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Load Shedding Battery Cut-Off Circuit for Solar Powered System

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Abstract: Most countries have high demand of electricity. Load shedding is a way of shedding loads when the electricity demand is higher than the total generation, Butt et al. (2020). Therefore, to protect the system solar powered systems are used in households. The experimental design set up system includes a battery, comparator and control of the system. The design allows energy conservation and the design process uses Droid Telsa application. Simulations of circuit battery voltages are simulated at different voltages. The design is sensitive to slight voltage changes.

Keywords: Solar System, Load Shedding, Cut – Off System, Comparator.

BACKGROUND

Many households in Zimbabwe use solar energy to power their electrical systems, Conway et al. (2019); Mukisa et al. (2022); & Shafiullah (2021). The challenge with these solar systems is that they lack appropriate technology in the sense that the designs do not suit households of low socio-economic backgrounds, including those that are solely dependent on solar energy such as rural areas, Samarakoon (2020). These systems have been adopted from other nations where economic environments are better than in Zimbabwe, for example users cannot afford large battery banks and mostly use lower KVA rated systems.

Rechargeable batteries can be deep discharged this leads to a reduced lifespan, Ma et al. (2022). A need to conserve energy therefore arises, hence the need to preserve the batteries and increase their lifespan, Al-Rashed, (2022). It has been observed that solar systems in Zimbabwe have only one low battery cut-off voltage where by the battery cut-off system disconnects all loads at once. This cut off voltage is often not the safe cut-off voltage. For example most inverters disconnect at 11.8V for a 12V system.

EXPERIMENTAL DESIGN SET UP

Block diagram

Figure 1: Block diagram for load shedding battery cut-off circuit for solar powered system

Circuit Diagram

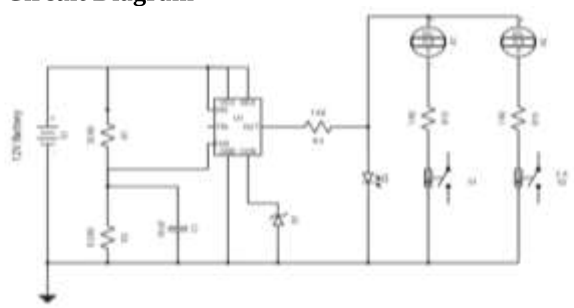

Figure 2: Circuit diagram of load shedding battery cut-off circuit for solar powered system

Load Shedding Battery Cut-Off Circuit

This design circuit cuts of loads in stages. The appliances are grouped into 3; the non-essentials, semi-essential and the essential loads. The non- essential loads are first to be disconnected from the load at 12.4V and the semi-essential loads are disconnected at 12.1V. The essential loads are the last to be disconnected by the circuit that already exists in the purchased inverter, be it 11.8V, 11.9V or 12V. Hence this design is for the non-essential and the semi-essential loads. The design therefore allows for energy conservation, and automatic switches allow for circuit to operate even when the owner is not in the house to switch of loads one by one as the battery discharges.

THE DESIGN PROCESS

Droid Tesla application was used to design and simulate the circuit due to its user friendly characteristics, the major advantage being that it works on android devices, allowing the designer to work on the circuit wherever they are on the phone. The design process involved a lot of calculations and a degree of trial and error. 12V solar batteries are considered fully charged at 12.8V and above. In this design simulation, the voltage value of the battery in the circuit is changed to values 12.8V, 12.7V, 12.6V, 12.5V, 12.4V, 12.3V, 12.2V, 12.1V and 12V to depict a discharging battery. The circuit is constructed using common electronic components, making the design simple and realistic. Two ammeters have been included to aid circuit analysis. The circuit consists of the following components and their values:

Table 1. Circuit components ratings

LABEL	COMPONENT	VALUE
E1	Battery	12V-12.8V
R1	Resistor	32KΩ
R2	Resistor	8.2KΩ
C1	Capacitor	10nF
U1	IC555	n/a
R3	Resistor	1KΩ
D1	Zener diode	5.6V
D2	LED	n/a
R13	Resistor	1KΩ
R15	Resistor	1kΩ
S1	Current controlled switch	774.31μA
S2	Current controlled Switch	775.08μA
A1	Ammeter	n/a
A2	Ammeter	n/a

Operation

The IC labeled U1 is wired as a comparator as shown in the circuit diagrams with its frequency set by the resistor R2 and capacitor C2. The value of R1 is such that the LED is always ON for values above 11.8V. The value was arrived at by placing a 24KΩ resistor in series with a 10KΩ variable resistor and adjustments made until D2 glowed with the battery replaced by an 11.8V D.C voltage source. The switches are calibrated in accordance with the ammeter readings at the voltages at which they switch ON. S1 switches ON when a current of 774,31μA and above flows through its coil, while S2 switches ON when a current of 775.08μA and above flows through its coil. The contacts of S1 are connected to the supply of the semi-essential loads and the contacts of S2 are connected to the non-essential loads.

At voltages of 12.5V and above both switches are ON. Switch 2 turns OFF when the voltage of the battery falls to 12.4V, while S1 remains ON. S1 switches OFF when the battery voltage falls to 12.1V.

Table 2. Switch Positions

BATTERY VOLTAGE	AMMETER READINGS	S1	S2
12.0V	773.78	OFF	OFF
12.1V	774.05	OFF	OFF
12.2V	774.31	ON	OFF
12.3V	774.57	ON	OFF
12.4V	774.83	ON	OFF
12.5V	775.08	ON	ON
12.6V	775.33	ON	ON
12.7V	775.58	ON	ON
12.8V	775.83	ON	ON

SIMULATION – MODELLING RESULTS

Simulation screenshots when the battery level is at the above mentioned voltages.

NB: Note the battery voltage, ammeter readings and switch positions in all the screenshots.

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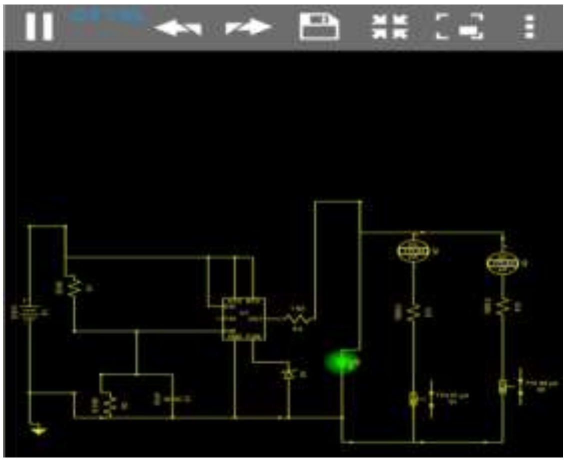
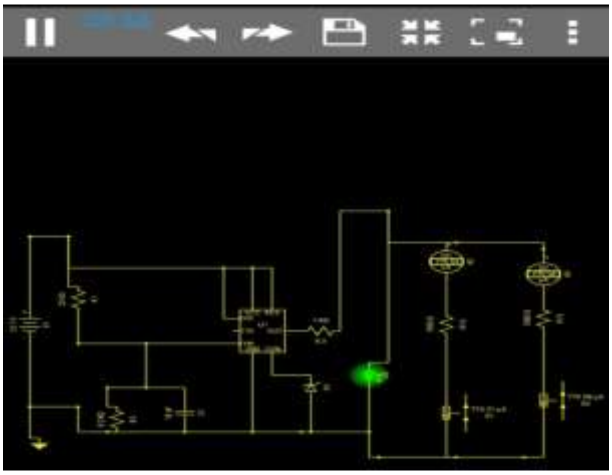
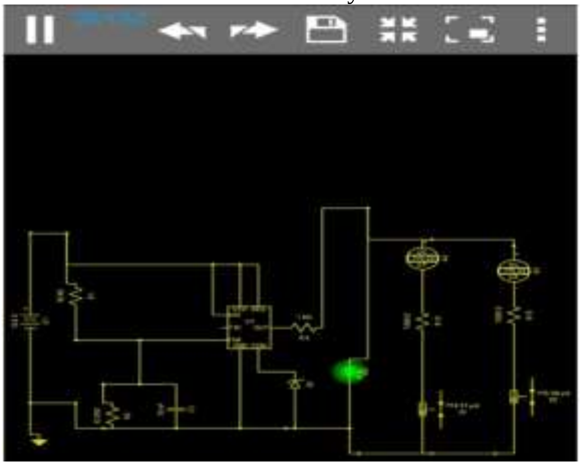


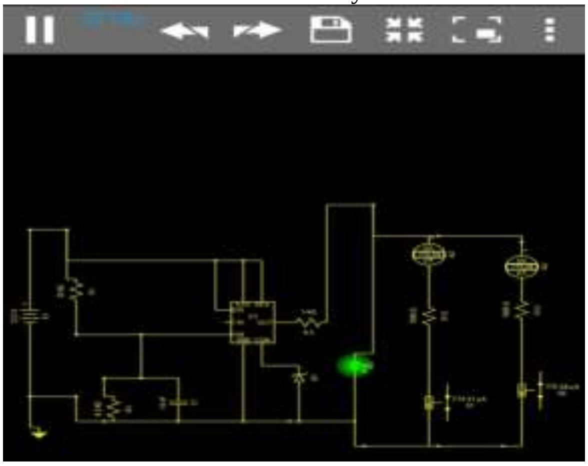
Screenshot 1: Battery at 12.8V



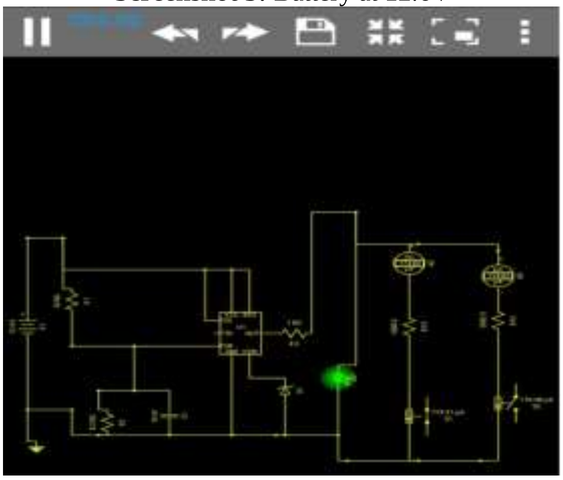
Screenshot 2: Battery at 12.7V



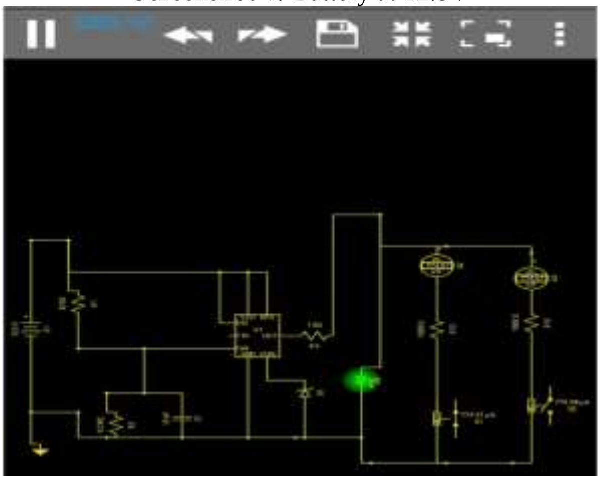
Screenshot 3: Battery at 12.6V



Screenshot 4: Battery at 12.5V



Screenshot 5: Battery at 12.4V



Screenshot 6: Battery at 12.3V

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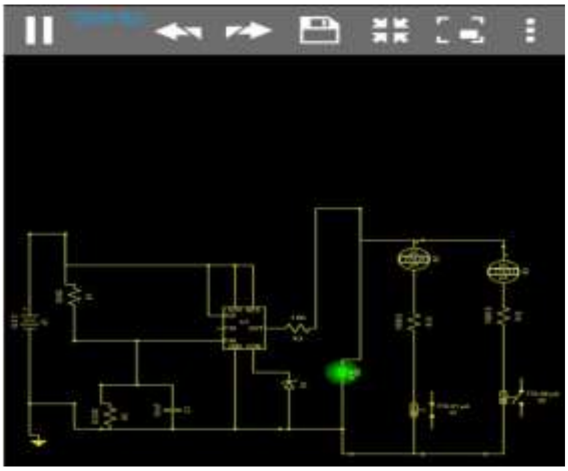
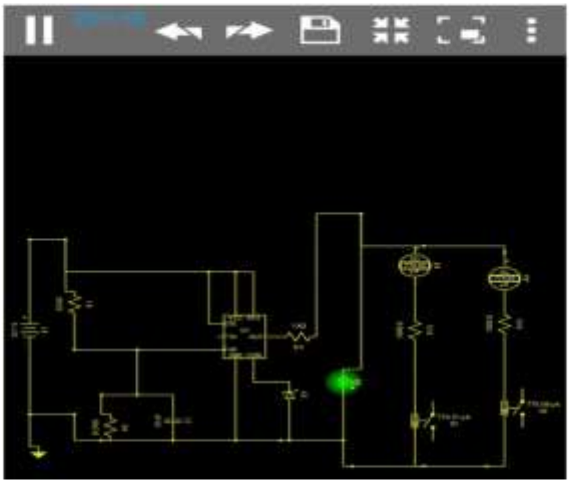
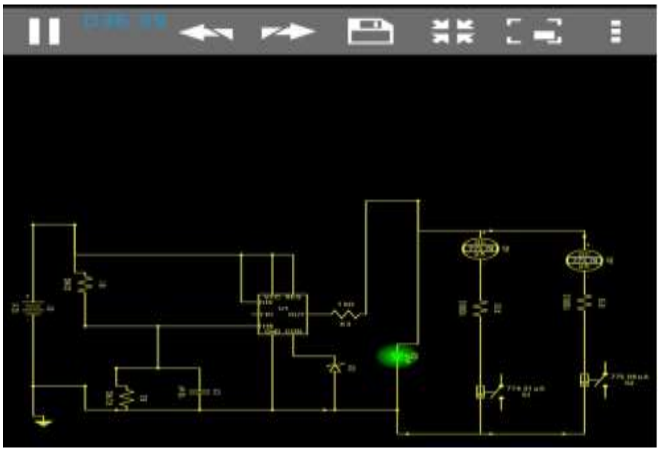


Screenshot 7: Batter at 12.2V



Screenshot 8: Battery at 12.1V



Screenshot 9: Battery at 12.0V

The design is sensitive to slight voltage changes when simulations of the circuit battery voltages are simulated at different levels.

CONCLUSION

The simulations using Droid Tesla proves the circuit to be functional. The components used are basic and easily available. The automatic battery cut-off circuit protects the battery from over discharge while also saving the battery for essential loads.

Recommendations

The integration of this circuit into inverters is highly recommended in order to improve the battery life. As it is a simple circuit that requires only a few components, the integration will bring value addition. The design may also be modified in accordance to the availability of materials and individual preferences for example the load shedding voltage values may be adjusted. This circuit design may be implemented as a separate component onto existing solar systems without much interference, we therefore recommend that this design be adopted, manufactured and sold as an additional product to solar users.

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