Photovoltaic Powered Uninterruptible Power Supply Using Smart Relay

I. Daut , M. Irwanto and Surya Hardi

***Abstract* – Uninterruptible power supply (UPS) sits between a power supply such as wall outlet and devices to prevent undesired feature that can occur within the power source such as outages, sags, surges and bad harmonics from the supply to avoid a negative impact on the devices. This paper presents a photovoltaic (PV) powered UPS using smart relay. It is a standby UPS whereas if the main power source fail to supply power to loads, a battery powered inverter turns on to continue supplying power. The battery is charged by the PV using solar charger and transfer switch controlled by smart relay. The UPS was tested to a load of 240 V, 20 W AC aquarium water pump. The test result shown that the UPS perform well, when the main power source fail, the battery could power inverter and the smart relay control the transfer switch, the load and battery current were 0.1 A and 1.56 A, respectively.**

***Index Terms*-- Photovoltaic, Uninterruptible power supply, Smart relay.**

I. Introduction

Uninterruptible power supplies are widely used as standby power for critical loads in case of utility power failure. It is usually derived directly from the power line, until power fails. After power failure, a battery powered inverter turns on to continue supplying power. Batteries are charged, as necessary, when line power is available. This type of supply is sometimes called "offline" UPS [1].

Nowadays, PV power generations are widely used for converting solar energy to direct current (DC) electrical energy, using inverter the DC can be converted to AC. A method of relay controller that efficiently utilizes PV array to UPSes is describe by [2]. The UPSes have three-relay controller using a low cost microprocessor. The relay controller, through its port, may indicate anomalies detected by examining open circuit and maximum voltage.

This paper presents a photovoltaic (PV) powered UPS using smart relay. It is a standby UPS whereas if the main power source fail to supply power to loads, a battery powered inverter turns on to continue supplying power. The battery is charged by the PV using solar charger and transfer switch controlled by smart relay.

II. Type And General Operation of UPS

There are four major type of UPSes that will discuss below [1], [3]:

A. Standby UPS

The standby UPS is the most common type of UPS system encountered on a day to day basis. It can be found with personal and office computer. The input line voltage is routed through a surge suppressor, filter and transfer switch before finally being routed to the output of the UPS device. In the event of a full power line failure the device will switch over to battery back up power within a few milliseconds.

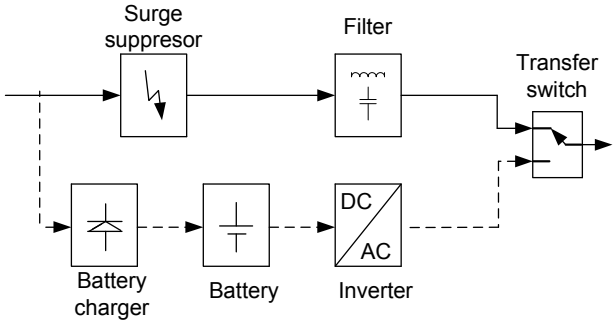

Fig. 1. Simplified block diagram of the standby UPS

A simplified block diagram of the standby UPS is shown in Fig.1. The surge suppressor is an important component in the UPS. When the output of the device is not completely isolated from the input line voltage there is a need to protect the out put equipment from current spikes that can occur on the input line. The line filter usually comes after the surge suppressor in the input line power circuit. This filter is designed to remove any noise that may be getting introduced from the input power supply line. The filter is designed with inductors, resistors and capacitors in a "turned" designed to allow only the 50 Hz voltage to pass through removing any unwanted higher or lower harmonic frequencies.

B. Ferroresonant or Hybrid UPS

The ferroresonant or hybrid UPS is an improvement on the design of the standby UPS. As with a standby UPS, the primary power source is line power from the utility and the secondary power source is the battery. The battery and inverter are still waiting "on standby" until needed. The big difference is that the standby UPS's transfer switch that selects between power sources has been replaced by a ferroresonant transformer as shown in Fig. 2.

The transformer has a core of metal with two coils of wire wrapped around. When the current is applied to one coil, the other coil will magnetically couple to the first coil and will induce the current. The transformer will smooth out power problems from the input, without passing the problems to the output. The transformer is transformer is therefore very well suited as a line filtering component in a UPS.

The transformer has three winding in a ferroresonant UPS. Two are input and one is an output. This allows the transformer to act as a switch. Even better, however, is that since the core of the ferroresonant transformer stores energy in its magnetic field, this acts a buffer in the event that the primary power cuts off and the switch must be made to the secondary power source.

The authors are members of Power Electronic and Machine Design, School of Electrical System Engineering, Universiti Malaysia Perlis (UniMAP), Perlis Malaysia, (e-mail: irwanto@unimap.edu.my).

The benefits of the ferroresonant UPS is usually available in a size range of up to about 15,000 VA, making then suitable for even the largest servers.

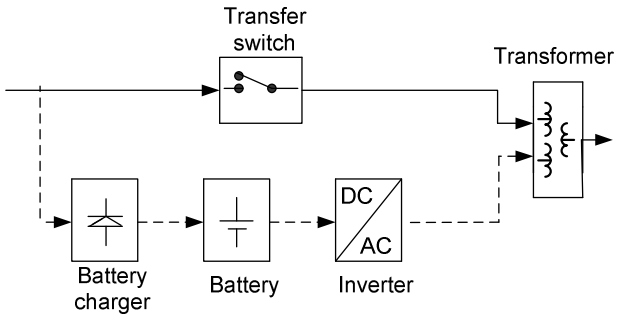

Fig. 2. Simplified block diagram of Ferroresonant UPS

C. Line interactive UPS

The line interactive UPS a third type of uninterruptible power supply. It uses a totally difference design than any type of standby UPS. In this UPS, the internal components are replaced by an inverter/converter assembly as shown in Fig. 3.

The inverter/converter receives the line voltage and then conditions it for output. The device also delivers a DC charging voltage to the battery of the UPS. In the event of a power failure the battery will then begin to discharge through the inverter/converter where the DC voltage will be inverted to an AC signal for output to the connected device.

The main benefit of this type of unit is that the inverter/converter is continuously tied to the output. This will decrease the amount of time it takes to switch in the event of a power failure. The time that it does take for the switching is significantly less than the back-up style UPS units.

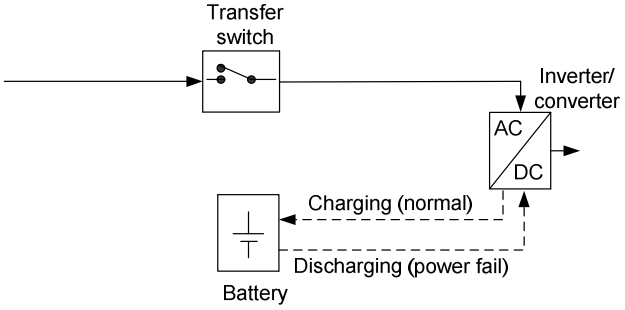

Fig. 3. Simplified block diagram of line interactive UPS

D. Online UPS

The type of uninterruptible power supply in also sometimes referred to as a "true" UPS and is the most costly of UPS type. Its internal components are similar to the standby UPS, but the way in which they are used is much different.

The online power supply gets its name from the fact that the input line power is not connected to the output during normal operation. Instead, the input power first goes through an AC to DC converter where the DC voltage is used to charge the UPS main battery. The battery then, in turn, is discharging through a DC to AC inverter and routed through a transfer switch for the output voltage. This process can be referred to as a double conversion of the input power. Fig. 4 is a simplified block diagram of the online UPS.

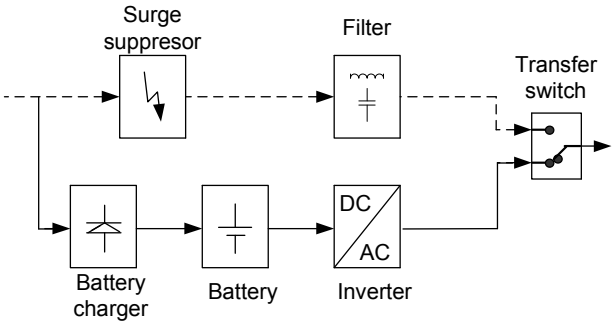

Fig. 4. Simplified block diagram of the online UPS

The online "true" UPS will only use the line input as output when the battery charger, battery, or inverter fail. In this case the line voltage will go through a surge suppressor and filter before reaching the output of the device.

The major advantage of this type of UPS is the total isolation between the input line voltage and the output voltage.

III. Components of Proposed UPS

The proposed UPS in this paper is a photovoltaic powered uninterruptible power supply using smart relay. Based on types of UPS that are discussed above, it is a standby UPS whereas if the main power source fail to supply power to loads, a battery powered inverter turns on to continue supplying power. The battery is charged by the PV using solar charger and transfer switch controlled by smart relay.

A proposed circuit of photovoltaic powered uninterruptible power supply using smart relay is shown in Fig. 5. Based on the circuit, its components will be discussed as this below.

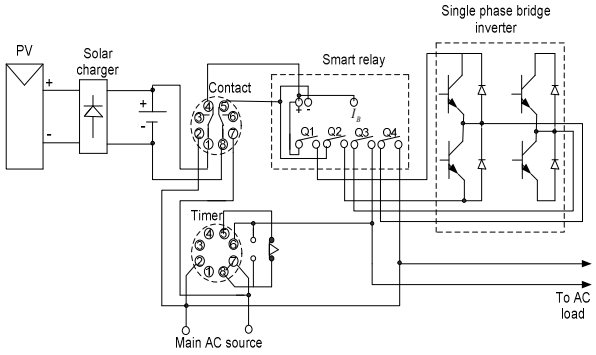

Fig. 5. A proposed circuit of photovoltaic powered uninterruptible power supply using smart relay

A. Photovoltaic

22 V, 10 W, 0.45 A photovoltaic is used in this UPS. The PV can convert solar energy become DC electrical energy. The PV is as main DC source, it used to charge battery using solar charger. Output voltage and current of the PV depends on sun intensity and temperature, the needed output voltage to charge battery is usually above 12 V and the flowing current through the solar charger follows the voltage change.

B. Solar charger

Function of the solar charger is to charge the battery. The used solar charger in this UPS is shown in Fig. 6 [4].

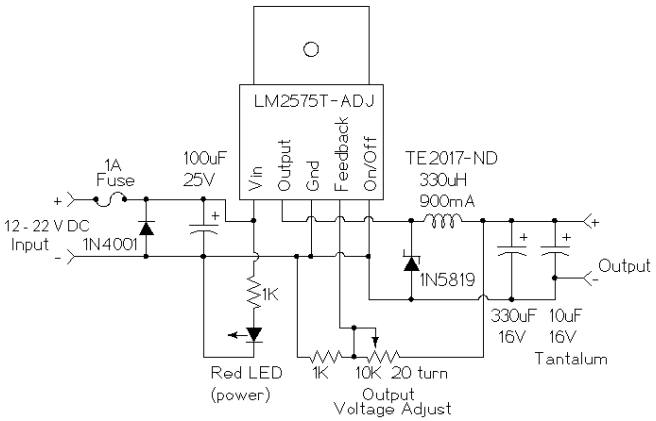

Fig. 6. Circuit of solar charger

The 12 – 22 V DC power is sent to the input of the circuit. The 1N4001 diode is used as a crowbar device, if reverse power is applied to the circuit, the diode causes a short circuit and the 1 amp fuse blows. The input voltage is stabilized with the 100 uF capacitor, this is also used as a local power reservoir for the switching regulator. The 27 V transzorb device prevents high voltage transient voltages on the input circuit from damaging the LM2575T-ADJ voltage regulator. The optional 1K red LED in series with the 1K resistor provide an indication that the circuit is powered.

The LM2575T-ADJ voltage regulator provides variable width DC pulses to the 330 uH toroidal inductor. When the output pulse is on, the inductor stores energy, when the pulse turns off, the inductor discharges energy into the 330 uF capacitor through the current loop with the 1N5819 schottky diode. The 1K resister and 10K trimmer potentiometer form a voltage divider circuit, this is used as feedback by the LM2575T-ADJ IC for setting the output voltage. The 10 uF tantalum capacitor is used to reduce the DC switching noise from the output circuit.

C. Transfer switch

Transfer switches of the UPS consist of timer, relay and smart relay. Functions of the transfer switches are to change connection between main source power and UPS inverter.

Type of timer is AH3-1, 250 V AC, 5 A, its time can be set from 0 second to 10 second and its function to set time of main source power input to AC load.

Type of relay is OMRON MK3P-I, 250 V AC, 5 A. It has 8 pins, pin 2 and 7 are connected to main source power, pin 1 and 8 connected to battery. Its function is for connecting battery to smart relay, if the main source power fails.

Type of smart relay is SR2B121JD, 12 V DC, 8 A. It has 8 inputs $(I_1, I_2, I_3, I_4, I_A, I_B, I_C, I_D)$ and 4 outputs (Q_1, Q_2, Q_3, Q_4). Input of I_B is used as voltage comparator that will detect the battery voltage. In ladder diagram voltage comparator is given symbol A1 as in Fig. 7. The ladder diagram is created using zeliosoft2.

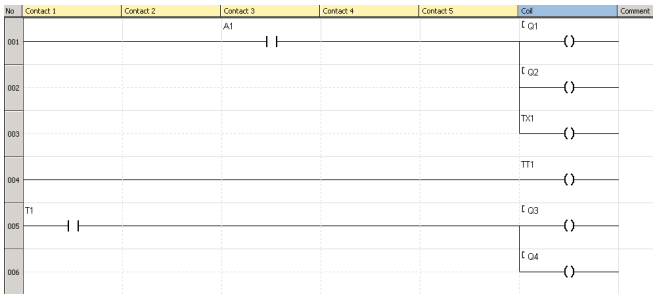

Fig. 7. Ladder diagram of smart relay

When the smart relay is supplied by voltage of 12 V DC, A1 will detect the battery voltage. If the battery voltage is higher than 11 V so output of smart relay Q_1 and Q_2 will be shorted, respectively for supplying 12 V DC to inverter and the display of smart relay will appear text " AC SOURCE FROM UPS INVERTER". In the ladder diagram the text is shown by TX1. TT1 is timer that set 2 ms for shorting output Q_3 and Q_4 that will connect the output of inverter to AC loads.

C. Inverter

The inverter is a single phase bridge inverter, its output wave form is quasi square wave. This inverter is a modified square wave inverter where low orders of harmonics content are reduced.

IV. SULT AND DISCUSSION

A. Water Pump Load

The AC load of UPS is 240 V, 20 W AC water pump. The water pump is used to give water circulation of aquarium and have to run continuity. If the AC main source (TNB) fail, the water pump can be run by UPS inverter. Fig.8. shown experiment set up for the water pump was supplied by UPS.

Fig. 8. Experiment set up

B. Steady State Voltage of Main Source and Proposed UPS Inverter

Fig.9. shows steady state wave form of main voltage with water pump load condition. when run the water pump.

Fig.10. shows the experimental wave form of the voltage of the proposed UPS inverter with the same water pump load condition.

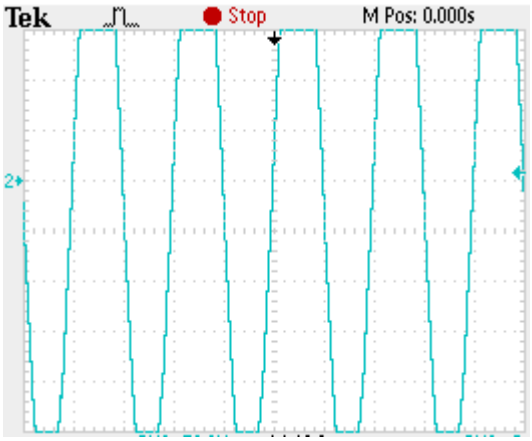

Fig. 9. Steady state wave form of main voltage

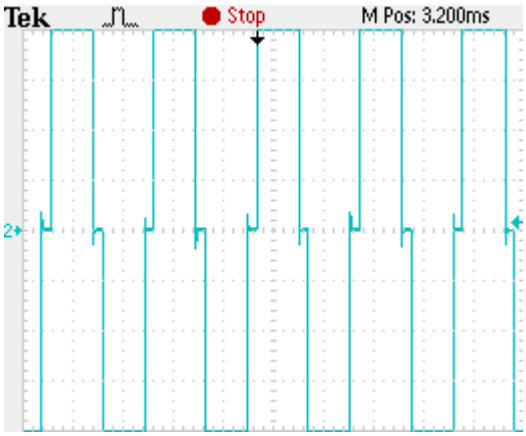

Fig.10. Experimental wave form of the voltage of the proposed UPS inverter

C. Failure Voltage of Main Source and Proposed UPS Inverter

ON and OFF condition of power supply were done to get voltage wave form of main source and proposed UPS inverter. Fig.11. shows voltage wave form of main source failure. When the main source fail, the water pump have to run continuity, therefore the UPS inverter have to operate. For 0.5 second relay OMRON MK3P-I have to over change to battery connection for supplying inverter and operate smart relay, therefore the water pump still run. Voltage wave form of proposed UPS inverter when over change form main source to UPS inverter is shown in Fig.12.

Fig. 11. Voltage wave form of main source failure

Fig. 12. Voltage wave form of proposed UPS inverter after the main source failure

D. Current Measurement

After finish up the project, the current had measured using multimeter. The reading of AC Current (from power supply/ load) is 0.1 A and recorded, while the reading of battery current is 1.56 A and recorded.

V. CONCLUSION

This paper presents a photovoltaic (PV) powered UPS using smart relay. It is a standby UPS whereas if the main power source fail to supply power to loads, a battery powered inverter turns on to continue supplying power. The battery is charged by the PV using solar charger and transfer switch controlled by smart relay. The UPS was tested to a load of 240 V, 20 W AC aquarium water pump. The test result shown that the UPS perform well, when the main power source fail, the battery could power inverter and the smart relay control the transfer switch, the load and battery current were 0.1 A and 1.56 A, respectively.

VI. REFERENCES

[1] M. S. Racine, J. D. Parham and M.H. Rashid, "An overview of uninterruptible power supplies", IEEE Explorer, 2005.

[2] S. Jayasimha and T. P. Kumar, " Photovoltaic UPS ", TENCON 2003.

[3] W. bower, " Bimode uninterruptible power supply compatibility in renewable hybrid energy system ", IEEE AES magazine, August 1990.

[4] G. F. Cook, "Buck Mode Switching Regulator for Solar Applications", http:// www.solorb.com/elect/solarcirc/buckreg1/ index.html, June 23, 2006.

VII. BIOGRAPHIES

Ismail Daut received his B. Elect.Eng. (Hons) from University of Science Malaysia in 1980 and MSc in Electrical and Electromagnetic Engineering from University of Wales, College of Cardiff, United Kingdom in 1991 and PhD in Energy Conservation and Power Engineering from University of Wales, College of Cardiff, United Kingdom in 1994. His research interest includes energy conversion, electrical machine design and high voltage. He has authored and co-authored more than 150 technical papers in the national, international journal and conferences.

Muhammad Irwanto received his BEng from Medan Institute of Technology in 1998 and Master Degree in Electrical Power System from University of Gadjahmada, Jogjakarta, Indonesia in 2002.He is currently a lecturer in the School of Electrical System Engineering at University Malaysia Perlis (UniMAP). He is member of Cluster Power Electronic and Machine Design School of Electrical System Engineering University Malaysia Perlis (UniMAP) Perlis, Malaysia. His research interest includes electrical power system stability and solar power.

.

Surya Hardi received the Bachelor and degree M.Sc degree in electrical engineering from university of North Sumatra (USU), Indonesia and from Institute of Bandung Technology (ITB), Indonesia in 1985 and 1992, respectively. He is currently a lecturer in electrical engineering USU and the University Malaysia Perlis (UniMAP), where he is also Ph.D student. His research interest includes electrical energy economic, power system grounding and power quality.