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A Smart On-grid Solar Charge Controller

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Abstract:

The theme of this project is to design a hybrid system which harnesses electricity from renewable source that is the sun using photo-voltaic solar panels as long as the Sun is available to charge batteries and operate load and when it is not available For example at night or in cloudy weather or in the rain the charging of batteries is switched from sun to the other alternative source such as UPS (Uninterrupted Power Supply) or through AC source.AC source of 220V in the project is given through AC source. This project focuses on utilization of renewable source of energy.

Ofcourse the energy from sun varies along the day which varies the energy generated from it. So to protect our batteries from being overcharged or fully-discharged we have designed a charge controller which determines the battery's SOC (State of Charge) and determines whether to charge it from solar or the alternative source if provide by us. This hybrid system aims to keep our batteries often running and that in the healthy condition [1].

1.Introduction

The untenable nature of fossil fuels and its appalling effect onto environment create concerns for an environmental friendly alternative energy source as fossil fuel dependence increases exponentially. Fossil-fuels are motive for greenhouse emissions, incompetent use of energy and deliverance of harmful contaminant to the atmosphere we realized usage of renewable energy sources concerning the safety of our environment. Due to expensive prices and declining of fossil fuel, we are introducing Charging mechanism for solar powered vehicle. Also, solar energy is clean and green source among all renewable sources because it provides 3.8 x 10^{26} Joules/day**,** low maintenance cost**,** also researcher focus on new techniques with innovative ideas on solar energy that's why its efficiency Improves day by day, if we review today's market solar energy is fastest alternative for standalone system. We are implementing this technology because of its improvement in efficiency, growth and effectiveness. Application Area of our project that it can be used as hybrid charging of battery. We can use charge controller as grid connected especially it is best for villagers where there is load shedding of about 20/24h, one cannot survive without electricity, that's why we have proposed a charge controller which is charged by using national grid supply as well as solar.

Our charge controller charges the battery with 20A and 24V whenever voltages of solar reduced below the 20V automatically WAPDA supply charges the battery by triggering relay 2 and our PWM

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charge controller prevents the battery from overcharging. Over Discharging and reverse power flow, and charge our battery smoothly hence the life time of battery is increased and continue to supply our loads [2].

2. Charge Controller

As the output of solar is varying and fluctuated because the energy and direction of sun is always changing at every second or due to bad weather, the electrical desired values for battery charging are not achieved. So we need here charge controller which also prevents battery from over-charging, over discharging and reverse battery control [3].

Functions of charge controller

Functions of charge controller are defined below.

- Prevention from Overcharging: transistors are used to limit the Amperes if battery is charged.
- Prevention from Over Discharging**:** cut-off the supply if voltage of battery falls down threshold level.
- Blockage from Reverse Charging**:** Diode are used as reverse bias for prevention of reverse voltages towards solar side.
- Control-Functions**:** timer is used to control the load connection and disconnections.

3. Types of Charge Controller

There are basically two types of charge controller PWM & MPPT**,** now a days these two methods are mostly used in Off-Grid system, the decision to use any of the above has not depend on power output, but it depends on the design of system and as well as weather conditions. If we want to differentiate between these two controllers, Power curves is best. It shows the power generation based on potential difference and current [4].

PWM Charge controller

PWM activates when battery is almost fully charged. When the controller supplies voltage to battery until panel voltages equals to battery voltage and there is direct connection between panel and battery. When the battery and panel voltages are equals, controller disconnects the PV and battery, and battery voltage is constant this fast-connecting method is called as shown in figure 1.

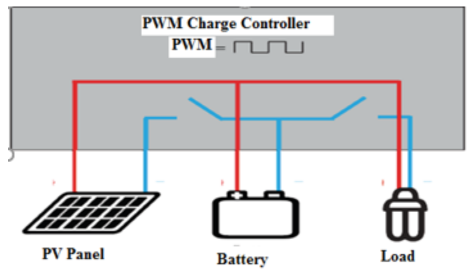

Fig 1: PWM charge controller

Battery is protected by overcharging, it works slightly above the maximum power point of solar panels as shown in figure 2.

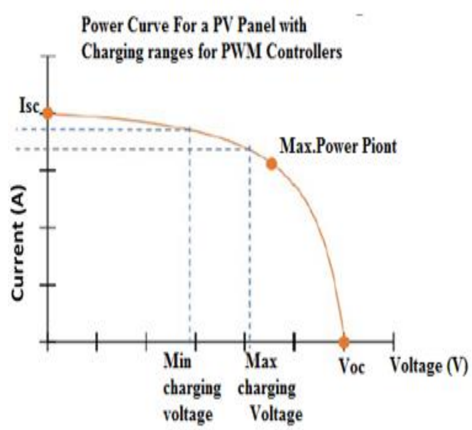

Fig 2: Power curve for PWM controller

MPPT Charge Controller

This controller has unintended link between solar panels and battery, unintended link consists of DC-DC converter that actually gets Solar voltage and converts it into current and reducing voltages where Power is not affected, Block diagram is shown in figure 3.

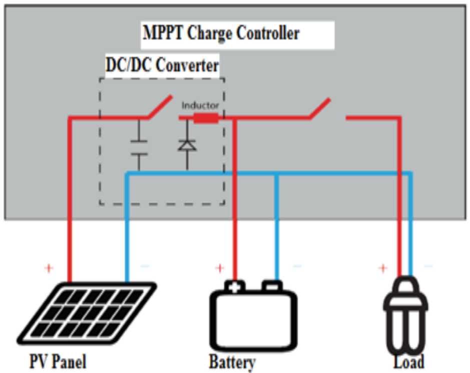

Fig 3: MPPT charge controller

The power curve for maximum power transfer is shown in figure 4 below.

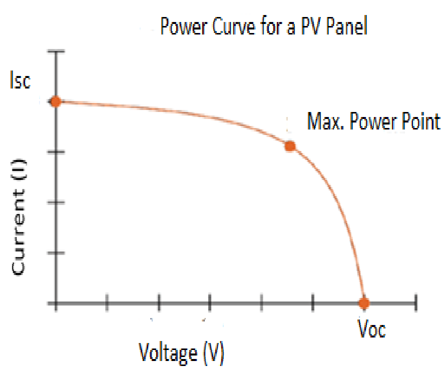

Fig 4: Power curve for PWM charge controller

Difference between both controllers

We are going to select a suitable charge controller on the basis of cost, efficiency, complexity, availability. That is why we understand the difference between charge controllers in below Table I.

Table I: Difference between both controllers

PWM	MPPT
Cost efficient almost half of MPPT	Expensive
Longer lifespan because of complex circuit	Lifespan is less because of electronic circuit
Less thermal stress	High thermal stress
Smaller Size	Bulky Size
Used for 150-200W power system	Used above 200W design
PV array sized on voltage basis	PV array is sized on basis of power

Two way on-grid solar charge controller

Charge controllers are designed to control the device voltage and open the circuit, halting the charging when the battery voltage is supposed to reach a certain level. Most of the charge controller uses mechanical relays to make or break the circuit of device and battery. The charge controller that we have designed is on the method, which continuously monitors the battery voltage, and based on that monitoring it charges the battery through solar panel voltages. It is also known as hybrid charge controller because it keeps on charging the battery even when solar panel voltages reaches below a certain limit. That is done through main 220V WAPDA source. During day time when solar panel voltage goes above 20V the controller switches to charging of battery through solar sources, and during night or due to unconditional weather when solar panel voltage goes below 20V, the controller switches to main WAPDA source for the charging of battery.

4. Experiment

Our experiment goes through four stages.

- Solar panel
- Charge controller
- Batteries
- Load

Solar Panel

Solar PV cells consist of silicon or particular types of semiconductor materials which converts the solar energy into DC electricity. Batteries are required to store energy for use in emergency and night time. A PV or solar energy system, is consisted of solar cells. These cells are connected in series and parallel to provide required current and voltage which in turns forms PV module. Likely these modules are connected in parallel and in series making a network of modules to produce the desired current and voltage. However, the PV output current and voltage is dependent on ambient temperature and irradiance hence (I-V) characteristics of PV module changed nonlinearly in accordance with change in irradiance and temperature. Commonly, there is a special point on the current-voltage I-V or power-voltage P-V curve of a photovoltaic array where the output power of module has maximum value. In order to get maximum power from the array, it must be operated constantly at this maximum power factor (MPP). Due to the nature of the photovoltaic system, the maximum output power varies with the variation in solar radiation and climate conditions, mainly the temperature. The position of the MPP on the I-V curve of the module is not always acknowledge, so it needs to be decided either through calculation methods or with the help of any search method and algorithm [6].

PV module is modelled in MATLAB SIMULINK by modelling standard equations and equations are given below.

$$I = I_{ph} - I_D - I_{sh} \quad (1)$$

$$I_D = I_s\,[\exp\,(V_D/V_T)-1] \quad (2)$$

$$I_{sh} = \frac{V+IRs}{Rsh} \quad (3)$$

$$I_{ph} = [\ I_{sh} + K_{SC}*(T_C - T_O)*(\frac{G}{Gs})\ ] \quad (4)$$

Now module current equation become

$$I = I_{ph} - I_s\,[\exp\,(V_D/V_T)-1] - \frac{V+IRs}{Rsh} \quad (5)$$

All these equations were modeled in SIMULINK and resultant model will become as show in figure 5.

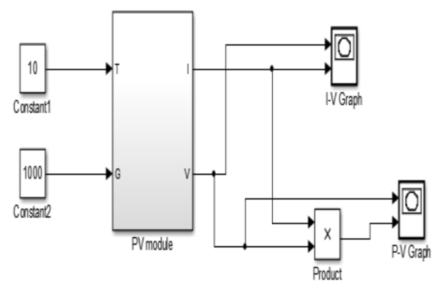

Fig 5: Presentation of whole PV module

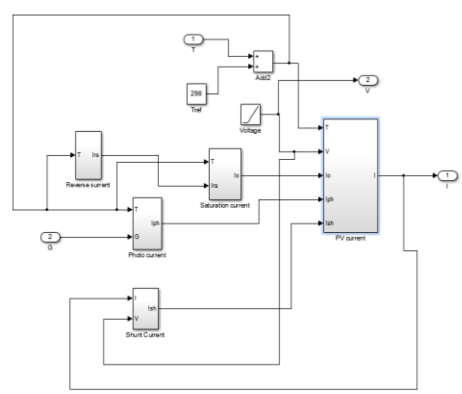

Fig 6: Grouped Subsystem of PV module

Analysis of PV Model

The model has been run under different ambient condition by changing temperature and irradiance as the input to the model to observe the I-V and P-V characteristics of the panel. When we vary the temperature, the irradiance is kept constant and vice versa. The module data used is shown in Table II.

Table II: Module Data

Solar module SM55		
Electrical parameters		
Maximum power rating P_{max}	[Wp] 1)	55
Rated current I_{MPP}	[A]	3.15
Rated voltage V_{MPP}	[V]	17.4
Short circuit current I_{SC}	[A]	3.45
Open circuit voltage V_{OC}	[V]	21.7
Thermal parameters		
NOCT 2)	[°C]	45 ±2
Temp. coefficient: short-circuit current		1.2mA / °C
Temp. coefficient: open-circuit voltage		-.077V / °C
Qualification test parameters 4)		
Temperature cycling range	[°C]	-40 to +85
Humidity freeze, Damp heat	[%RH]	85
Maximum permitted system voltage	[V]	600 (1000 V per ISPRA)
Wind Loading PSF	[N/m²]	50 [2400]
Maximum distortion 3)	[°]	1.2
Hailstone impact Inches	[mm]	1.0 [25]
MPH	[m/s]	52 [v=23]
Weight Pounds	[kg]	12 [5.5]

Effect of Variation of Irradiance

Here as the irradiance increases, short circuit current also increases along with the open circuit voltage. Because of both increasing of V and I, the P_{max} also increases according the irradiance. I-V characteristics under varying irradiance are shown in Figure 7 and 8.

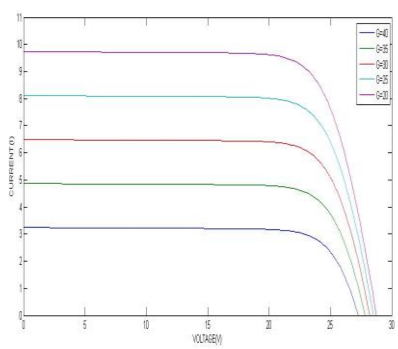

Fig 7: I-V characteristics under varying irradiance

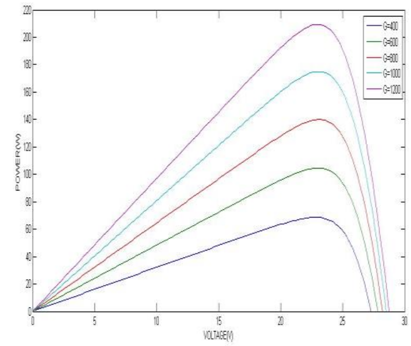

Fig 8: P-V characteristics under varying irradiance

Effect of Variation of Temperature

The simulation is run under the condition of variable temperature and constant irradiance. The open circuit voltage falls as temperature increases, but the short circuit current is less in high temperature. The maximum power point is also inversely proportional to the temperature. I-V characteristics under varying temperature are shown in Figure 9 and 10.

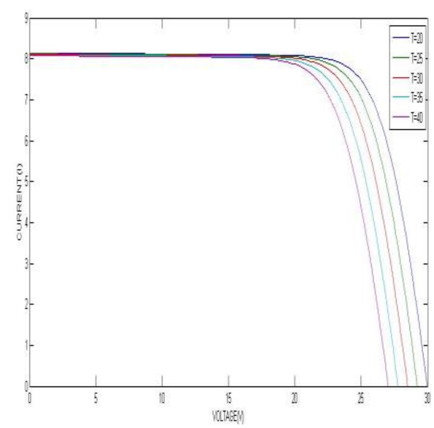

Fig 9: I-V characteristics under varying temperature

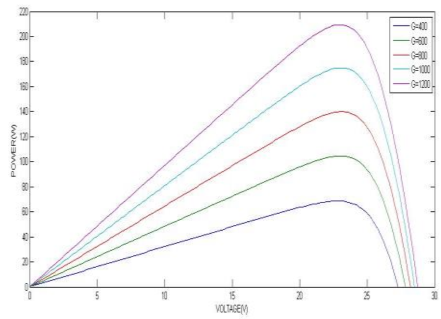

Fig 10: P-V characteristics under varying temperature

Charge Controller

Charge controllers are designed to control the device voltage and open the circuit, halting the charging when the battery voltage is supposed to reach a certain level. Most of the charge controller uses mechanical relays to make or break the circuit of device and battery. The charge controller that we have designed is on the method, which continuously monitors the battery voltage, and based on that monitoring it charges the battery through solar panel voltages. It is also known as hybrid charge controller because it keeps on charging the battery even when solar panel voltages reaches below a certain limit. That is done through main 220V WAPDA source, During day time when solar panel voltage goes above 20V the controller switches to charging of battery through solar sources, and during night or due to unconditional weather when solar panel voltage goes below 20V the controller switches to main WAPDA source for the charging of battery.

Batteries

The main theme of the Battery is to convert chemical energy to electrical energy and vice versa. It is two terminal devices: a positive (Anode) and negative (cathode), voltage difference depends upon the chemical reaction of the electrolyte, this battery may be used to store the charges or used as Power supply for the loads. We used lead acid battery in our project due to its prominent feature ad advantages [7].

Lead acid Battery

In this battery, chemical reaction takes place between Electrolyte of H_2SO_4 and H_2O, this is earliest battery, a separator is used between these two electrolytes.

When load is connected to this battery, Sulphate ions are bonded with sheet and sulphuric acid discharge from battery as shown in shown as Figure 11.

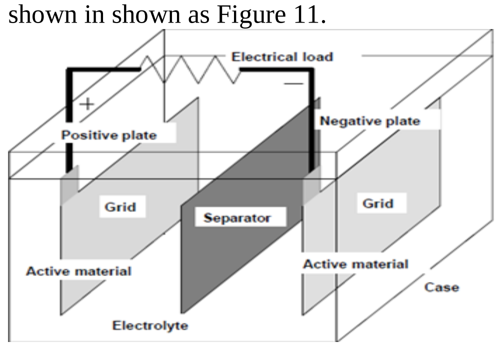

Fig 11: Lead Acid Battery

Load

For testing LOAD we used two 12V DC Fans connected with the battery as shown in Figure 12.

Fig 12: DC Fans (as a loads)

5. Results

We are taking the results of hardware step-by-step first connecting whole setup, all the results will display on the LCD and LCD provides us user friendly information.

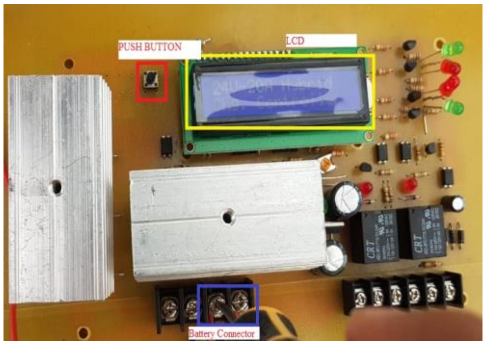

Fig 13: Connection of Battery with System is displayed

In order to charge batteries, we connect our batteries with charge controller, and when batteries will be connected the LCD will display the capacity of system i-e 24V and 20A. If required voltage is being supplied from panels, charge controller will start to charge the batteries as shown in Figure 14. In case weather is much cloudy or it is night time, then controller will switch to alternative 20V supply and continue to charge batteries as shown in Figure 15.

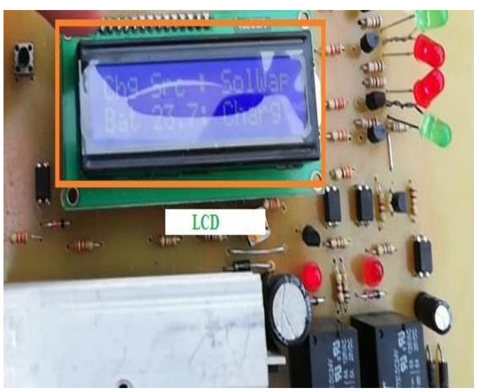

Fig 14: Batteries Charges from Solar

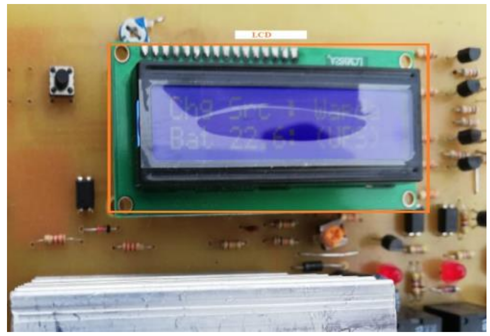

Fig 15: Charging of Battery through AC source

Figure 16 shows the whole circuit of solar charge controller which is being designed in this work of research.

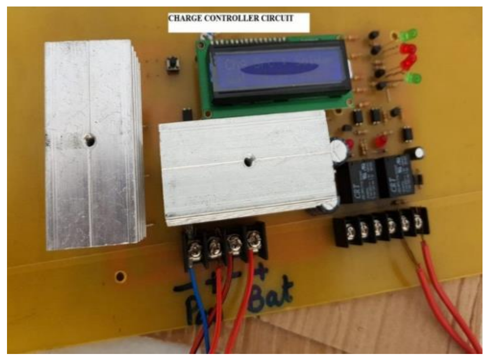

Fig 16: Solar Charge Controller

6. Conclusion

The efficiency and the performance of renewable-energy sources can be harnessed further by the development of the maximum power point tracking and the battery charging control techniques. The proposed hybrid charge controller will be reliable and will accurately charge batteries through solar panel via sun light in day time and also charge batteries through any A.C supply in night time or in cloudy days. So we can use generated electricity for daily life and domestic purpose. Renewable energy solutions are becoming increasingly popular. Photo voltaic systems are good examples of this. In order to implement a solar system, need of good charge controller is necessary for good efficiency and performance of our system. So hybrid charge controller is one of the best options to employ it in solar systems. Due to availability of hybrid charge controller we can charge our battery either by solar energy in day time or charge our batteries by an A.C supply in cloudy days and in night time. So it is very beneficial for such application.

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