DEVELOPMENT OF AN AUTOMATIC OUTDOOR LIGHTING SWITCH.

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ABSTRACT

The development of an automatic light switch for the purpose of electrical energy conservation is presented in this paper. Out door lighting in offices, schools and residential buildings etc, contribute significantly to the waste of electrical energy in developing countries of the world particularly during the daylight hours when their services are not essential or needed, if not switched off during this period. This device automatically switches ON external lighting installation during the dark periods and automatically switches them OFF during the day-light hours. The automatic switching would enhance conservation of electrical energy as most out door lightings are usually forgotten to be turned OFF during the day. Energy consumed is measured by the product of power supplied (kilowatts) and the period of usage (hours). Therefore, power should be utilized only when needed to conserve energy and minimize cost.

Keywords: Conservation of Energy, Automatic Control, Out Door Lighting, Photo Conductive Cell.

1.0 INTRODUCTION.

Many lighting control systems have been developed for the control of lighting installation convenience. Such lighting control systems vary in their sophistication ranging from the common wall – mounted switch, dimmer switch to the remote controlled and micro-Processor controlled unit [1]. These may be used to achieve various objectives, one of which is to conserve electrical energy depending on the manner of control. This work is aimed at minimizing the energy losses that are associated with the manner of controls of out door installations in domestic, commercial and industrial places such as security lighting and street lighting. It is a common and obvious act in the third world nations that people ignorantly leave external lightings on during the day light when the lighting is actually serving no purpose. Ideally out door lightings are only supposed to be switched on during the night (dark hours) and switched off during the day (day light hours). This would enhance to a very large extent the level of conservation of energy. The development of light dependent resistor switch in this work provides an automatic switching of outdoor lighting installations with very high level switching sensitivity. The use of discrete components, the switching precision and sensitivity of this device make it more adaptable for domestic use. This practice will also provide convenience for travelers who will not bother about switching of their outdoor (security lights) when they are away from home.

2.0 DESIGN CONSIDERATION

Automatic switching of outdoor installation was considered most economical since lighting is switched on only when required and off when not, thereby providing significant savings. The optimal result of such switching can minimize hours of usage taking advantage of daylight [2]. Thus providing both control for consumption and conservation of electrical energy. Cheaply and readily available discrete components such as photo cell, transistors, resistors and relays were used to achieve the design. The current consumption of the light to be controlled is equally considered which will aid in determining the rating of relay or contactor to be used. The very common lamps considered here, which are generally used for external lighting include.

1. Tungsten filaments lamps with efficiency of about 8 Lumens per watts.
2. Fluorescent Lamps of about 1.5 meters with efficiency of 48lumen per watt.
3. Tungsten iodine lamps (flood lighting) of about 30 lumens per watt.

3.0 DESIGN PROCEDURE.

The automated model for the out door lighting control for the conservation of electrical energy consist of four stages. First is the power supply section, the photo-cell (sensor) section, the control section and the switching section. The power source require the transformation of 220-240V, 50HZ ac supply to 24volts, rectified, filtered and regulated dc, before supplying the circuit.

4.0 PHOTO-CELL IN THE CIRCUIT.

A photo conductive cell is a semi- conductor device whose resistance varies inversely with the intensity of light that falls upon its photosensitive material [2,3]. They are known as photo-resistors or photo resistive cells. In this work, the photo resistor is a light dependent resistor (LDR), made of cadmium sulfide which is very responsive to light time constant of 100ms and spectral band of 0.47 to 0.71µm.

The resistance of the cadmium sulfide cell (LDR) at 100ms is given by [4],

$$R_t = R_l + (R_d - R_l)\left(I - e^{t/r}\right) \qquad (1)$$

$$R(100ms) = R_l + (R_d - R_l)(0.7504)$$

Where r = 72.05X10^{-3} internal resistance

R_L = resistance under light =2kΩ

R_d = resistance in darkness = 900KΩ

R_t = resistance at time under consideration

$$R_t = 2 * 10^3 + (900 * 10^3 - 2 * 10^3)(0.7504)$$

=675.86kΩ

The input voltage across the LDR and R_t is V_1. Variable resistor R_1 is preset. Applying voltage across the preset variable resistor and the light dependent resistor (LDR) forms a voltage divider network as shown in Figure 1.0.

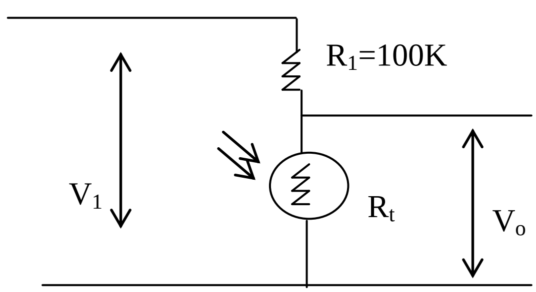

Fig.1.0 Voltage Divider Circuit with LDR

$$V_o = V_1 * {R_t}/{(R_1 + R_t)} \qquad (2)$$

Where V_1 = 12 volts.

Under bright light (light intensity), Rt_{Low} = 2KΩ.

In total darkness (no light), Rt_{high} = 900KΩ.

Therefore

$$V_o(Light) = \frac{12 * 2 * 100^3}{2 * 10^3 + 100 * 10^3}$$

= 0.2353Volts (Low)

$$V_o(Darkness) = \frac{12 * 900 * 10^3}{900 * 10^3 + 100 * 10^3}$$

=10.8 Volts (high)

5.0 COMPARATOR CONTORL UNIT.

The Comparator IC (LM324) compares the voltages at point A with pre- set or reference voltage at point B as shown in Figure 2.0.

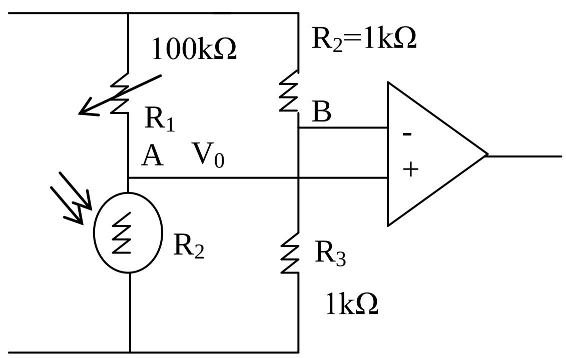

Fig.2.0 LDR and the Comparator Circuit

The potential at point B, is determined by voltage divider rule [4,5];

$$V_B = \frac{12 * 1 * 10^3}{1 * 10^3 + 1 * 10^3}$$

=6Volts

Therefore voltage at point B is set at 6Volts by the two resistors R_2 and R_3 which are 1KΩ resistor each. Comparing the voltages obtained under light and darkness conditions, it can be deduced that initially when there is light the resistance of the LDR decrease [3,4,5], and the output of the comparator goes low because V_B (6V) becomes greater than V_A (0.2352V). During the dark period, the output of the comparator goes high because V_A (10.8V) is greater than V_B (6V). The measured value under light condition is 0.12Volts while the value under darkness is 10.05Volts. The output of the comparator Vo is fed into logic circuit as Vo_1 as shown in Figure 3.0

6.0 THE DIGITAL LOGIC IC

The digital IC, CD4001BE is a CMOS that consist of four, two input NOR- gates. It is invariably an OR gate followed by an inverter [1,5] In the design of this circuit, it is connected as a NOT gate as shown in the Figure 3.0. It consists of four sections which gives the output for switching the various circuits as may be required.

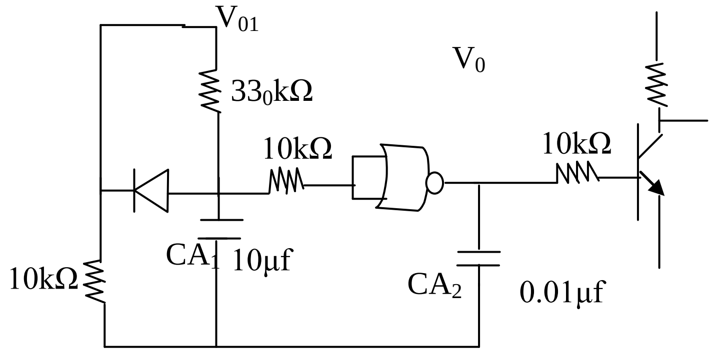

Fig.3.0 Circuit Showing the Input and Output of a Wired Inverter

7.0 MODE OF OPERATION

Under bright light, the output voltage of the comparator V_o in Figure 2.0 is low and it is fed into the logic circuit. However since the initial capacitor value of CA_1 and CA_2 have no charge, the capacitor CA_1 will have a low value. This low voltage will be inverted by the NOT gate IC in Figure 3.0 to a high and capacitor CA_2 holds this high value and the connected transistor will switch on and the relay contacts opens. No current will flow and hence bulbs will not come on. When there is no light (i.e. darkness) the output voltage of the comparator goes high and the capacitor CA_1 charges up to a high value. This high voltage will be inverted by the NOT gate to a low value and capacitor CA_2 holds this low value. Output voltage Vo becomes very low and it switches off the transistor and as such the relay contacts close. Current now flows along the power circuit where the external lightings are connected. The lightings can be connected in sections or stages for examples the bulbs on the main walls of the building, second the garden lights and thirdly the walk way lightings

8.0 RESPONSE TIME TO SWITCHTING

The response time to switch (time taken to open and close relay contacts) is dependent on the switching time of the transistor, and the switching time of the transistor is in turn dependent on the time constant of the capacitors in the circuit. The time constant is given by [3,6].

$$T = RC \quad (3)$$

For stage 1,

R = 470KΩ and C_{B1} = 47µf

$T = 470 * 1000 * 47 * 10^{-6}$

= 22.1 seconds

For stage 2,

R = 470kΩ and Cc_1 = 100µf

$T = 470 * 100 * 100 * 10^{-6}$

= 47.0 seconds

For stage 3,

R =560KΩ and C_D =100µf.

$T = 560 * 1000 * 100 * 10^{-6}$

= 56.0 seconds.

9.0 TRANSISTOR SWITCHING.

The control circuit consists of a relay with relay coil, free wheeling diode and a transistor switch (C 945). When the output of the NOT gate is high it turns the transistor on and the relay coil is energized and its contact opens. The time taken to turn on the transistor, t_{on} and time taken to turn off the transistor t_{off}, both form the switching time of the transistor. This switching time is dependent on the time constant, T= RC of the capacitor. Since the digital IC, CD4001BE consists of four, two input NOR- gates, three of the gates were used in the same connection as discussed above, this enables the switching of three circuits though in sequence using the tripping timing. This tripping time is the time taken for the lighting in each of the three sections to come on and off. This principle is called section loading and it helps to reduce the amount of current taken to turn on all the lamps at the same time and hence sustain the durability of the relay contacts.

When a high voltage enters the transistor it turns on, the relay energizes and the bulbs or lights come on.

The voltage V_{BB} = 12Volts and Resistance R_B =10KΩ

∴ The base current needed to turn on the transistor, i.e the transistor biasing current is given by [4,6]

$$I_B = \frac{V_{BB}}{R_B} \qquad (4)$$

$$= \frac{12V}{10X10^3} \qquad = 1.2mA$$

10.0 ECONOMIC CONSIDERATION.

Suppose P is the capital outlay required for an installation and r is the interest per Unit. The installation should obviously provide r P as annual interest, which is added to annual running cost. Where the installation is to last for a very long time, then this would have been the only charge to be made. But as the useful life of the installation has a denote value, it is necessary to provide a sinking fund to produce sufficient amount at the end of the estimated useful life to replace the installation by new one. Let the cost of replacement be denoted by Q. This Q will be equal to P if the used installation has zero scrap value, less than P if it has positive scrap value and greater than P if it has negative scrap value. If the useful life is n years, then the problem is to find the annual charge q to provide a sinking fund which will make available an amount Q at the end of n years

11.0 CONSERVATION OF ENERGY

A kilowatt hour is the unit commonly used for large amount of electrical work or energy. The amount of energy consumed is calculated simply as the product of the power in kilowatts multiplied by the time in hours during which the power is used [6],

Energy = Power * Time

= IVt (5)

Table 1.0 Shows the rating of electrical fitting and energy consumed per hours. Kilowatt of energy is estimated at the cost of #4 (four naira per kilowatt.) for domestic installation.

Table 1.0 Economic Effect of Usage of 60 Watts Tungsten Bulb With Time,

Bulb Rating (watts)	Hour of usage (Hours)	Energy /Kw	Cost/Kw	Charges
60	1	0.060	4	0.24
60	2	0.120	4	0.48
60	3	0.180	4	0.72
60	4	0.240	4	0.96
60	5	0.300	4	01.2
60	6	0.360	4	1.44
60	7	0.420	4	1.68
60	8	0.480	4	1.92
60	9	0.540	4	2.16
60	10	0.600	4	2.4
60	11	0.660	4	2.64
60	12	0.720	4	2.88

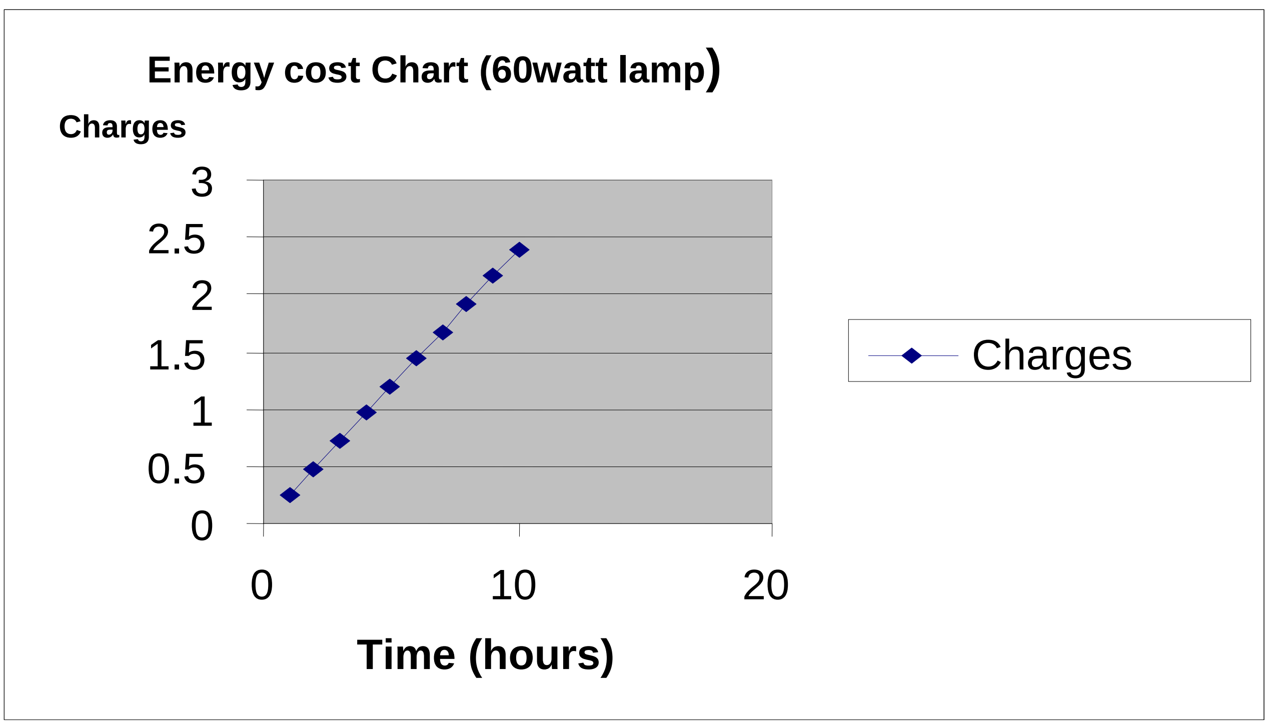

Fig 4.0 Energy Cost Chart For a 60watts Lamp

12.0 TEST RESULT

A Test of the response time to day light and darkness (switching) was carried out and result recorded in Table 2.0

Table 2.0 Shows Test Results Obtained in Presence of light for the Three Circuit Switching

Circuit	Switching time
1	10 Sees
2	18 Sees
3	25 Second

When the photo-cell of the circuit was suddenly submerged in a dark vacuum from daylight the lamps connected to the first circuit switched ON after 10 seconds, the lamps connected to the second circuit switched ON after 18 seconds and the lamps connected to the third circuit switched ON after 25 seconds.

When the photo-cell was exposed to day light all lamps turned off at the same time. This result showed a satisfactory performance in terms of switching for the purpose of the design.

13.0 CONCLUSION.

The problem arising from the negligence, inefficient ways or attitude of majority of people in developing countries of the world, in terms of controlling the utilization of electrical energy results to a significant waste of energy and consequently a waste of funds. The practical implementation of this work will substantially reduce the associated wastage arising from such act of negligence.

This automatic switch control is a very useful device and can be used for the effective automation of street lighting systems, in major streets, roads and highways. However the overall aim is that out door or external lighting are ON only when required. This will go a long way in reducing waste of electrical energy, cost of running such installation and subsequently the life span of the lamps or bulbs used for the lightings but most importantly energy is conserved and savings is made as a result of reduced payment of tariff, since tariff in terms of energy consumed is a function of time of usage. The energy cost chart above shows that the more the hour of usage the more the charges.

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