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RESEARCH ARTICLE

# DESIGN AND TESTING OF A SOLAR-OPERATED CLOCK FOR CAMPUS USE

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## ARTICLE INFO

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## ABSTRACT

In this work the design and testing of a solar-operated clock system for campus use has been implemented. The design uses three solar panels each of 130W capacity and two solar batteries each of 200AH/12V capacity to power four identical giant quartz clocks synchronized to keep uniform time collectively. A pulsed automatic alarm system that provides time alert at hourly intervals was also incorporated. On testing the system was found to keep accurate time showing that design was successful.



## INTRODUCTION

The campus community is one place where time management and keeping of appointments are very important. Students and staff are faced with beehives of activities on daily basis which compete for their lean time resource. For today's time keeping "clocks" are the instruments used to measure and display time. The word "clock" comes from the French word "cloche" meaning "bell", (Bellis, 2012). The world has experienced different types of clocks over the ages. These include sun and water clock, sand or hour glass, and so many others before the evention of mechanical and quartz clocks. The recording of time was referenced on planetary motions until 1927, when Warren Marrison developed the first quartz clock based on the regular vibrations of a quartz crystal in an electric circuit. This clock was large in size and found to be very accurate, (Bellis, 2012). In 1967, the cesium atom's natural frequency was formerly adopted as the new international unit of time. The second was then defined as exactly 9,192,631,770 oscillations or cycles of the cesium atom's resonant frequency, replacing the old second that was defined in terms of the earth's motions, (Bellis, 2012). The second became the physical quantity most accurately measured by scientists. The best primary cesium standards now keep time to about one-millionth of a second per year. Prior to the battery operated clock system, the energy of the clock was either supplied by a wound coil of spring or by hanging weights. This work is aimed at designing and testing a solar-operated clock for campus use. Solar electricity is now becoming a potential competetor to fossil fuels and is widely used to power traffic signs and consumer electronics, (Flavin and Dunn, 1998). Solar cells with conversion efficiencies greater than 30% are now available, (Holladay, 2008). This work encourages the use of solar energy for part of our electricity generation. Most communities within south east Nigeria have high insolation values. Umudike for instance has an average insolation value of about $7KWhm^{-2}$ (Asiegbu and Nduka, 2006), which is quite similar to that of Algeria, (Benatiallah, *et al*, 2009). Insolation value of Owerri as a Nigerian town is estimated to be $4.7kWhm^{-2}$ (Dike *et al*, 2011)

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**Theory of Design**

The pV-array required to power any given system according to Shimin (2008) should have an output capacity given by the expression;

$$Q_p = E/(HN_bN_cN_i) \quad \dots (1)$$

Where

E = Energy requirement of the system
H = Peak sun hour or insolation
$N_b$ = Charge effiency of battery
$N_c$ = Efficiency of system controller
$N_i$ = Efficiency of the inverter

Similarly, the battery group required to sustain such a system according to Shimin (2008), should have an output capacity $Q_b$, given by;

$$Q_b = ED/(N_bN_cN_iV_bA) \quad \dots (2)$$

Where

E = Energy requirement of the system

D = Number of days of storage
A = Battery discharge depth
$V_b$ = Voltage of battery group
$N_b$, $N_c$ and $N_i$ are explained in equation (1)

Solar cells with conversion efficiencies greater than 30% are now available, (Holladay, 2008). This work encourages the use of solar energy for part of our electricity generation.

## MATERIALS AND METHODS

Materials used in this design include:

2 Pieces of solar panel (150W)
2 Pieces of battery (200AH/12V)
1 Piece of automatic charge/discharge controller
4 Giant quartz wall clocks
1 Piece of pulsed automatic alarm system
Rigid supports/frames
Switches, fuses, wires and connectors
Measuring instruments, etc.

The power budget for the solar-operated clock system was done as an initial step. Other aspects of the design followed.

### Design of The System

This design considered four major components namely, insolation at the site, panel size, battery size and power requirement of the clock system which serves as the load. Since the clock is dc-operated an inverter was not required. This also minimized cost. The block diagram for the system is shown in Fig 1. In Fig 1, the panel is connected to the battery via a charge controller while the battery is connected to the load via a discharge controller. This should regulate the charging and discharging of the battery from getting over a certain set value. If a discharge depth of 60% is selected then the controller ensures that battery does not discharge more than 60% of its energy value (Asiegbu, 2010). The power budget for the design is shown in Table 1.

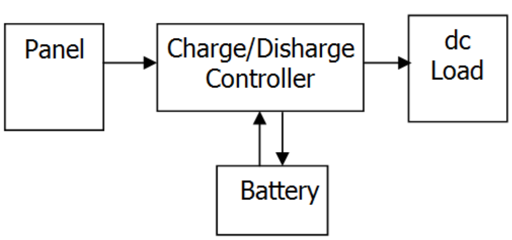


**Fig. 1: Block diagram of the solar operated clock**

**Table 1: Power Budget for the system**

| Equipment | Load (W) | Quantity | Daily Work Hours | Energy Consumed (Wh) |
|---|---|---|---|---|
| 12W Quartz Clock | 48 | 4 | 24 | 1152 |
| 12W Pulsed Alarm System | 12 | 1 | 0.4 | 4.8 |
| TOTAL | 60W | | 24.4Hrs | 1156.8Wh |

### Panel Capacity

Capacity of the panel group required to power the system should be able to generate enough power from available radiaiton to charge the battery to full capacity and provide enough energy to drive the daily load of about 1157Wh. Considering the worst insolation case of about 4.0kWm$^{-2}$ for the campus, Federal University of Technology Owerri (FUTO) and substituting in equation(1) we obtain:

$Q_p$ = 1156.8 /( 4.0x0.8x0.98)
= 1156.8 / 3.136
~ 370W

Where the values of $N_b$ and $N_c$ are given as specified. This implies that 3 panels each of 130W capacity will be enough to power the system

### Battery Capacity

The battery capacity obtainable from equation (2) should be strong enough to power the loads (clock and alarm system) all through the night when there is no sunlight. It should also be able to retain enough power to sustain the system on days when there is poor or no radiation due to cloud cover. This is specified as storage days in the design equation. Substituting values in equation (2) and considering storage days of 2 as well as a discharge depth of 60% for a battery group of 12V, we have:

$Q_b$ = (1156.8x2)/(0.8x0.98x12x0.6)
= (2313.6)/(5.6448)
~ 410

Where the values of $N_b$ and $N_c$ are given as specified. This value of $Q_p$ shows that 2 batteries each of 200AH/12V will do.

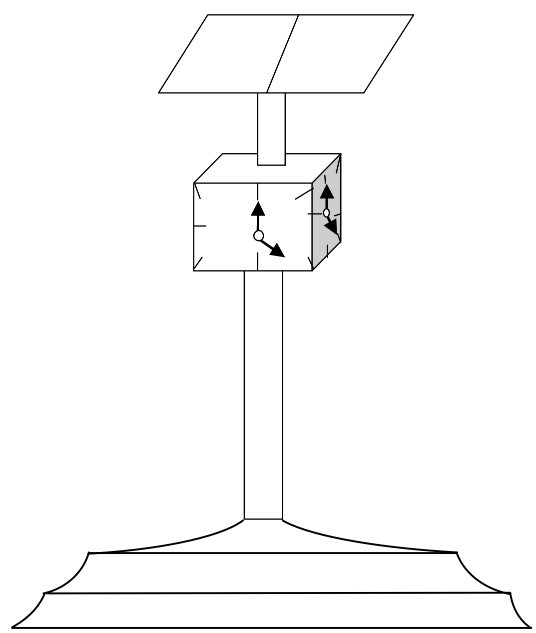

**Fig. 2: The mounted solar operated clock system**

### The Load

The load consists of four giant 12W Quartz clocks expected to operate 24hours of the day and a 12W pulsed automatic alarm system that gives time alert at hourly intervals. Together, they consume energy of about 1157Wh daily.

### Testing

The components were assembled for preliminary observation. On testing the pulsed alarm sounded announcing each hour of time. The system was found to work normally and kept accurate time.

## DISCUSSION

All the four clocks selected were of the same model and size for uniformity. They were synchronized for uniformity of time keeping with each face of clock on a rigid base. By this arrangement the system was ready for mounting. Fig. 2 shows the designed solar-operated clock when mounted. Mounting could be done on a frame or pillars. It could also be done on a tower to serve as a “clock tower” (Hornby, 2001). The mounting arrangement ensures that the battery box is encapsulated by the rigid base supporting the clocks. If mounting is strategically done on a specially designed framework, in addition to time keeping, this could create an aesthetic scenerio which will further add to the beauty of the campus environment. Apart from the initial cost of installation, the running cost of the clock system is free, thus helping to decongest the already congested demand of power from our national grid. This is another aspect of integration and use of solar energy as a renewable resource in our daily electricity consumption as advocated by Stadler, *et al.* (2003).

### Conclusion

The design and testing of a solar-operated clock system has been implemented using three, 130W solar panels and two, 200AH/12V batteries. The system operates 24hours of the day drawing energy from solar radiation in the day and using energy stored in the battery at night. No further running cost is incured after installation. The design was successful and should be encouraged.

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