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A Sensor-Less and Energy Efficient Street Light Control System

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ABSTRACT: Work in this paper is directed towards the design of a cost effective and energy efficient Street light control system. The main idea is to provide an alternative to LDR and Hardware timer based street light control systems which have reliability and efficiency related issues. Light dependent resistors are prone to signal variations due to factors such as presence of dust, humidity etc. and therefore their outputs cannot always be relied. Hardware timer based controls have no such issues but due to the improper and untimely manual changeovers of time settings of the controls, they are not quite efficient. Some recent research work has been done on controls employing LASER gates to detect traffic in vicinity which switch on the lights only when there is presence of vehicles but such types require huge infrastructure for installing Laser transmitters and receivers at a height of two feet near each street lamp post which is not feasible keeping in mind the scope of the paper.

KEYWORDS: Energy efficient, open loop, Variable intensity control

I.INTRODUCTION

The ever increasing global concern regarding the rational use of electric energy [1] due to factors such as rapid consumption of finite fossil fuel resources and environmental pollution generated by their combustion has led to the evolution of various technologies such as smart grid technology, home automation etc. but it's quite surprising that not much importance has been given to street light systems which remain switched on for almost 12 hours a day.

As a step towards this direction a control system has been proposed in this paper which makes use of the astronomical data of daily sunrise sunset times of a geographical location to decide the switching on-off of street lights and their gradient brightness control. The main concern is to reduce the amount of time for which the street lights remain on in the existing installed systems unnecessarily while fulfilling all the mentioned objectives.

II.LITERATURE SURVEY

The work which has been done so far for energy optimization of street light systems can be classified mainly into the following four categories:

A. Street light control (SLC) system using LDR as sensor: [10], [11], [12]

B. SLC system which makes use of LASER gates to detect traffic in vicinity:[13]

C. SLC system based on wireless sensor networks: [3], [4], [7], [8].

D. Sensor less SLC systems which utilize time sensing from Real time clock (RTC) device: [12], [14] and [15].

III.SCOPE OF IMPROVEMENT

Knowledgebase of systems in section II has been taken and efforts have been made to reduce the cost of system and to increase the preciseness of control action by selecting a very basic microcontroller and incorporating reliable day wise astronomical sunrise sunset time data into the system which has not been done in [12], [14] at all and inefficiently done in [15].

IV.PHENOMENON OF SUNRISE SUNSET TIME VARIATIONS

Fig. 1 shows the sunrise and set times on June 21 which is the longest day and those for Dec 21 which is the shortest.

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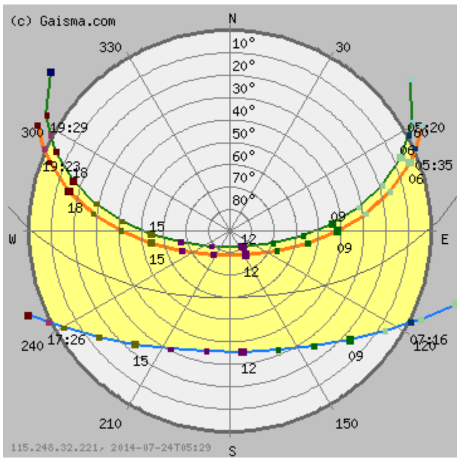

Fig.1. Sun path diagram

V. ASTRONOMICAL DATA OF SUNRISE AND SUNSET TIMINGS

The data has been sourced from [30] and [31] and shown in Fig. 2.

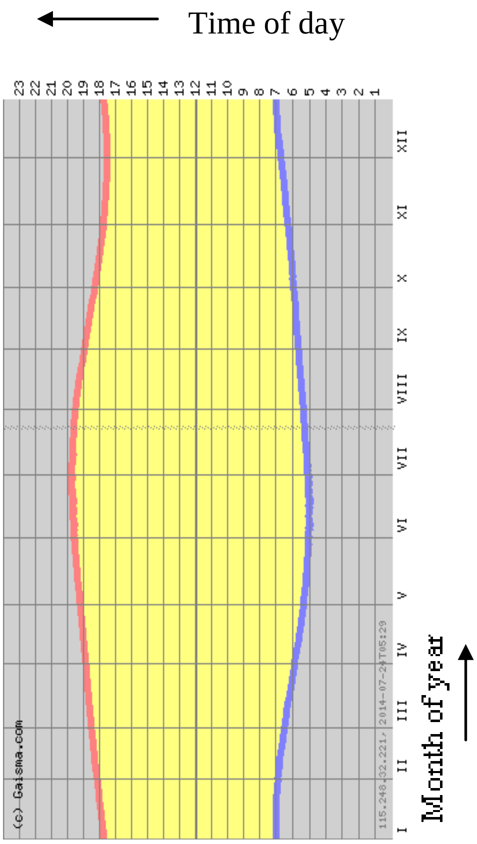

Fig.2. Sun-rise, set, dawn and dusk graph of year 2014 for Chandigarh (India)

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VI. PROPOSED SOLUTION

A low cost basic microcontroller has been used in the proposed control system. External memory chip has been added to store the look up table of 4 year sun-rise and set data. The interfaced RTC IC provides the current time and date to the microcontroller for time sensing purpose. Code designed for microcontroller takes care of switching as well as gradual brightness control of the LED array street light at proper times depending upon the astronomical sun-rise and set data.

Control system has been designed for LED array street lights, since such lights have advantages over traditional sodium vapour street lights as concluded in detail from [2] and [9]. The comparison of LED array vs. Sodium vapour lights as shown in table I.

The LED array consumes 5 times less power for the same intensity output as compared to Sodium vapour lights. Also the former has more life hours and possibility for intensity control which is not at all available in the latter.

TABLE I. CHARACTERISTICS OF LEDLAMPS VS SODIUM VAPOR LAMPS

Parameter	**LED Array**	**Sodium Vapour lamp**
Power	36W	150W
Life	50000 Hrs	5000 Hrs
Intensity Control	Possible	Not possible

VII. HARDWARE IMPLEMENTATION

Following components have been used in the proposed hardware of control system:

1) Microcontroller (AT89C58)
2) Liquid Crystal Display (LM016L)
3) External Memory (6264)
4) Octal D-type Latch (74HCT573- with Tri-state outputs)
5) Real Time Clock (DS1307)

Circuit diagram of the proposed system is shown in Fig. 4.

U1: Microcontroller (AT89C58)
U2: Real Time Clock (DS1307)
LCD1: Liquid Crystal Display (LM016L)
U4: External Memory (6264)
U5: Octal D-type Latch 74HCT573

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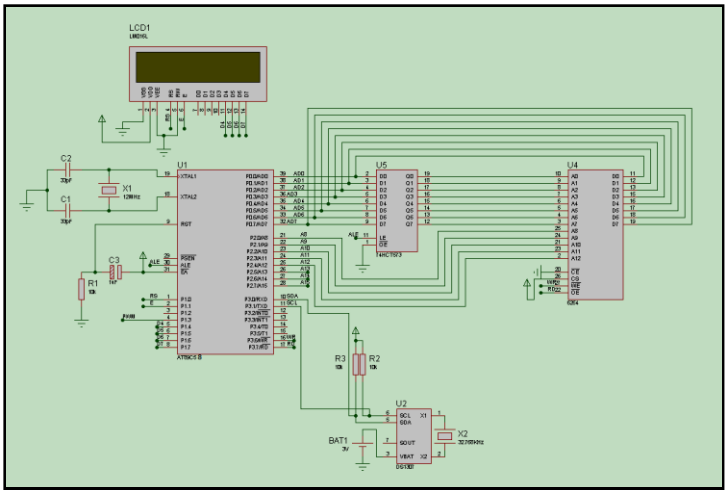

Fig.4. Circuit diagram of proposed system

VIII. DRIVER AND STREET LIGHT LOAD CIRCUITRY

Driver and load circuit has been designed after considering suitable design criteria and methodology from [29] and [21]. 15V DC power supply has been connected to source of ‘Q1’which is an n-channel MOSFET (IRF540). The Gate of the MOSFET is fired through Output pin of ULN2803 buffer IC which is getting an inverted PWM signal from the microcontroller. The diode IN4148, MOSFET (IRF540), inductance of 4.7mH and capacitor of 100uF combined in the circuitry form a Buck chopper (Output voltage is proportional to the input duty cycle). The circuitry has been designed to generate a voltage of 12V and can source a load current of 900mA required for powering the LED array of nearly 10.7 Watt (High intensity LED specifications are –Forward voltage 2V and forward current 120mA, referred from [23]).Fig. 5 shows just 1/3 part of the total load. In actual 3 such circuits can be combined to get the required wattage and luminous intensity of a 36W street light.

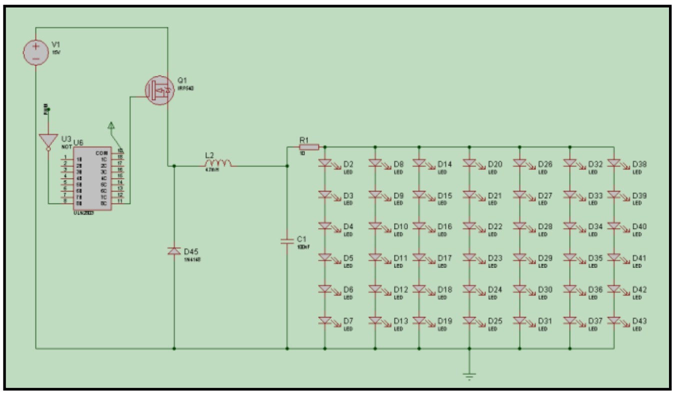

Fig.5. Driver and street light load circuit

IX. SOFTWARE IMPLEMENTATION

For designing the Control Algorithm the main Prerequisites are:

1) Knowledge of Duty Cycle of PWM signal vs. illumination intensity in Lumens of LED array.This data has been sourced from [15] and is shown in Fig 6:

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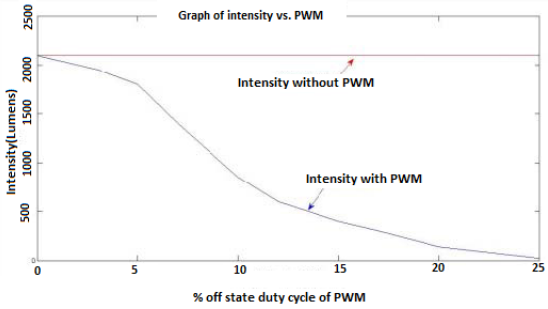

Fig. 6. PWM vs. Luminous intensity characteristics of LED array

2) Knowledge of Duty Cycle of PWM vs. Power consumption by LED array. Data has been sourced from [15] and is shown in Fig. 7.

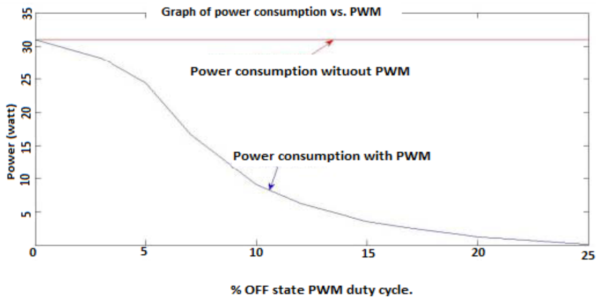

Fig. 7. PWM vs. Power consumption characteristics of LED array

3) Daily sunrise sunset data of Chandigarh to be loaded in a look up table. The data has been sourced from [30] and [31] for the year 2014.

X. CONTROL LOGIC

Thus considering the pre-requisites following are the Steps of the Algorithm for Control logic:

Algorithm 1:

1) Set the Current Date and Time data.
2) Initialize the RTC for proper date and time.
3) End

Algorithm 2:

1) Define a Look up table with Daily sunrise sunset data in the form of an array of structure.
2) Initialize the LCD for Display of Date and time.
3) Initialize the Timer in microcontroller to function as a PWM output source.
4) Read the RTC data for determining the Current Date and time.
5) Display the Date and time on LCD.
6) Find out the data corresponding to the Current Date in the look up table.
7) Mark the data as Reference.
8) Start PWM in increasing duty cycle mode for Half Hour (Starting from 75% On State Duty Cycle up to 100% On State Duty Cycle) if the current time has become equal to the Reference Sunset time.
9) Keep the Output for Street Lamp fully ON after PWM cycle has finished.
10) Start PWM in decreasing duty cycle mode for Half Hour (From 100% Duty cycle to 75% Duty Cycle and after that immediately to 0%) if the current time has become equal to the Reference Sunrise time.
11) Keep the Output for Street Lamp fully OFF after PWM cycle has finished.
12) Go back to STEP 4.

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XI. RESULT

The Control Logic has been tested in Proteus Simulation Environment. When tested for a given date (24 June, 2014) with Dusk time begin data as 7:30:25 PM and Sunrise data of next day as 4:55:11 AM, the Real time results achieved, have been shown in Fig. 8 to Fig. 10

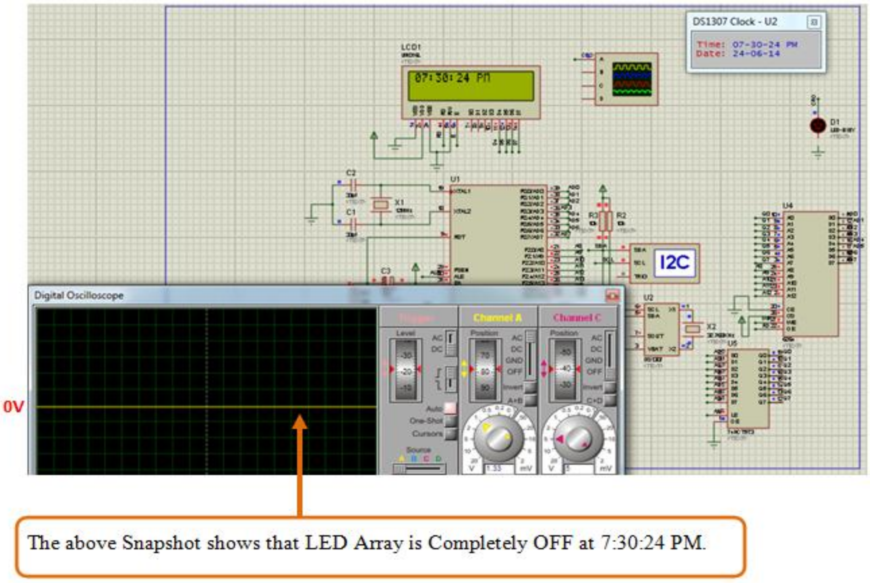

Fig. 8. Proteus snapshot

The straight line in the CRO at zero voltage level indicates Street lights as completely off at 7:30:24 PM

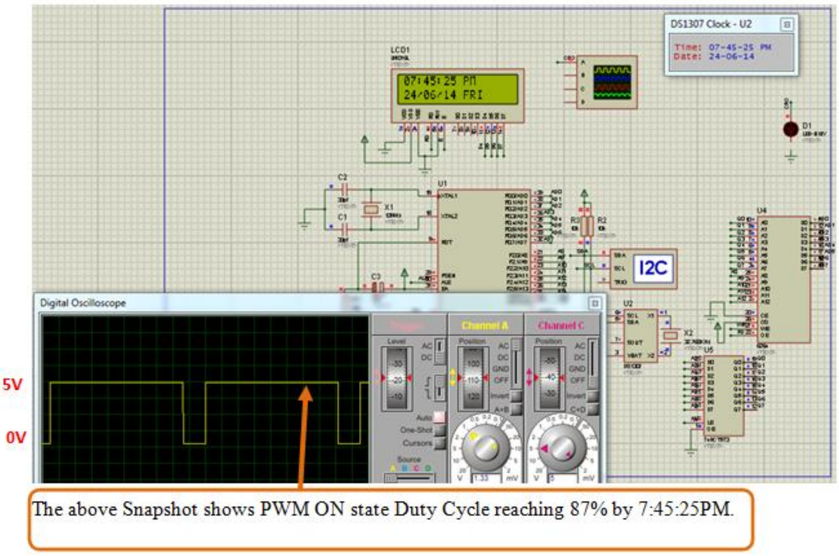

Fig. 9. Proteus snapshot

The pulse in the CRO indicates Street lights glowing with 87% brightness at 7:45:25 PM

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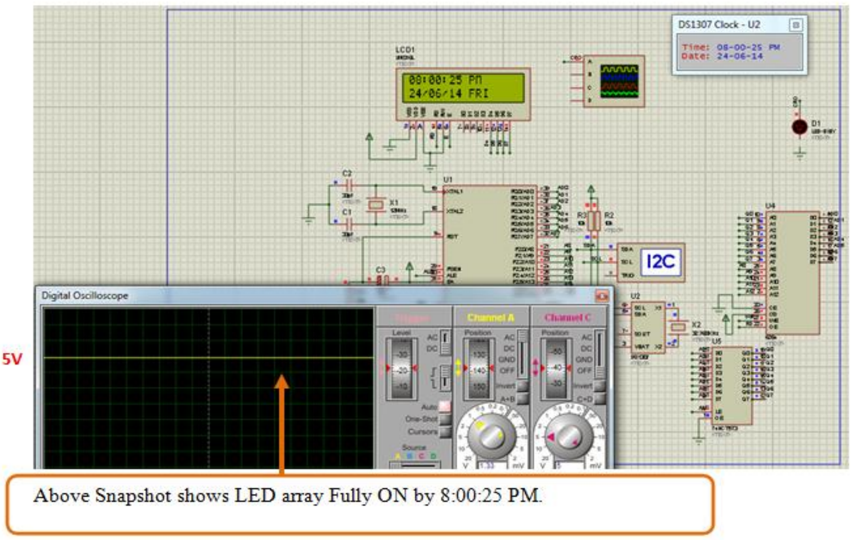

Fig. 10. Proteus snapshot

The straight line in the CRO at 5V voltage level indicates Street lights as completely ON at 7:30:24 PM

XII. CALCULATIONS FOR AMOUNT OF POWER TO BE SAVED

Calculations must be done against some reference (Like if the Street light timings are controlled manually).
Hence Power saving has been calculated by Subtracting the amount of Power consumed in Case 1 from the amount of Power consumed in Case 2.
Case 1: Street light operation is controlled as per control logic designed in this Thesis.
Case 2: Street light ON-OFF timings are controlled through a hardware timer whose time settings are adjusted manually time to time (i.e. after a period of few months) without any intensity control of Street light LED Lamp.
Analyzing interpretation of Case1 & Case2 with Sunrise Sunset data graph of Chandigarh in Fig. 14:

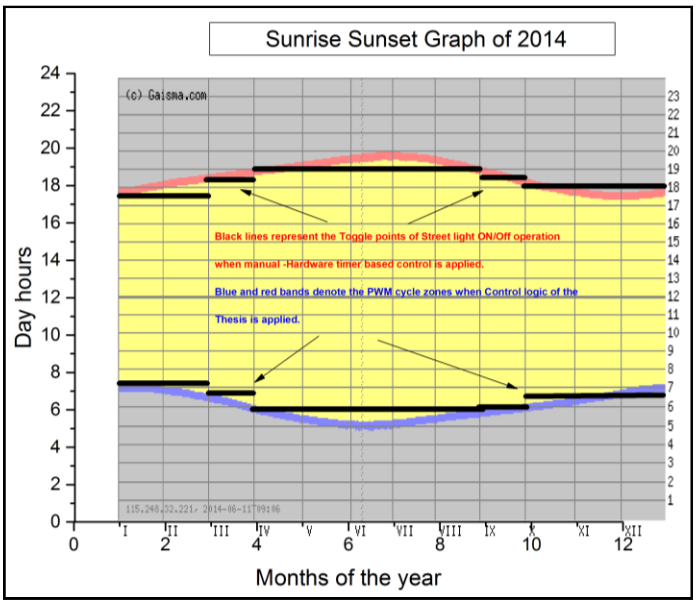

Fig.14. Interpretation of manual vs. automatic control on Sunrise sunset graph of Chandigarh for the year 2014

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Now, Electric power saved in a Year (2014)

$$= \sum_{Day=1}^{Day=365} \text{power saved in a Day} = 10.84 \text{ KWhr (Comes out after precise calculations).}$$

XIII. DISCUSSION

Thus from the above Results and Calculations we find that 10.84 KWhr power will be saved in an year (2014) by Control logic of proposed solution against manual control in which the correction of Time setting of hardware timer is done 5 times in the year(i.e. beginning of January, March, April, September, October) by the technician. If data of timings of doing correction of Street light ON/OFF settings in Manual control mode is taken as per the author of [15] then the amount of power saving comes out to be 18.766 KWhr for the year 2014.

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