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An automated WPT based EV charging with renewable sources of energy

Rajkumar G[1,2]

[1]Department of Electrical and Electronics Engineering, Nehru College of Engineering and Research Centre, Kerala, India
[2]Department of Electrical and Electronics Engineering, Hindustan Institute of Technology and Science, Chennai, India

Correspondence to
Department of Electrical and Electronics Engineering, Nehru College of Engineering and Research Centre, Kerala, India
Email: rajkumarg.eee@ncerc.ac.in

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ABSTRACT

A cost effective and completely renewable energy based power generation is performed and utilised for charging the electric vehicles and street lighting. This paper aims in conservation and production of energy from speed breaker and solar, later this energy is stored and utilised for Automatic Street lighting system and charging of Electric Vehicles (EV) using Wireless Power Transfer (WPT) technique. On controlling the MPPT of solar panel as well as Automatic Street lighting, LDR's with simple controllers are employed replacing the complex and costly controllers which needs maintenance also. And induction based power generation is obtained from speed breakers for reducing the space utilised by the generating system. The complete system is fully automated, for obtaining the energy conservation as well as utilising the renewable energy in an effective way. A small prototype is developed and tested to ensure its effectiveness.

Keywords: EV, WPT, solar actuator

1. INTRODUCTION

In the present scenario when country like ours is thriving to meet end to end energy requirement, it is a total necessity to produce electricity required from road, then and there itself, rather than relying on power grid. This paper portrays a methodology for production and conservation of electricity from road unit. In any city, 'street light' is one of the major power consuming factors. Even in daytime, when there is no requirement of streetlights, it is frequently seen that these lights remain ON violating the energy conservation rule [1-4]. This continuous lighting pollutes the environment by depending on conventional energy based power generation as well as increases the tariff of the electricity [5-8]. The vital use of streetlight is when public transportation during night time or when the daylight is very feeble. Therefore the design and controlling of street lighting is an important area of work for maintaining safe transportation in our daily life. A number of researchers have concentrated on the work to reduce the energy consumption and also to reduce environmental pollution [9-13]. Switching to production side, speed breaker based energy production system using electromagnetic induction is being employed here. In parallel, a model of solar panel or 'Solar Actuator', which tracks the sun, is being employed [14-17]. This model is solely economical and non-polluting on every basis. Usually efficiency of a conventional solar panel is 20-25%. But here based on availability of sunlight efficiency it can be increased up to 30 to 35% that is 5 to 10% more than the actual case [18-20].

Coming to the application of this produced energy, the best way to utilize is to charge Electric Vehicle (EV). EVs have been proposed as the prospective mode of transportation to address environment, energy and many other issues. In spite of receiving many government subsidy and tax incentives, EVs have not become an attractive solution to consumers [21-24]. Major drawback of EV is with the energy storage technology. Short comings of today's battery technology include cost, size, weight, slower charging and low energy density. For example, energy density of commercial Lithium-Ion complete battery pack is around 100 Wh/kg. This value is much smaller than that of gasoline engine. It is infeasible to achieve range of a gasoline vehicle from a pure EV with current battery technology. Long charging times and mechanical hassles with charging cables are main drawbacks of present EV technology that impede the widespread proliferation of EVs.

Wireless Power Transfer technology can be used as a solution in eliminating many charging hazards and drawbacks related to cables. The concept of dynamic WPT enabled EVs, which means the EV could be charged while moving in a road will increase the effective driving range while reducing the volume of battery storage. Not only from the consumer perspective, but also from sustainable energy point of view WPT enabled EVs are greatly beneficial. For example, the concept of Vehicle to-Grid to enrich distributed energy generation model can be brought into next stage with WPT facilitated EVs. Some futuristic concepts of motor/ capacitor/WPT EVs have been proposed, where EV is continuously charged and possible to run forever without batteries.

The Wireless Power Transfer (WPT) technology, which can eliminate all the charging troublesome, is desirable by the EV owners. By wirelessly transferring energy to the EV, the charging becomes the easiest task. For a stationary WPT system, the drivers just need to park their car and leave. For a dynamic WPT system, which means the EV could be powered while driving; the EV is possible to run forever without a stop. Also, the battery capacity of EVs with wireless charging could be reduced to 20% or less compared to EVs with conductive charging.

In the existing technology have the wired charging for EV's, the major problem is after a certain time period, the charger may get damaged so, the charging won't be proper. This problem can be resolved with the use of static WPT for charging the vehicles. Identifying the presence of vehicle, transferring the required amount of power and stopping charging after the vehicle left the location is fully automated in the proposed technology.

2. REVIEW

The Capacitive Power Transfer(CPT), Compared to traditional inductive power transfer technology, advantage of CPT include the ability to supply power through metal barrier reducing standing power losses, maximum power transfer capacity elevating EMI. But the problem is it can be only used in low power devices due to hazardous issue. Many materials are strongly affected by high power electric fields (human body). So, it is not suitable for bio medical applications [13].

Use of helical antenna's in WPT, in this scenario a small size antenna that can be equipped on the bottom of a vehicle and analysed its electrical characteristics with equilateral circuit. Size of the antenna is considered to be too big to be equipped on the bottom of EV's. Characteristics of the antenna and relation between power and efficiency are poor [20].

De-centralized plugged-in charging for EV's, here a charging selection concept for plug-in electric vehicle to minimize user convenience levels while meeting predefined circuit level demand limits is made. They have problems like, more resistive loses, more space requirement, separate plug-in electric pumps required [23].

The objective of this paper is to reduce power-load requirement from road to power grid, to resolve problem of transformers or electric posts at roadside which may cause danger, to meet renewable and cost effective production requirement.

Conflict of Interest

In WPT, the Inductive Power Transfer (IPT) and Capacitive Power Transfers (CPT) principles are available, from the review it is found that the CPT can transfer power even during the presence of obstacle, with less standing power loss and EMI. But in the proposed system IPT is used, because CPT can transfer power applicable only for low powered devices and it produces strong field which affects the biological creatures. Here in the proposed system the load is EV, which requires large power transfer, so IPT is used. The antennas involved in the WPT has to be carefully chosen regarding its size and dimensions for CPT, in the proposed system the IPT is employed for that, such design constraints are not there. In modes of charging static and dynamic charging are there, since dynamic charging is not practically reliable, static charging is the only option which can be established either plug-in or wireless, in plug-in resistive losses are more, space is required in the vehicle for keeping the charger and electric pumps also needed, such drawbacks can be overcome in the proposed methodology. In street lighting system, there are various methodologies with different controls are available, but in the proposed system a simple LDR is doing the task so more cost effective. With the same LDR, the MPPT in the solar panel also achieved so there is no need for expensive controllers. In speed breaker energy generation, the rack-pinion method is the traditional one but it requires a large area, the induction based speed breaker power generation needs only a small area for generating the same amount of electricity.

Block diagram

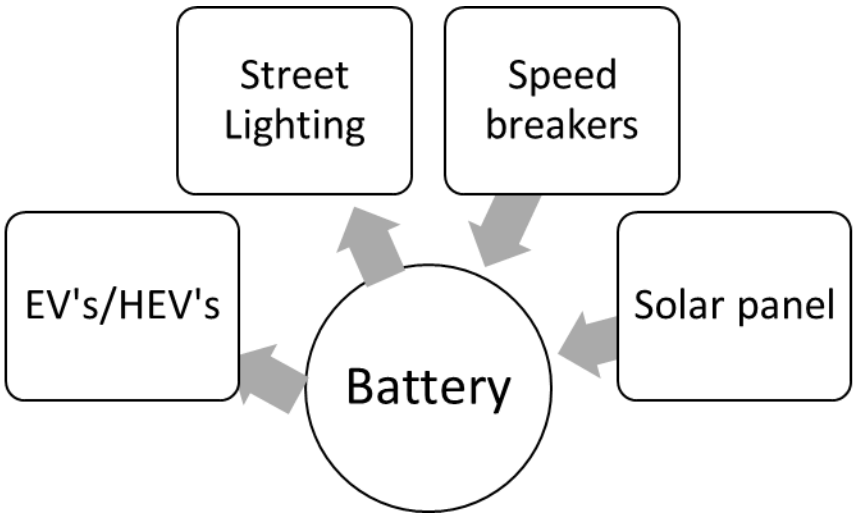

Figure 1 Block diagram of the system

It consists of two production sources and two consumption sources. Production side consist of an automated solar panel with Maximum Power Point Tracking (MPPT) system and speed breaker power generation arrangement both will charge the battery. The charged battery gives power to automated streetlight and also provides power for charging EV through WPT (figure 1).

Solar actuator

Solar is an abundantly available renewable source of energy from the sun. Solar PV have a panel made with silicon cells, so called solar panel, this panel convert the light emitted by sun directly into electricity. The generated electricity either can be stored or utilised directly. Since the solar panel efficiency is very low due to certain constraints, it is better to have a Maximum Power Point Tracking (MPPT) to gain more amount of energy from sun. Here three LDR's are doing this function of identifying the maximum light exposure direction and the measured values are given to PIC16F73, which is programmed to control a gear motor, placed on the side of the panel in such a way that, until the middle LDR gets maximum exposure of light, the motor rotates. The reason for using

the gear motor is to have rotation with precise angular movement of panel in both directions which is not possible in the case of a stepper motor (figure 2).

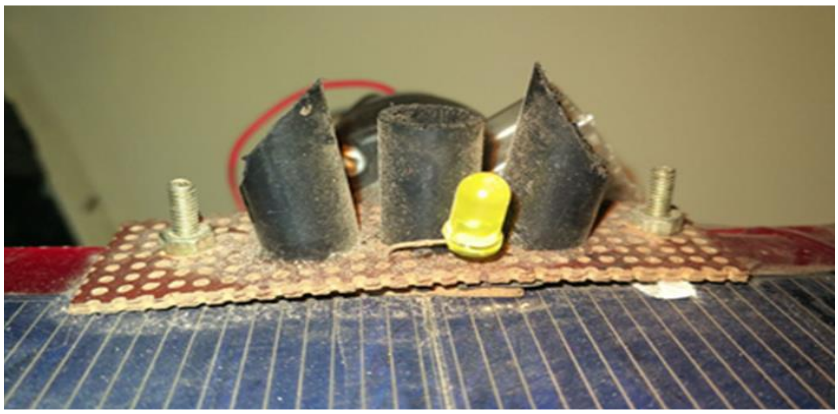

Figure 2 LDR based MPPT

The MPPT consists of a solar panel, driver IC, a motor and a motor driver. Panel which is faced towards sunlight produces energy and stores it to battery. This energy is used as per need. Solar panel is made to rotate towards the direction of sunlight by combined co-ordinated working of LDR (Light Dependent Resistor) and Driver IC which controls the operation of motor.

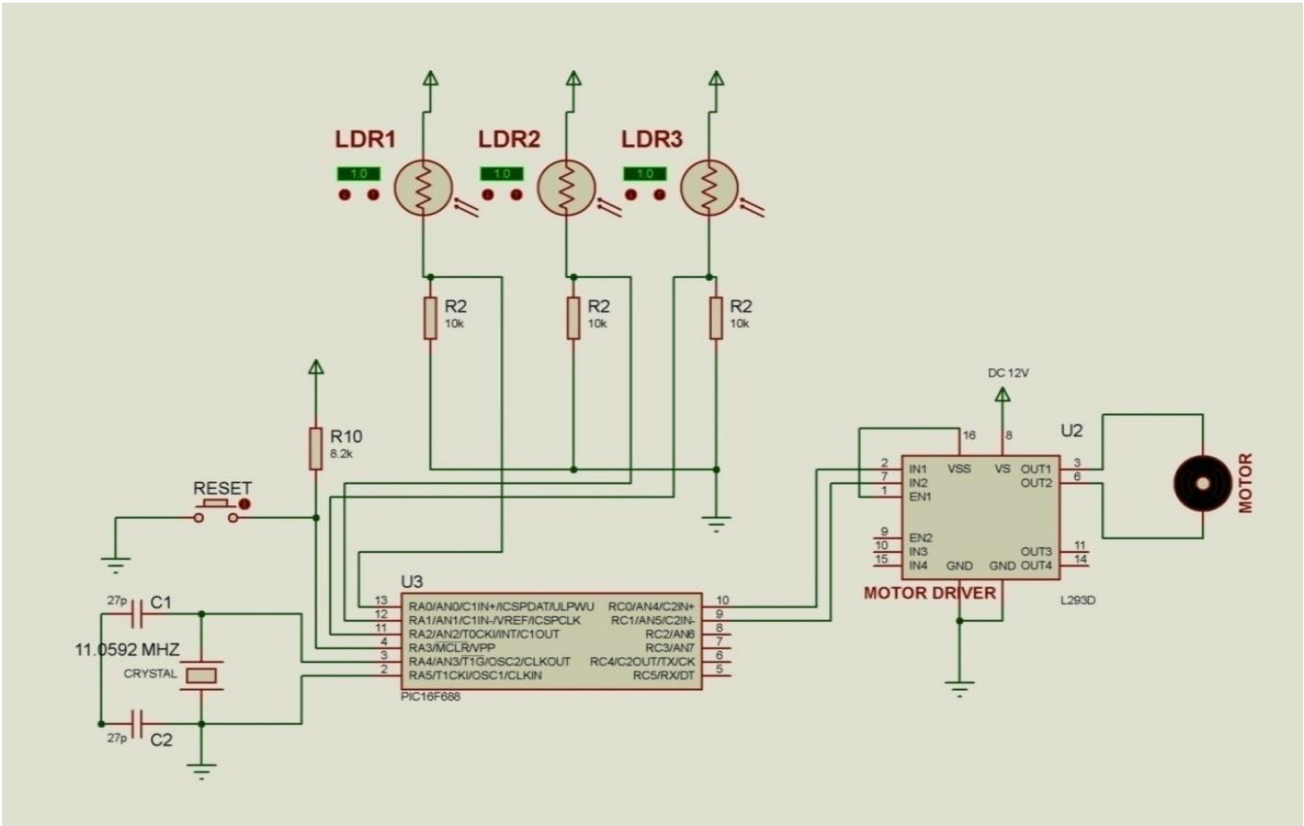

Figure 3 Circuit diagram of solar actuator

In Figure 3, Three LDRs are connected to pin 11, 12 and 13 of PIC micro-controller respectively. The input of PIC micro-controller i.e. pin 2, 3 and 4 is connected to crystal oscillator for obtaining clock pulses for is operation. The output of the micro-controller is connected to pin 2 and 7 of motor drive which controls the speed and direction of motor. Pin 1 and pin 10 of the motor drive is shorted, 8th pin is given to 5V DC supply. Output of motor drive (pin 3 and 6) is connected to 12V DC gear motor.

Automatic street lighting system

The vital use of streetlight is in public transportation during night time or when the daylight is very feeble. Therefore the design and controlling of street lighting is an important area of work for maintaining safe transportation in our daily life. A number of researchers have concentrated on the work to reduce the energy consumption and also to reduce environmental pollution.

If the intensity of the lighting system can be controlled by varying the brightness of the LED's it will be possible to conserve more amount of electricity. A fully automated illumination technology is used in this proposed system with the help of light luminance sensor and IR sensor. Another autonomous street lighting control and monitoring system was proposed using Vehicular Ad-Hoc Networks (VANET) technology where the vehicles will be equipped by an on- board unit having a wireless transceiver and controller, so that they can exchange messages with the nearby ones.

A ZigBee model was also proposed for optimizing street-lighting management and its efficiency depends on area. In this, LEDs and multiple sensors were interconnected with ZigBee based transmitters and receivers, and controlled by a centralized server.

In this proposed system, it consists of two basic units for street light work processing. First unit is motion detection, to analyse the direction of vehicle movement. It consists of an IR sensor for detection of vehicle movement connected to a comparator (LM358) to recognise it. It is an OP-AMP IC used to compare the signal from IR sensor, which works in non-inverting mode. The output of comparator is given to a monostable multivibrator, which is a NE555 N IC. This is then connected to an AND gate, here a set of three LEDs are used, where first and third LEDs is controlled by AND gate and second LED don't have any connection to it. So when any motion is detected (presence of vehicle/human) one of the outputs to AND gate becomes 1 otherwise 0.

Second unit consist of street light ON/OFF control which consist of LDR which changes its resistance based on intensity of light LDR connected to a LM358 comparator and the output of it is given to second input of AND gate it works, based on truth table of AND gate.

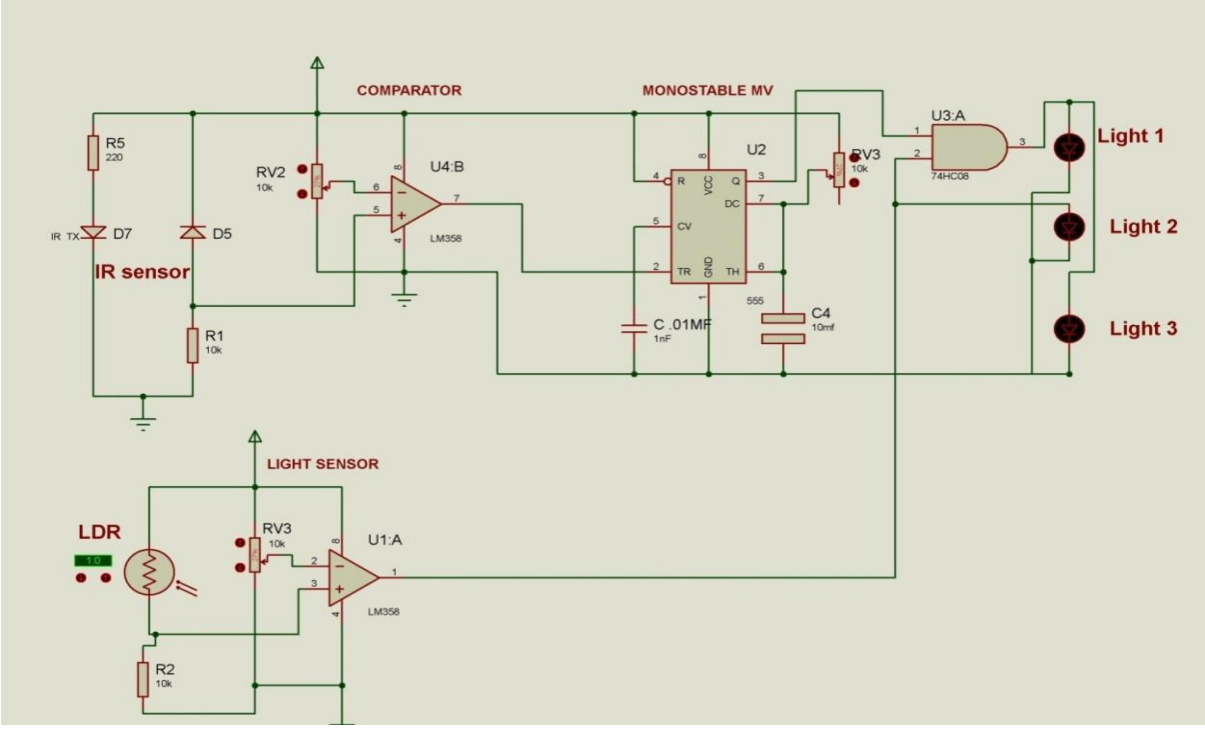

Figure 4 Circuit diagram of automatic street light system.

In Figure 4, LDR is used to detect presence of light. A LM358 IC is used here as a comparator, which is a dual channel OP-AMP IC with low power consumption, its pin 2 acts as Inverting, and pin 3 acts as Non-inverting, pin 4 is grounded and the supply (Vcc+) is given to pin 8. Output of LM358 given to AND gate. The motion detection circuit contains, an IR sensor (here a LDR) connected to LM358, its pin 7 is the output, pin 5 acts as inverting end and pin 6 acts as non-inverting, pin 8 is the input, pin 4 is grounded.

Comparator is given to the mono stable multivibrator. Mono stable multivibrator is a NE555 N IC used as timer to make all light glows for 3 seconds.

WPT system

Here the analysis is been made with inductive WPT, it consist of micro controller -16F684 used to provide commands to the H-Bridge module to produce a pulsating dc from constant 12V DC supply. But the microcontroller work at 5V, so a voltage regulator 7805 is used to regulate the supply with constant 5V. From voltage regulator 5V supply is given to both microcontroller and sensors. Sensor detects the presences of vehicle and gives the signal to microcontroller and microcontroller gives command to relay. Relay used here, acts as a switch which will work only on the signal from sensor. So if a vehicle is present sensor gives signal to relay and relay turns ON. H-Bridge works based on the gate signal from microcontroller. So as the microcontroller can provide opposing signals (1 and 0). H-Bridge pulsate the DC and a varying magnetic field is produced in the primary coil, the primary coil is connected to the battery at road system and the secondary coil will be in EV's. As a result of flux linkage variation, mutual induction occurs between primary and secondary coils, an EMF is induced in secondary coil and wireless charging is enabled. The induced EMF in secondary coil is turned into constant DC with a bridge rectifier and gets stored in the battery inside EV. H-bridge consists of 4 transistors connected reciprocate (1-4 and 2-3) are connected. When a true (1) is given to A and 0 to B, current passes through transistor 1 and through inductor and then to transistor 3. Transistor 2 and 3 remains OFF condition. Similarly when a true signal is given to B current pass through transistor 2, then through inductor but in opposite direction and then through transistor 3. Transistor 1 and 4 remains in OFF condition. By this way a pulsating DC with high frequency is produced from constant DC (figure 5).

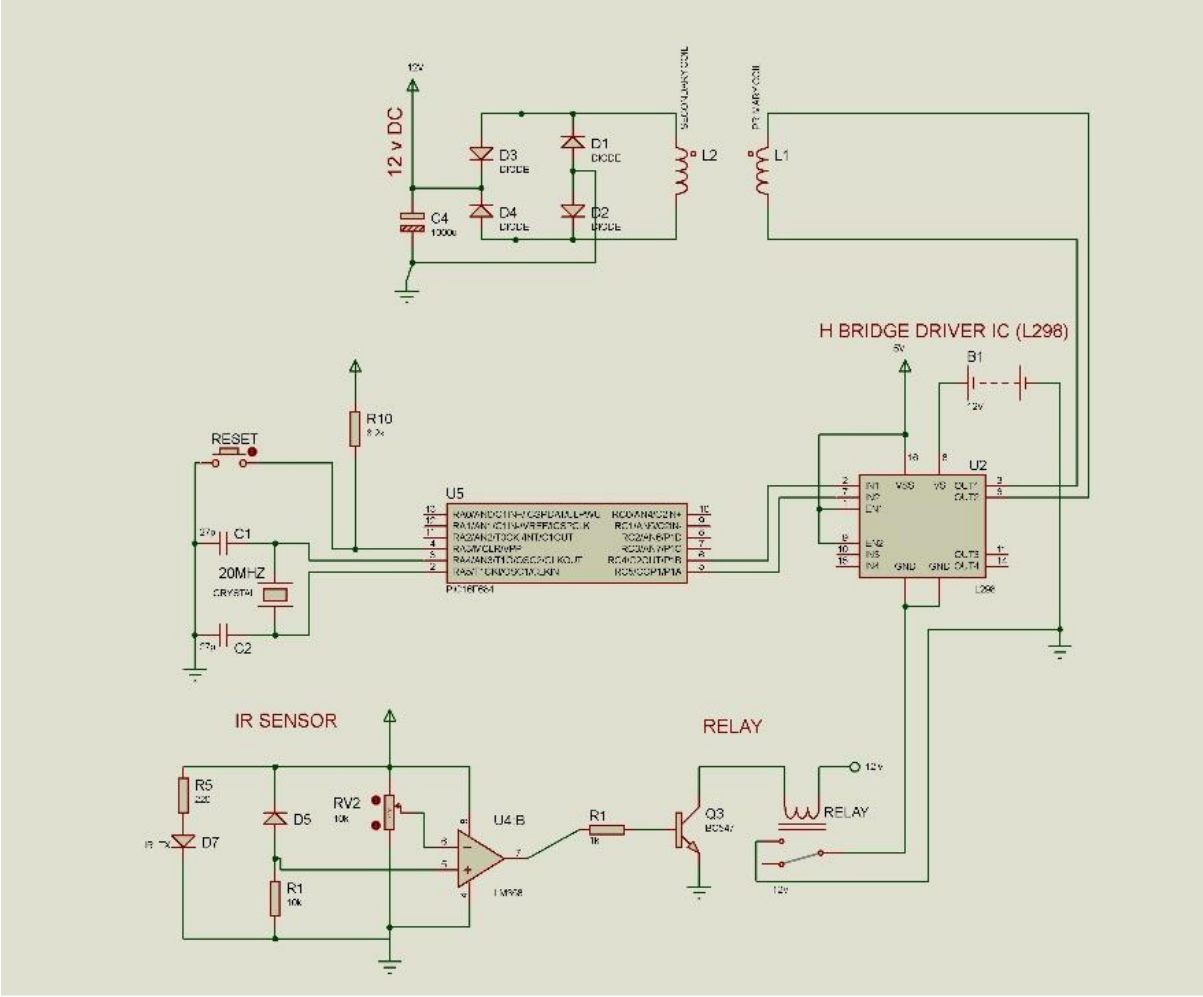

Figure 5 Circuit Diagram of WPT system

It consists of a microcontroller PIC16F684, clock signal is given by 20MHz crystal oscillator. Signal from microcontroller is given to H-bridge L298, for induction based transfer, the DC stored in the battery is inverted to AC with high frequency using H-Bridge module, and then it is transferred to EV. The primary side of circuit diagram has an IR sensor which detects the presence of a vehicle, which is connected to the 12V relay. Here relay acts as a switch which makes the H-bridge turn on, when it receives signal from PIC16F684 micro controller which will be mutually opposite (1 and 0). High frequency AC from H-bridge is given to primary coil. On secondary side, due to mutual induction change in flux in 1° coil will create an induced emf in 2° coil. This induced emf is rectified using a bridge rectifier and approximately 12V DC (considering 100% efficiency) is received as output (with primary 100 turns and secondary 200 turns).

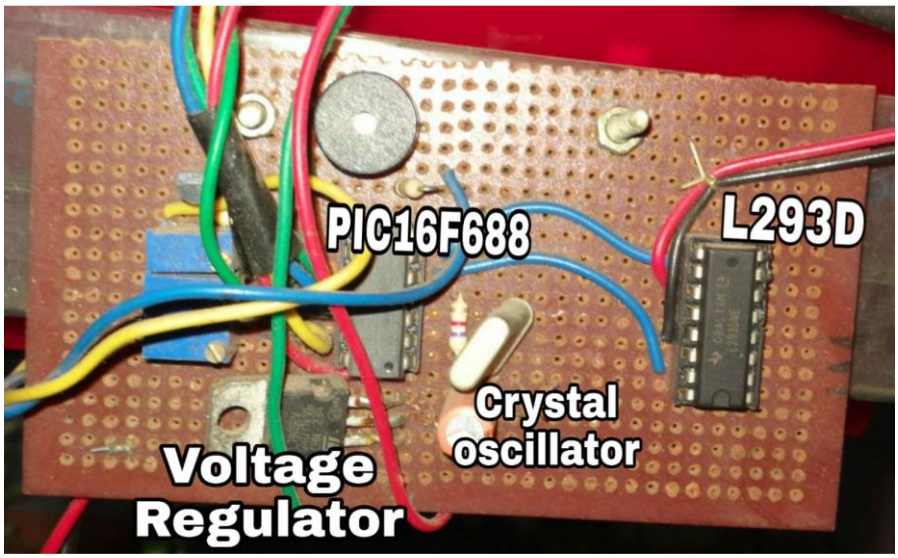

Figure 6 Solar actuator

The Figure 6 shows the experimental setup solar actuator in solar panel. It consists of a PIC16F688 microcontroller used as driver IC. Signal from driver IC is given to L293D motor driver. Voltage regulator is used to make voltage of all components compatible. A 20MHz crystal oscillator is used to give clock pulse to PIC microcontroller. A buzzer is used to provide sound based on rotation of panel. A preset is used to provide varying resistance to the circuit.

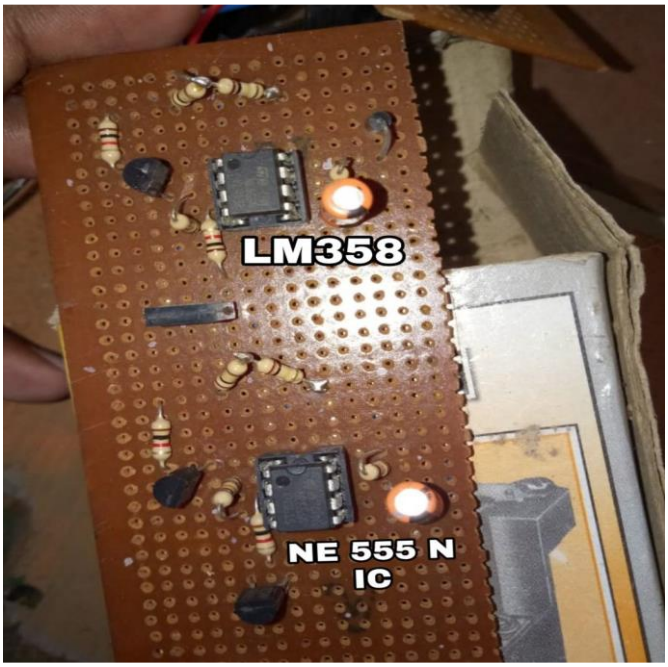

Figure 7 Automatic street lighting system

The Figure 7 shows the experimental setup in automatic street light system. It consists of a LM358 comparator with 8 pins which reads the signal from sensor used for motion detection and day light sensing. LM358 comparator is connected to NE555 N timer IC used to provide clock pulse. AND gate is created using two transistors and circuit also have further accessory components like resistors and two electrolytic capacitors.

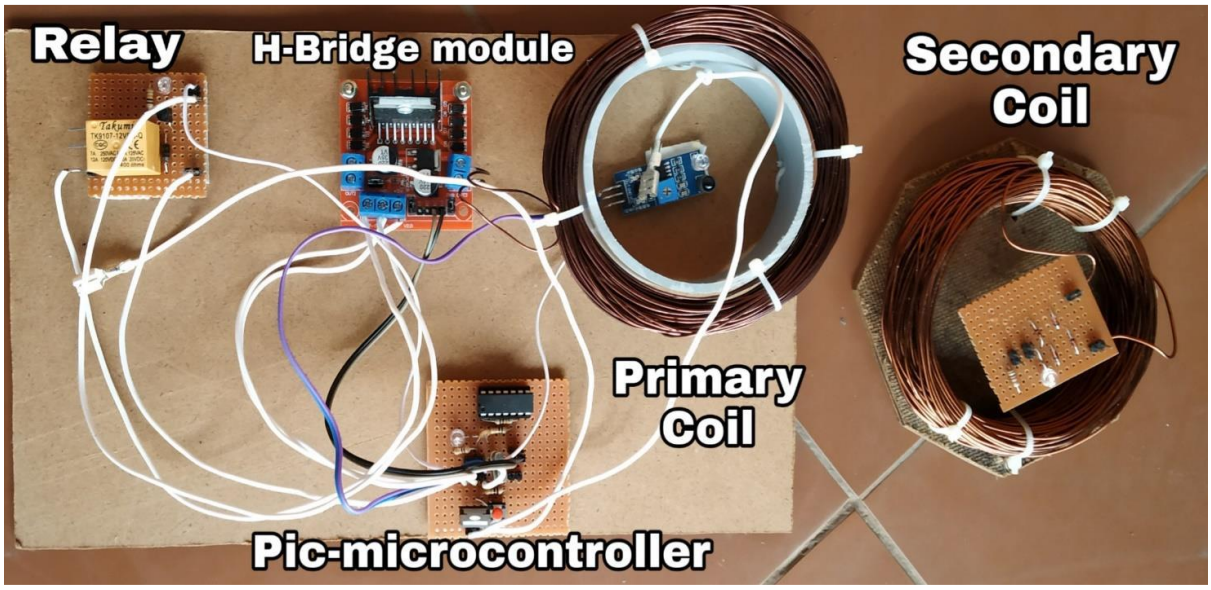

Figure 8 Wireless Power transfer (WPT)

The figure 8 shows the experimental setup of WPT. Primary circuit consist of a PIC16F684 microcontroller. A clock pulse is given by a crystal oscillator to PIC microcontroller. Signal from microcontroller is given to H-bridge. The whole circuit will work as per the signal of relay which is connected to IR sensor. Relay acts as a switch, the Pulsating DC signals from H-bridge is given to primary coil of 100 turns (copper coils of 21 gauges). Secondary coil consist of 200 turns (23 gauge copper coil) connected to bridge rectifier which converts AC to DC output. The overall system is shown in figure 9

Figure 9 Overall system combining streetlight automation, MPPT and WPT

The speed breaker arrangement is made in between the two roadways shown above, whenever a vehicles gets over the speed breaker the piston below will move the magnet and the coil present around the magnet obtains an induced emf. This emf is rectified and stored in the battery.

3. CONCLUSION

'One man one vehicle' a norm arising in our present society. By priority to increase in number of vehicles, it is clear that the necessity of increase in number of roadways. Based on emerging nocturnal lifestyle of cities, the need for lighting our road ways is a sole responsibility. So the amount of electricity for this purpose gets waste and unending. Here a model is developed as a self-sustaining road system to serve this purpose. Referring to phrase self-sustaining means to meet both production and conservation requirements. By meaning conservation a fully automatic street light system which avoids wastage of electricity by timely switching is obtained. And another important feature is that, a street light which can vary intensity based on density of roads is made practical. The electricity is produced from road speed breaker is energy pool where lots of kinetic energy was being wasted, so by simple law of Electromagnetic induction this wastage is used to produce electricity. But this energy may not be up to our requirement for self-sustenance, so solar actuators which can track the direction of sun is made parallel with speed breaker for energy production. This model is a cost effective and totally efficient prototype for production and conservation of energy from road system. Moreover, it depends on basic principles of energy production technique rather than depending complex technique, which is fully renewable. So when our society is in a bottle-neck of energy scarcity, this model may be a complete solution for energy requirement in roads, which may reduce burden to existing conventional power grids. When this conservation and production lead to surplus energy availability, an idea of using this surplus energy is thought. So in a road, vehicles are the key part; based on present rate of fuel consumption, our society is not far from total fuel depletion. HEVs and EVs are gaining much importance in our road transport system, but charging these vehicles for a long drive, faces difficulty which can be resolved by this wireless charging technique Coming to solar panel, by enabling MPPT the major limiting feature of solar panel is low efficiency can be overcome, so it is far more economical. As the Earth's population continues to grow, the demand for electricity will outpace the ability to produce it and transmit it around world.

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Conflicts of Interest: The authors declare no conflict of interest.

Supplementary

Algorithm for WPT charging

STEP 1: Start
STEP 2: Set timer
STEP 3: Set pins A and C
STEP 4: Declare values of
GIE=1
PEIE=1
TMR2IE=1
STEP 5: Give pre calculated value for PR2=49
STEP 6: Provide first and second bits of duty cycle value to CCPICON (0X0C)
STEP 7: Provide remaining 8 bits to CCPR1L (0X19)
STEP 8: Give PIM1=1 and PIM0=0 to make microcontroller work in half bridge mode
STEP 9: Set TMR2 to 0X00
STEP 10: On the timer (TMR2ON=1)
STEP 11: If all conditions are true, enable the while loop
STEP 12: Stop

Program for WPT charging

```
#include<pic.h>
void interrupt timer()
```

```
{
if(TMR2IF==1)
{
TMR2IF=0;
//CCP1CON=0x0C;
//CCPR1L =0x19;
//PR2=49; //20MHz crystal equivalent value
//P1M1=1;P1M0=0;
}
}
void main()
{
TRISA=0x00;
TRISC=0x00;
GIE=1;
PEIE=1;
TMR2IE=1;
PR2=49; //Frequency 100Khz & 20mhz crystal equivalent value
//Frequency 100Khz SO.. Time period is 10uc.
/* Duty cycle value here is 50% = 5 uc. We get 100 by calculation */
/* We need to load 100 in CCP1RL:CCP1CON<5:4> */
/* ie value here get is 100 = {00011001:00} */
CCP1CON=0x0C; //C IS PWM mode selection & 0 is the 1st & 2nd bits of duty cycle value (:00)
CCPR1L = 0x19; // 0x19 is the remaining 8 bits (00011001:)
P1M1=1;P1M0=0;
T2CON=0x00; //TMR2ON=1 , prescaler - 1
TMR2=0X00;
TMR2ON=1;
while(1)
{
}
}
```

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