Design and Development of Enhanced Road Safety Mechanism using Smart Roads and Energy Optimized Solar Street Lights

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***Abstract*—Energy optimization is an important aspect in these days and it is applied in every domain. Technologies like smart street lighting and automated speed breakers are few which are applied in transportation domain. The work focus on two aspects. First one is to optimize the energy consumed by the street lights by introducing smart solar street lights. Second one is to enhance road safety and thus by optimizing the fuel consumption. To achieve the smart street lighting, a combined technology of piezo sensors and LDR sensor is proposed. The piezo sensors are used for detection of vehicle speed, which will actuate the speed breakers. The LED's are powered using batteries which are powered by a solar panel. A controller circuit is installed for the monitoring of charge in the batteries, to prevent from overcharging. The power output from the solar panel is given to the MOSFET which is used for lighting the LED. To actuate the speed breaker, a servo motor is paired with a rack and pinion, for the translation of rotatory motion to linear motion. To perform all this control functions, Arduino micro controller is used.**

Keywords— Smart street lighting; Piezo sensors; LDR sensor; Speed detection; Speed breaker; Solar energy; Photovoltaic; Arduino microcontroller; MOSFET; LEDs; Servo motor; Rack and Pinion.

1. INTRODUCTION

With the urbanization of towns and cities, the power consumption is increasing in a rapid manner. To control this, we have to reduce the rate of energy consumption in all the possible ways. In the past few years, the concept of Smart Grid is becoming more popular, mainly due to the fact that it provides a more intelligent, efficient, and reliable use of the power resources, while also promising a better service to the customers. In line with this, a system is proposed to reduce the amount of power used in street lights and reduce the fuel consumption in cars by implementing smart technologies on the roads which enhances the safety also.

Attempts have been made to optimize the energy consumption of street lights by replacing traditional AC street lights with LED DC street lights.Due to their higher efficiency, longer lifetime, lower maintenance costs, and the fact that they are mercury–free, making them environment-friendly [1].Another approach is to use high intensity discharge lamps (HID), which are similar to LED lamps. HID lamps acquire high luminous efficacy and good colour rendition, along with their relative long lifetime [2]. In one of the study, it was observed that if the street lighting systems in the city were upgraded to LED, 64% energy is saved, and 33192 tons of equivalent carbon dioxide are avoided without even using the renewable energy sources [3].

Various techniques are suggested to use piezo sensors to control the LED lights [4].To reduce the power consumption by the street lights, a scheme is suggested to control the street lights by sensing movement of vehicles as well as pedestrians. The system made use of the PV panels for the power to LED lights. A charge controller circuit is used to prevent the overcharging of battery. A motion sensing circuit, for the control of street lights, to reduce the power consumption, if there are no pedestrians [5].

Another aspect of energy optimization discussed in few of the research is about optimizing fuel consumption and enhancing road safety. Schemes have devised to alert the vehicle driver about the speed breakers in his route, before 10-12 metres, using a mobile application, to avoid the road accidents. The system calculate the speed of the vehicle using piezo sensors and alert the driver using a sign board, which is a few metres away from the automated speed breaker [6].

The proposed system addresses two aspects of energy optimization. An effort is made to optimize the power consumption by the street lights by introducing a smart streetlight system in which the street lights will

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function only when there are vehicles or pedestrians in the vicinity. Also the street lights are powered by solar power which makes the energy consumption more eco-friendly. In the second part of the proposed system, fuel consumption is optimized by a driver alert system. Large amount of fuel is consumed when the driver applies sudden break. Speed control of vehicles on road is achieved by speed barriers or humps. But both speed barriers and humps force the vehicles to consume large amount of energy to reduce the speed. Instead of these approaches, a smart speed barrier is introduced only if the vehicle is travelling above the threshold speed limit. This saves the unnecessary fuel consumption by other vehicles which travels in low speed.

The proposed system is implemented in both hardware and software, where the hardware design imbibed various circuits, such as the customized street lighting circuit, the circuit that connects the street light and the PV panel and the automated speed breaker circuit while the software focused on developing the control algorithm using Arduino, which acts as a bridge between input sensors and output actuators, and controls the operation of the different circuits in the system.

To assess the performance of the proposed system, software simulation is carried out using software Webots. Webots is development software used to model, program and simulate mobile robots. Webots can be used to design complex robotic setups, with one or several, similar or different robots, in a shared environment. The properties of each object, like shape, colour, texture, mass, friction, etc., can be fixed by the user. A large choice of readymade sensors and actuators are available to equip each robot. The robot controllers, can be programmed with the built-in IDE. The robot behaviour can be tested in physically realistic worlds. The controller programs can optionally be transferred to commercially available real robots.

The rest of the paper is organized as follows. Section II describes the smart street lighting system and its operation. Section III presents the simulation of automated street breaker system using Webots. The hardware implementation of automated speed breaker system is presented in Section IV, which also explains the operation of the whole system in general. Section V outlines the results of the project. Section VI provides an analysis of the system efficiency, and Section VII concludes the paper.

II.SMART STREET LIGHTING SYSTEM

In the proposed system, Photovoltaic (PV) cells are used for powering the street lights, which charges a set of batteries. Energy conservation at night is also essential when there is no vehicle or pedestrian movement on the streets; thus, the proposed system is equipped for customized lighting using piezo sensors for the maximum intensity of street lights, otherwise the lights will glow at a minimum intensity. In many places, we can see the street lights are still on at day times and at some places, the light is turned off at nights. These are mainly due to the human errors, to overcome this problem, LDR sensor is used which monitors the environmental light and control the street lights.

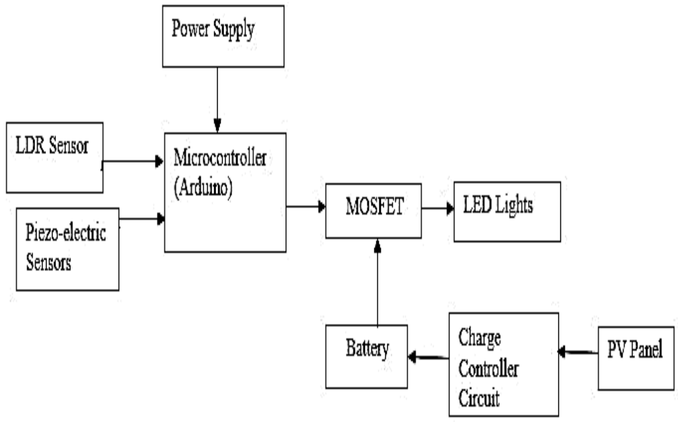

Fig.1-Block Diagram of Automated Street lighting system

Fig.1 explains the working of Automated street lighting system. The Arduino microcontroller acts as the brain of the system. The Arduino controls the LEDs by driving the MOSFET, whenever it receives the input commands from LDR and piezo sensors. The power supply to the LEDs are provided by solar powered batteries connected to the MOSFET and for the remaining circuit it is provided by a DC battery. A charge controller circuit is incorporated to control the battery from overcharging. The LEDs are automatically turned on, when the LDR senses darkness, and the LEDs glow with an intensity of 25% of the maximum intensity and if the LDR senses light the LEDs are turned off automatically. The piezo sensors are used for customized street lighting. When the piezo sensors sense any pressure applied on them, it sends a signal to the microcontroller and the microcontroller increase the lighting of LEDs to 100%.

III. AUTOMATED STREET BREAKER SYSTEM

When a car passes through a speed breaker, there will be a shift down from a higher gear to a lower gear, for which there will be an extra fuel consumption of 5 to 10 ml. Suppose if a car which is passing the speed breaker in the prescribed speed, still there is an extra fuel consumption. The main aim is to alert the vehicle driver not to exceed the speed limit. So it is decided to remove the speed breaker and if the vehicle driver exceeds the speed limit, with prior indication and before a proper distance, a speed hump is actuated and reduces the vehicle speed. Also near a school zone or public places, the speed is controlled because of the pedestrians, during day times, while night times there is no need to control the speed, in case of no pedestrians. By achieving this automated speed breaker system, thus we can save a lot of fuel energy.

In the Webots software, to start with the simulation, a new file need to be created, in which it is possible to create any object by using in-built nodes in the software. It is also possible to modify the environment. This file is called a world file. In the simulation of the proposed system, two robots, a car and an automated speed breaker are created, in an environment, which consists of roads arranged in a particular manner to form a track. These two robots have two different controllers for their operation. These controllers run in a loop, once the simulation is started, so the whole setup is similar to a real world. We can also add a Physics plugin, which gives the object, features like Mass, Shape, Friction, Gravity. So by adding all such properties, the world is much closer to the real world.

To test whether the world file environment is near to the real world, a road is created with a curve. So when the car passes through this curve should slow down, to avoid skidding. The controller of the car is programmed to run with constant speed of 60 km/h. At this speed, the car got skid and was off the road, as shown in Fig.2.

Fig.2 – A picture of car at 60k/h driven off the road

Hence, the speed should be reduced. Another simulation of the car travelling at sped 40km/h is shown in Fig.3. In this simulation, the car does not skid, instead it continues further.

Fig.3 – Car passing through the curve at 40km/h

But, if the car continues to travel at 40km/h, it is not running at its full efficiency, which reduces the mileage. If there is a speed breaker at this curve, the car slows down automatically, due to the speed breaker which is enough for the car to pass through the speed breaker safely. Fig.4 shows, the car passing through the speed breaker.

Fig.4 – Car passing through the speed breaker at 60 km/h

Two distance sensors are added which can sense the speed of the car and actuate a linear motor to which the rumple strips are attached.

IV. Experimental Results

The Piezo laid on road, when activated by vehicle movement converts the pressure into pulse and send it to microcontroller. Thus the LEDs near to the activated piezo sensors start glowing at its full intensity. This can be implemented to save the energy wasted in lighting the empty roads.

Speed breakers on road leads to a wastage of 2-5 ml of fuel, even for slow goers. Thus to prevent the wastage of fuel, artificial rumble strips is used. Speed of the car can be detected by the two layers of piezo sensors laid on road. Here the distance between the two piezo strips is constant and time taken by the car to cross both the strips can be calculated from the microcontroller, when the piezo sensors are actuated. Thus if the speed of the car is above the pre-set value, the microcontroller actuates the linear actuator placed below the road. The hump setup is pushed up by the linear actuator above the road. These Rumble strips are 13-15 mm of height and gives vibration to the car and reduce the speed

As shown in Fig.6, the IR sensors are placed at a distance of 1.5 times the average length of car ahead to these Rumble strips. These IR sensors are controlled by the Arduino. Until the car crosses the IR sensor and pulse sent by IR sensor to microcontroller, the Rumble strips remain above the road. Once the car crosses the IR sensor, pulse is sent from sensor to microcontroller and linear actuator goes back to the normal position making the rumble strips to the level of road.

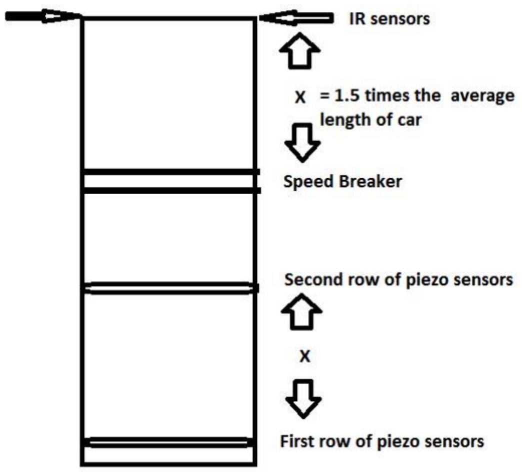

Fig.6 – The Layout of Automated Speed Breaker System

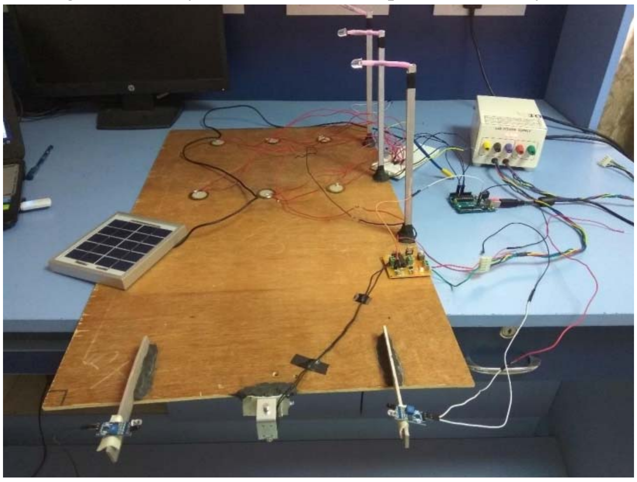

Fig.5 – Hardware setup

The hardware consists of Piezo plates, LED lights, LDR sensor, Solar panel, H-Bridge, IR sensors, Arduino microcontroller, HCF4075B IC and a linear actuator as shown in Fig.5. The LDR senses darkness, the LEDs are lighted up to 40% of maximum intensity. When the first row of piezo plates are actuated the first and second lights glow to 100% of maximum intensity and the third light glows at 40% of intensity, similarly when the second layer of piezo plates are actuated the second and third lights are lights will glow at 100% intensity and the first light glows at 40% intensity. The 4075 IC is used as an OR gate for the three piezo plates of first row and second row.

The time taken for the vehicle to pass from first row of piezo plate to second row of piezo plate is calculated using the program uploaded in the microcontroller. If this time is less than the prescribed time limit corresponding the speed limit, then the vehicle is over speeding. This sends a high pulse to the H-Bridge which actuates the linear actuator. If the time is more than the prescribed time limit, then the car is below the speed limit, which will not actuate the speed breaker. After passing through the speed breaker, the vehicle passes through the IR sensors, which sends a signal to microcontroller, and it in turn sends a low signal to the H-bridge, which de-energises the linear actuator and the rumble strip goes down.

Two independent microcontrollers are used for automated street lighting and automated rumble strips respectively. The microcontroller used for automated street lighting is powered from the battery, which is in turn powered by solar panel. For the automated street lighting the linear actuator needs 12V, so a 12V DC power supply powers the H-Bridge. The H-Bridge powers the microcontroller, the microcontroller controls the linear actuator using H-Bridge.

V. CONCLUSION

Thus, by implementing this project, we can save a lot of energy wasted on street lights and the fuel wasted while crossing the speed breaker for the slow goers. We can further develop this project by sensing the speed using various circuits. Depending on the speed, we can have different variations on the actuations of rumble strips.

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