A Wearable Solar Power Vest for Small Electronic Devices

携帯電子機器のためのウェアラブルな太陽パワーベスト

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Abstract

With the increase of the number of portable electronic devices presently available in the market, the issue of low power consumption and longer battery life must be taken into consideration. This study investigates the feasibility of a solar power vest that could be utilized to generate power for these devices.

Keywords: Amorphous solar cell, Illuminance, Solar angle, Solar elevation angle, Orientation

Introduction

Since the introduction of the Sony Walkman in 1979, our society has seen the influx of portable electronic devices such as cell phones, music or mp3 players, PDA's, portable electronic dictionaries, and portable game players. Manufacturers are constantly coming up with lighter, faster, and smaller electronic devices for entertainment, or for practical purposes. Various wearable electronic devices from wearable computers[1)] to wearable health sensors[2)], have been proposed and studied by researchers over the years. One important design issue is the power source. A low energy consumption coupled with a longer battery life is a necessary element in the development of wearable electronic devices.

The purpose of this study is to investigate the feasibility of a solar power vest that can be used to directly power such electronic devices utilizing the clean energy provided by the sun.

Experimental Setup

A solar cell that provides power to small portable electronic devices should be light enough to justify its use. For this purpose, an amorphous silicon solar cell was utilized for its flexibility, and its resistance to crack. It has a 3.0V, 343.0mA range at 100mW/cm^2, a 3.0V, 154mA range at 50,000 Lux（cloudy-fine weather）, a thickness of 0.4 mm, and a weight of only 13mg. Two amorphous silicon solar cells were parallel connected to increase the current rating.

Lux readings were obtained using an illuminance meter with a range of 0 to 999,000lux. Current and voltage were measured with a digital multi-tester. The solar angle was obtained with an apparatus that measures the position of the sun.

Two commercially available vests were prepared. One vest was fitted with Velcro tapes at the front and back, and at both shoulders in which the illuminance meter could be directly attached. See Figure 1. The other was fitted with transparent pockets specifically dimensioned to fit two solar cells, one at the front and the other at the back of the vest. This is shown in Figure 2.

Discussion

I. Determination of the optimum solar cell location on the solar power vest.

To determine the optimum solar cell location on the solar power vest, six locations on the vest were decided. Two are located in front（LF=left front, RF=right front）, two at the back（LB=left back, RB=right back）, and two on the shoulders（LS=left shoulder, RS=right shoulder）. Measurements were made on a clear sunny day at 10:00AM, 12:00noon, 2:00PM（14:00）, and 4:00PM（16:00）. The vest's orientation was moved from North, East, South, and West. North means that the front of the vest

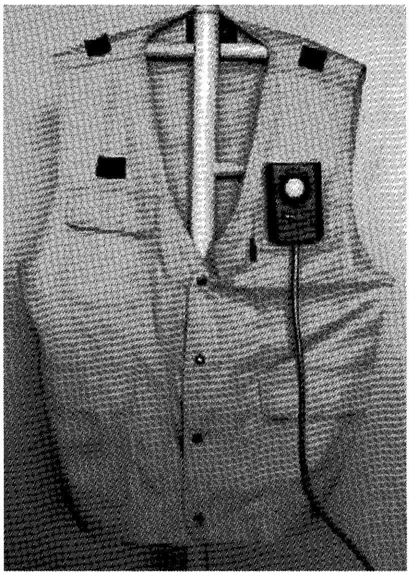

Fig.1. Vest fitted with Velcro tapes with the silicon photo diode sensor of the illuminance meter.

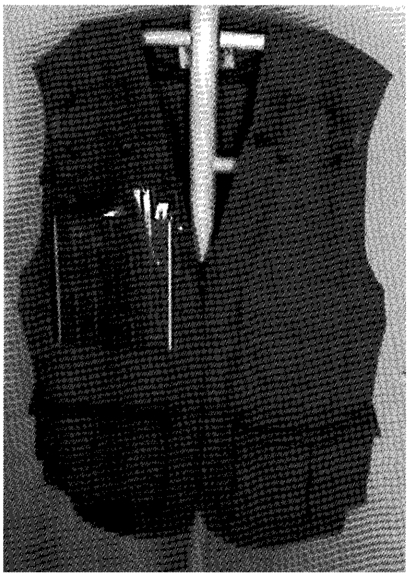

Fig.2. The solar power vest.

was oriented facing North. The lux readings in relation to the vest's orientation are shown in Figures3-6.

At 10:00, the maximum total illuminance (387,975lux) for all the locations on the vest was at south orientation. At 12:00, the maximum total illuminance (317,725lux) was also at south orientation. However, the difference between the readings at south and west orientations was only 18,100lux. At 14:00, a maximum total illuminance of 373,875lux was measured. On the other hand, at 16:00, there was no significant difference in the total illuminance for all locations on the vest. This is due to the weaker solar intensity at this time. If the scale of the lux readings were minimized, the west orientation can be shown to give the maximum total illuminance.

These findings indicate that the position of the sun in relation to the orientation of the vest is one of the predominant factors in determining the optimum location of the solar cell in the solar power vest.

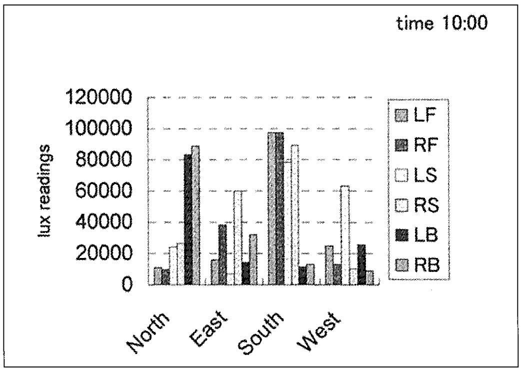

Fig.3. Lux readings at 10:00AM.

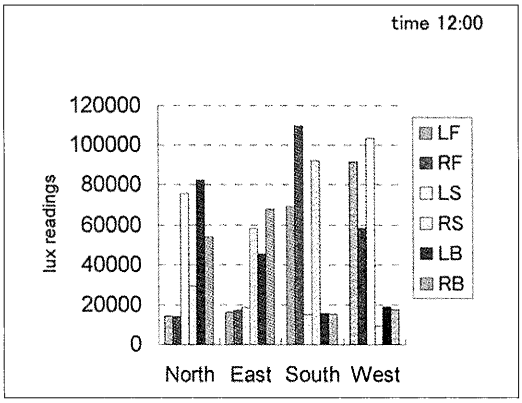

Fig.4. Lux readings at 12:00 noon.

Unlike a fixed solar power generating system which can be permanently set at the optimum orientation, a solar power vest's orientation is rather random. It's orientation depends on which direction the wearer of the vest takes. Thus, the average illuminance or lux readings for all the six locations on the vest, at different orientations, and at different times of the day need to be considered.

The plot of the lux readings for the different conditions is shown in Fig.7. Highest values of the average readings were determined at the left and right shoulder locations (RS and LS), and at the front locations of the vest (LF and RF). However, it should be worth noting that the difference in the maximum and minimum average lux readings is only approximately 8,000lux. Since the amorphous solar cell used in this study measures 146mm by 167.6mm, they cannot be attached at the shoulder locations of the vest. The authors decided to affix the solar cells at the right front location, and at the back (center) of the vest. See Figure2.

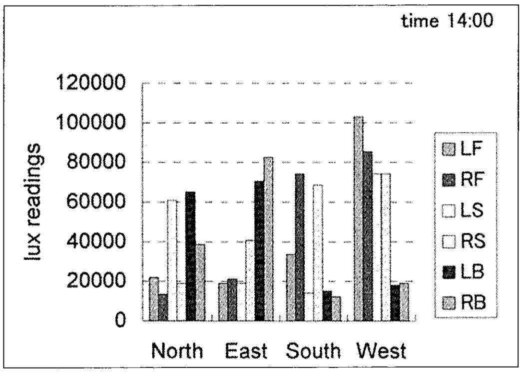

Fig.5. Lux readings at 2:00PM (14:00).

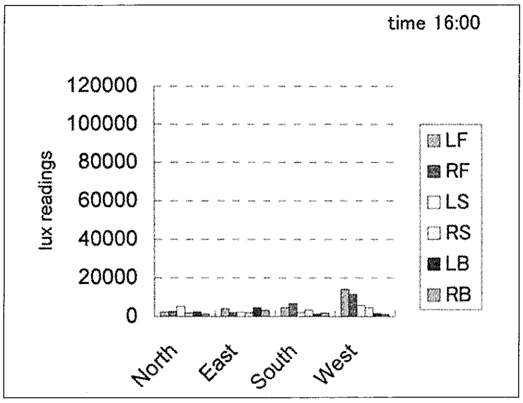

Fig.6. Lux readings at 4:00PM (16:00).

II. Lux and Solar Vest current measurements.

a) At different locations within the campus

Since the major function of the solar power vest is to provide power for small electronic devices, it is imperative to investigate how the solar vest performs in different locations in the campus. Five locations with different solar intensity or lighting conditions were chosen. These are the following: lobby (clear roof), computer room with lights on and off, classroom with lights on and off, library with lights on, school grounds (with shade), and school grounds (open space).

The illuminance (lux) and the generated current (mA) for these locations and conditions are shown in Fig.8. Here, the direct relationship between the amount of light received per unit surface which is represented by the lux readings, and the amount of current generated by the vest is shown. At open space conditions, a maximum of 86,500lux, and 163.56mA were measured. The solar vest calculated power in watts for these conditions are shown in Fig.9. The maximum power generated was at 0.741w at open space (sunny conditions). This is more than enough to power directly a small electronic device such as Nintendo's Game Boy Color (0.6w). It is clear that at the other locations and conditions, the generated power is insufficient.

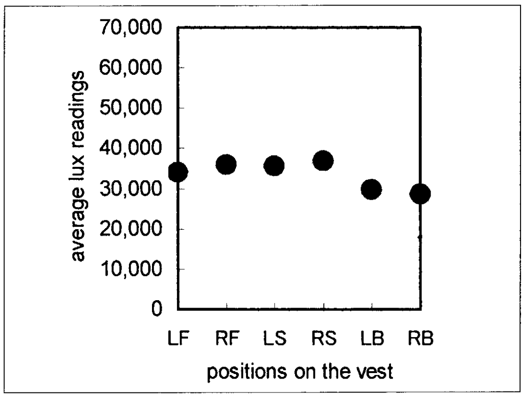

Fig.7. Average lux readings for various locations on the vest

b) Open space conditions with different orientations

Here, the solar power vest was placed in open space at sunny conditions, from 10:00AM to 4:00PM (16:00). The orientation of the vest was at North, East, South, and West. The maximum lux reading was at 12:00noon, while the maximum current was at 14:00.

Since, the solar power density is a function of the angle the sun makes with the normal of a solar cell lying flat on the ground[3], the solar angle was determined from the measured solar elevation angle. The solar elevation angle or altitude angle is measured between an imaginary line between the observer and the sun and the horizontal plane. If the solar cell were to be placed flat on the ground, the solar angle could be determined by subtracting the measured solar elevation angle from 90 degrees. If this was the case, the maximum solar power density is at 0 degrees solar angle or when the sun is directly above the solar cell.

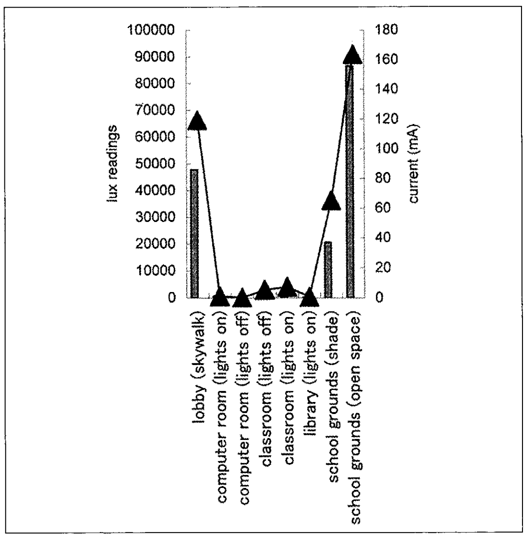

Fig.8. Lux and solar vest current measurements at different locations and conditions.

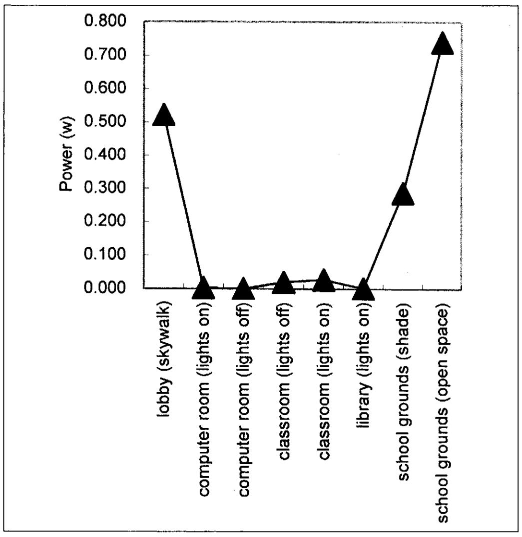

Fig.9. Solar vest calculated power.

However, since the the solar cell is normal to the ground (the solar cell being attached to the power vest), the solar angle is simply equal to the measured solar elevation angle.

Figure 10 shows the current (mA), the lux readings, and the solar angle. Both the maximum current (205.15mA) and maximum power (0.951w) was determined at 14:00 when the solar angle was at 56 degrees. If the solar intensity or the illuminance in lux was constant, we would have expected the maximum current and power to occur at 16:00 when the angle between the sun and the solar cell was at its lowest value. However, as shown Fig.10, a significant decrease in the lux values can be clearly recognized. This explains why the values of current (196mA) and power (0.898w) at this time were lower than that at 14:00 even though its solar angle was not at the lowest value.

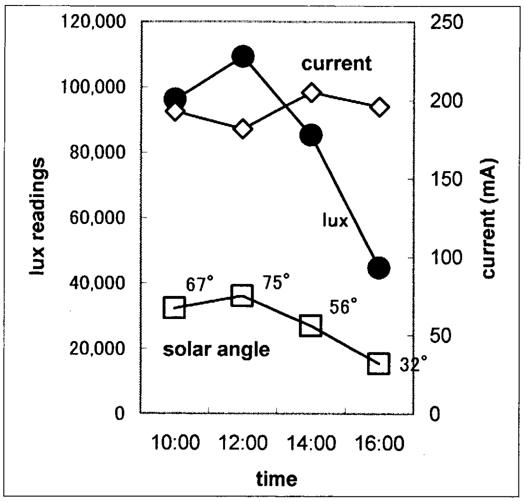

Fig.10. Current, lux readings, and solar angle.

Conclusion

Like permanently installed solar power generating systems, the solar power vest's performance depends on the solar angle, its orientation in relation to the sun, and the light intensity. However, the challenge to maximize the power output of the solar power vest is daunting since the wearer of the power vest is obviously mobile, i.e., its orientation relative to the sun changes randomly. The solar cells attached to the vest are also subjected to random and constantly varying conditions of light intensity or illumination. In this present study, the solar power vest with only two amorphous silicon solar cells fails to provide enough energy to directly power a small electronic device in most locations tested. The solution lies in attaching more solar cells to the power vest, and providing an electronic circuit that feeds the solar energy produced during favorable conditions into a rechargeable battery, from which an electronic device can draw power.

References

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携帯電子機器のためのウェアラブルな太陽パワーベスト

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要　約

最近，携帯電子機器の利用者が益々増えている．現在，ウェアラブルコンピュータが話題になってきた．しかし，低消費電力化とバッテリライフの向上が必要と考えられる．そのために太陽エネルギーを利用して，電力消費の低下することが可能になる．本研究の目的は携帯電子機器のためのウェアラブルな太陽パワーベストの可能性を調べることである．

キーワード：アモルファス太陽電池，照度，太陽角，太陽仰角，方向