus enhancing the operating life of the batteries and providing a good pay back option. The charge controller also has an interactive display for battery monitoring and efficient control over the parameters. MPPT solar charge controller is therefore very necessary for any solar power systems which need to extract maximum power from PV module under all given condition; it forces PV module to operate at voltage very close to MPP to draw maximum available electrical power.

C. Maximum Power Point Tracker

The Maximum Power Point Tracker is a high frequency (HF) DC to DC converter (Chopper). It takes the DC input power from the solar panels, change and processes it to high frequency AC power, and convert it back down to a different DC voltage and direct current to exactly match the PV panels to the batteries connected [4]. MPPT's actually operate at very high audio frequencies, usually in the 30-80 kHz range. The advantage of using high frequency circuits is that they are designed with very high efficiency transformers and relatively fewer components. Maximum Power Point Tracking (MPPT) is thus a unique technique commonly used along with wind turbines and photovoltaic (PV) solar systems to basically maximize power extraction under all conditions. Although solar power being the main source, the principle applies generally to sources with variable power: for example, optical power transmission. PV solar system exists in many different configurations with regard to its relationships to inverter systems, grids, battery backup, or other electrical loads[5]. Regardless of the ultimate application of the solar power, though the main problem addressed by MPPT is that the efficiency of transfer of power from the solar cell completely depends on both the amount of sunlight falling on the solar panels surface and the electrical characteristics of the load connected. As the intensity of sunlight varies, the load characteristic that gives the highest power transfer efficiency changes accordingly, so that the efficiency of the system is optimized in all conditions when the load characteristic changes to keep the power transfer at highest efficiency under all operating condition. This particular load characteristic is called the maximum power point and MPPT is the actual process of finding this point and keeping the load characteristic right there. Electrical circuits can be designed to present arbitrary loads to the photovoltaic cells and then convert the rms voltage, current, or frequency to suit load devices or systems, and as a result MPPT solves the problem of choosing the best load to be presented to the cells in order to get the most usable power out. Solar cells have a complex relationship between temperature and total resistance that produces a non-linear output which can be analyzed based on its I-V curve. It is this purpose of the MPPT system to sample and hold the output from the PV cells and apply the proper load to obtain maximum power for any given conditions of environment. MPPT devices are typically integrated into an electric power converter system that provides voltage or current conversion or even both, filtering, and regulation for driving various loads connected, including power grids, batteries, or even motors.[6]

D. Tubular Lead-Acid Batteries

The Tubular Lead-Acid battery used in the project has a 150 AH rating, having the charging and discharging rate of C20 on 12 V voltage. These types of batteries are best for solar applications and online UPS, Thus finding application in the project. The battery has special spine alloy composition which ensures long life roughly 4-5 years. The dimension of the battery unit is 503mm L x 189mm W x 362mm H. The cycle life is designed for more than 1250 cycles at approximate 80% DOD[7]. The battery is also designed with deep cycling capacities consisting of Electrolyte level indicators which provide users to easily identify water top-up time and refill the water accordingly. It also reduces the probability of interior short-circuits which gives this battery an upper hand over the conventional types of batteries. The complete unit is eco friendly because the vent plugs does not allow the acid gases to escape outside thus completing eliminating the hazardous effect from the refrigerant if any. The Tubular Batteries are thus more reliable than the conventional batteries because they are comparatively faster while charging & they Operate consistently even at high temperatures.

E. Smart Inverter

The output power rating of the smart Inverter is 750 VA and converts battery output in DC to 230 V AC which is then fed to the Compressor. The smart Inverter is designed to perform 6 stages of charging which is totally microprocessor based and provides the user the provision of multilevel charging to increase the life of the battery spontaneously. When there is any technical issue in the circuit, this inverter would bypass itself to provide you electricity from its mains, thus there is an uninterrupted power at all instants. As it uses smart battery technology, it cannot only perform efficiently at its rated conditions but also well in power conditions as low as 90 V. The Low Voltage Disconnect feature helps in keeping a specific amount of battery energy in reserve in case of any emergency which is called as ‘spinning reserve’. Its high crest factor enables it to supply enough power to highly sensitive freezer application even when the load varies alternately. The inverter is fitted with a special fuse that can be reset at the push of a button which acts a first line of protection. It is designed to beep 8 times before shutting down when experiencing overload issues thus proving sufficient time to the user to act accordingly. It comes in a totally compact shape and has LED indicators. The inverter also has as an intelligent ATC Technology [8] (Automatic Temperature Compensation) that adjusts battery charging according to the ambient temperature to maximize battery performance which makes such inverter completely intelligent and smartly automated. The sensor automatically senses the temperature and takes control of overcharging and under charging, thereby increasing battery life by minimum of six months and providing excellent battery back-up. This inverter is compatible with all sizes of batteries ranging from 18 Ah to 150 Ah. The smart inverter also provides protection against short circuits, High voltage, low voltage and sudden overload conditions.

F. Refrigerant

The Refrigerant used is R134A which is also known as Tetrafluoroethane (CF3CH2F) [9] belonging from the family of HFC refrigerant. The Refrigerant R134A is non-corrosive, non-flammable and non-toxic. It is widely employed in air conditioning system in newer automotive vehicles and can be used as good refrigerant options for deep freezer.[10] It exists in gas form when expose to the naked environment as the boiling temperature is -14.9°F or -26.1°C. The R134A refrigerant is easily replaceable and comparatively cheaper than the existing refrigerant with similar properties.

G. AC Compressor

The AC Compressor being the heart of the cooling cycle consumes approximately 110-130 watts of power operating at 230 V AC supply. The cycle begins when the compressor draws in cool, low-pressure refrigerant gas (R134A) from the indoors. The motor-driven compressor's sole and main function is to "squeeze" the refrigerant [11], raising its temperature and pressure so that it leaves the compressor compartment as a hot, high-pressure gas. The compressor pushes the hot gas to the thin finned condenser coil in the outdoor side of the AC conditioner where fans would blow cool outside air over the coil and through the fins, extracting the heat from the refrigerant and then transferring with the outside air. When enough required heat has been extracted from the refrigerant, it tend to condense into a warm liquid that passes under high pressure to an expansion valve that turns the refrigerant into a cool, low-pressure liquid form. The refrigerant continuous goes from the expansion valve to the finned evaporator coil located in the indoor or inside of the air conditioner unit. When the refrigerant enters the evaporator coil where the pressure is much lower, it is compelled chemically to evaporate into a gas. This process requires heat, which comes from the freezer's warm air being blown over the evaporator coil by another fan. As freezer heat is transferred to the evaporating refrigerant, the freezer's air grows cooler and the cycle over its operating time.

III. BLOCK DIAGRAM

Figure (1) illustrates the block diagram of the Solar Powered Deep Freezer, the position of all the components and their circuit connection as required.

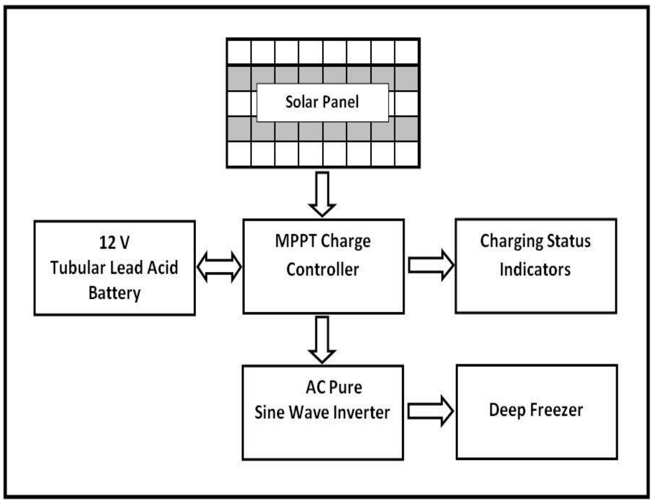

Fig (1) Block Diagram of the system

IV. ASSEMBLY LAYOUT

The assembly layout of the smart solar freezer is shown in figure (2) which basically describes the position of each of the components used

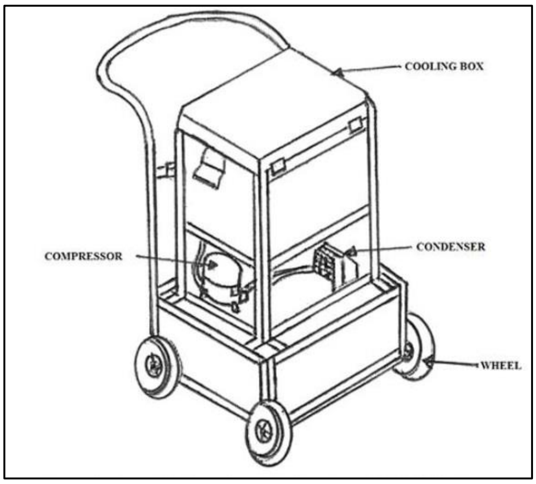

Fig (2) Assembly layout of the system
Source: Akinola, et al [12]

The smart solar powered chiller being incorporated has been designed with the following components, and mounted unto the refrigeration system as shown in Figure 3

The lists of components are

1. Compressor
2. Fan
3. Cooling compartment
4. Condenser
5. Frame
6. Wheel
7. Capillary tube
8. Solar Panel
9. Battery
10. Inverter

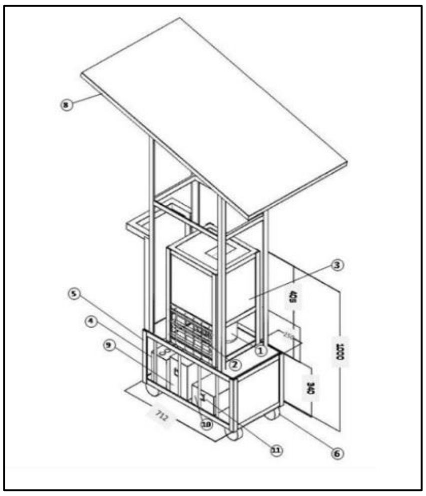

Fig (3) Assembly of the components [13]

V. KEY FEATURES OF SYSTEM

1. The refrigerator runs on storage power system which is charged by Solar Energy.
2. This project is capable of providing power for 6 hrs per day.
3. The batteries which are used are flooded cell tubular lead acid type which lasts up to 7-8 years.

4. The inbuilt charging system which is equipped with MPPT for optimum use of available solar power consists of priority switching to available power source
5. The charge controller is equipped with separate backup battery which is used to perform the following in absence of any power generated (a) Display the temperature of the ice-cream, (b) Display the dc-compressor run time, (c) Intermittent agitation for roughly 7-8 hours
6. The project also has an additional system protection using (a) Internal diode clamping for each channel through micro controller, (b) Opto coupler with triac drive for AC0DC line separation, (c)Emergency stop with a single switch
7. Full recharge time limited only by 5-6 hours
8. Internal circuitry power only 5V DC @ 250mA

VI. ADVANTAGES

The Smart Solar Powered Chiller system which eliminates completes reliable on the available electric grid, requires batteries, and stores PV (Solar) energy for most efficient application when sunlight is partially or completely absent. The Solar Chiller uses a variable speed, DC (direct current) vapor compression cooling system [14] which is connected to a solar photovoltaic (PV) module and in some case to the Solar Panel through novel electronic controls. This environmentally friendly system can be ideally used in commercial or household refrigerators, freezers, solar ice-makers and even vaccine coolers. It is ideal particularly for off-grid application. The above project is environmentally friendly which harnesses the energy of the sun efficiently to reduce complete dependence on fossil fuels and eliminates the need for large number of batteries that can be damaging to the Earth upon disposal. The project operates continuously for roughly 5-6 years as proven by prototype units. The smart solar powered chiller suits applications in a wide range of different sizes, from portable 50-litres solar chillers to car-size solar chillers.

VII. CONCLUSION

The developed system seems to be a good alternative for freezer in zones where electricity is not available continuously. Also, taking in account the features of the project, the project would find it application in the local market and commercial applications due to high efficiency, reliability of uninterrupted power supply, considerably low payback period and adjustability of operation with the change in temperature.

VIII. FUTURE SCOPE

1. Implementing highly efficient solar PV panels for better output power so that overall efficiency of the system increases.
2. Using higher capacity Tubular Lead Acid Batteries for much more running time.
3. Implementing different compartments in the deep freezer, in order to store different products altogether (Liquid & Solid).
4. Implementation of a system from where power can be supplied to the grid as required.
5. Making the Smart Solar Powered Chiller mobile and portable so that it can be transported easily.

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