Smart Automated and Connected Highway Engineering Technologies

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Abstract: The project SACHET (Smart Automated and Connected Highway Engineering Technologies) proposes various software-based methodologies for the optimization of electrified highways. Smart technology is adapted to make use of vibrational sensors embedded on the body of the vehicle in order to detect an accident as well as to relay information to respective family members and necessary services. Implementation of automated highway lighting which involves variation of light intensity based on the proximity of the electric vehicles to them in order to conserve energy has also been done. Hence, a proper connected set-up has been established which has resulted in optimization of highways. The simulation of respective circuits have been done using Proteus and Arduino software. Moreover, introduction of optimized electricity priority lanes to charge batteries of electric vehicles efficiently during motion on electrified highways to help travel longer distances, in order to overcome the biggest drawback of electrical vehicles i.e. time consuming charging, by employing the concept of DWPT(Dynamic Wireless Power Transfer) on MATLAB software using diverse engineering technologies has been proposed to save time and energy in a more efficient and environment friendly manner.

Keywords: highway, accident detection, DWPT, smart lighting

1. INTRODUCTION

The project SACHET (Smart Automated and Connected Highway Engineering Technologies) aims to optimize highways by making use of various software-based methodologies.

Due to the surge in reckless as well as careless driving and lots of other cumulative factors like increment in motorization growth rate across the globe, rapid expansion of road networks, increase in traffic, rapid urbanization as well as rise in demand for automobiles, the occurrence of road accidents has become quite common nowadays. It has been stated in [1] that majority of the accident deaths occur due to the dearth of immediate medical assistance especially on highways. In order to rescue wounded people, an efficient road accident detection and alert system is required. Thus comes the thought of an alert system that senses the accident and its seriousness to alert the family members of the victim or anyone else whose number has been pre stored within the system module so that medical aid as well as various other necessary services can be dispatched on time to the accident area and the same has been demonstrated with the help of our project.

The various limitations of power battery technology have limited the driving range of electric vehicles which has resulted into an increasing need for power battery charging. Moreover, existence of electrical security risks in case of plug-in charging has led to the introduction of wireless power transmission (WPT) charging process which is more safe and convenient as there is no connection between the source and load. WPT charging process has been further classified into static wireless power transmission (SWPT) and dynamic wireless power transmission (DWPT) out of which the latter one is better due to improved cruising range, reduced volume of the vehicle battery pack, and further improvement in the flexibility of the charging process [2]. This paper proposes a segmented dynamic wireless charging system of electric vehicle (EV) and a small scale model including resonant network module, rectifier filter module and primary as well as secondary circuit for efficient charging of electric vehicles in motion in an environment friendly manner.

Since the light is turned on continuously during night time in most of the countries irrespective of the road's occupancy, highway lighting often ends up consuming enormous amount of electrical energy. Generally, an inefficient lighting system incapable of adapting to traffic conditions is responsible for this excessive energy consumption. If hundred million street lights exist in such a way that they are always turned on with each light consuming 0.02 kW then it is mathematically estimated that energy consumption figure is equivalent to 0.8% of annual electrical energy consumption in Japan. In reality, such figures can be very high in other countries, e.g., Spain, France, and Germany have total power consumption of 116, 91, and 43 kW, respectively, per street light on an annual basis. Approximately 5.1 × 106 kW power is estimated to be consumed in USA on a roadway per hour [3]. Majority of street lights installed in cities as well as highways make use of constant illumination lighting during the entire night, which not only causes large energy waste, but also results in loss of lamp life. This paper proposes a circuit with PWM at its pinnacle, and via this improvisation we can maintain minimum intensity of lights without completely switching them off and on detection of motion, the lights can be switched to maximum intensity. Therefore, the system can still meet the lighting requirements while ensuring traffic safety and saving energy at the same time. Hence, the implementation as well as integration of these methodologies will lead to optimization of highways.

2. LITERATURE REVIEW

In [4], Shivangi Sharma et al. have proposed an IoT-based model along with integration of intelligent sensors with microcontrollers inside the car to locate the accidents' site and send it to the recorded number and nearby medical centers to report them about the accident in order to receive help immediately. In [5], G. Liang has proposed automatic traffic accident detection by utilizing Support Vector Machine (SVM) changed by Ant Colony Algorithm (ACA); for the prediction of traffic accidents. They made use of RFID Technology and wireless communication, and observed that SVM reformed by ACA could achieve faster-merging speed. In [6], Fizzah Bhatti et al. has designed an Intelligent Transportation model for Smart City Atmospheres by using car and hospital databases for collection of information by utilizing ICT for well-organized and quick rescue operations. In [7], Nimish Agarwal et al. have proposed a deep learning model which relies on cameras for instant detection of accidents. In [8], Elie Nasr, Elie Kfoury, and David Khoury have come up with a public safety agency model utilizing IoT and GPS for collision detection using a shock sensor or airbag deployment. High false-positive rate leads to inaccuracy when it comes to accident detection.

At present, the significance of optimization of the charging power and coil segment allocation is pivotal for an efficient DWPT system. In the literature [9], the authors have proposed the implementation of WPT by fabrication of a highly efficient nonlinear parity-time (PT)-symmetric model. When this system was theoretically analyzed, it was found that it automatically achieves a constant output power in addition to a constant transfer efficiency when the coupling coefficient was varied accordingly. The authors of [10] proposed an optimal power distribution scheme to accomplish the construction of multi-objective WPT systems, without communication networks. In the literature [11], Liu et al. concluded that the control of transfer power can be achieved by the regulation of either the phase-shift angle or the direct current (DC)-link voltage. Therefore, a combined control method is proposed which utilizes these two parameters to achieve higher system efficiency, well defined dynamic response, and increment in the adjustable power range. In the literature [12], an efficient method for determination of charging area has been proposed to be implemented in the double excitation unit wireless power transmission system to accomplish dynamic charging of EV. When the EV enters the charging area, the switching of the work mode of the system is achieved by the proposed switching control method which helps in improving the system power capacity, without augmentation of the current and voltage stress. The authors of [13] used a concept based on the particle swarm genetic algorithm by treating power supply rail's length and energy storage devices as constraints to find the minimum investment cost of the EV's dynamic wireless charging system by analyzing the features of the super-capacitor as well as the driving characteristics of the EVs. In the literature [14], Jiang et al. proposed the realization of the constant current (CC) charging for the battery by achieving the zero voltage switching (ZVS) operation of the primary inverter with the help of a control strategy incorporating a zero voltage switching angle (ZVSA) loop. In [15], the authors proposed a system for the optimal allocation of WPT system in a lane segment along with design of an improved EV speed profile which is based on mathematical optimization of these parameters.

In recent years, existing research efforts have mostly focused on efficiently managing the energy consumption of the street lights. Most of the fundamental studies adopted a sensor-based approach where real-time pedestrian and traffic sensing features were incorporated. Comparison of various dimming strategies (scheduled as well as real-time) was done by Pinto et al. [16] and he observed that real-time traffic-based lighting helps in saving energy. Leccese et al. [17] developed a connected lighting system which exploited ZigBee technology and local sensors for accumulation of data. Elejoste et al. [18] gathered traffic and weather information as part of the smart lighting solution by deployment of various sensors. Marino et al. [19] fabricated a model implementing a lighting control strategy which used models based on prediction of traffic. Even though proper illumination was considered pivotal, the aspects of the driver's comfort and fault detection were not addressed. Mustafa et al. [20] used a probabilistic model for the traffic by division of the road into sections. For a given section, whenever the lampposts are occupied by vehicles, they are turned ON and turned OFF or dimmed otherwise. While the energy consumption was reduced significantly, the system did not consider the driver's comfort aspect when it comes to the instantaneous switching of lampposts from one section to another.

Our proposed system aims at implementation of various methodologies like accident detection and alert system, smart lighting system and charging of EVs by DWPT based model altogether in a single project to optimize highways which has not been done before.

3. METHODOLOGY AND DESIGN

3.1 Accident Detection and Alert System

The **S**mart technology is adapted to make use of vibrational sensors embedded on the body of the vehicle in order to detect an accident as well as to relay information to respective family members and necessary services. The vibration sensor acts as an accident detection module by observing the vibrations of the vehicle and further sends the information to the micro controller when an accident occurs. Arduino has been used as a controller in this system for controlling all the modules in the circuit. The two pivotal modules of this system are the GPS module and the GSM module. The GPS module is responsible for receiving the respective coordinates of the vehicle after the occurrence of the accident and the received coordinates are sent to the respective pre-stored numbers of the family members or necessary services by the GSM module through SMS. An additional component namely LCD has been used for displaying status message or coordinates as shown in the block diagram depicted in figure 1.

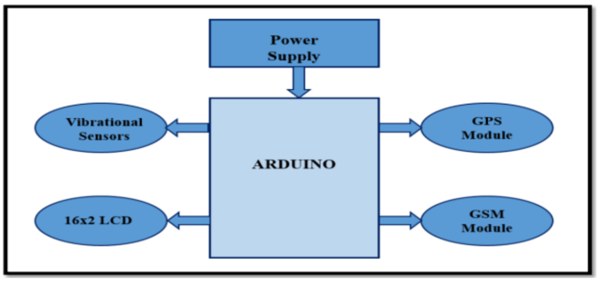

Figure 1: Block diagram of accident detection and alert system

In this proposed system, Arduino Uno has been used as the main controller of the entire circuit because with it programs can be directly loaded into the device without the need of a hardware programmer to burn the program. Vibration Sensor (SW-420) has been used because it is a high sensitivity non-directional vibration sensor, hence accident detection can be done more optimally as compared to other sensors. Sim900D GSM module has been used because it is cheap yet provides reliable transfer rate of data while consuming very low power. It has various other benefits which makes it the most suitable choice for our project. Transmitting pin of GPS module and receiving pin of GSM module are used for communication between the modules and the mobile phone. This system has been further modified by including an additional Google-map link which is sent along with the accident area's coordinates to the pre-stored numbers resulting in the reduction of the response time of emergency services.

3.2 Dynamic Wireless Power Transfer System

3.2.1 Coupling

Using the magnetic coupler, the power can be transferred from the primary side to the secondary side by utilizing the theory of magnetic coupling, acoustic coupling or resonant coupling. To improve the efficiency of energy transfer between inductively coupled circuits, the proposed system uses resonant circuits with an inductive coupling.

3.2.2 Circuit

It consists of the primary circuit with L1 inductance (power supply) and the secondary circuit with L2 inductance (receiving coil). A magnetic field is created when alternating current flows in the primary circuit, which in turn induces a voltage in the receiving circuit that is used as an energy source for powering devices or for charging the batteries of the EVs. In order to achieve more power handling by inductive coupling DWPT, the number of winding (both in primary and secondary) have been increased.

3.2.3 Compensation Topology

Many topologies can be used for various applications in DWPT systems, in order to achieve the resonance mode of the associated systems. The capacitor added in the emitting side compensates the total impedance whereas the capacitor in the secondary side helps reach the resonance mode operation. In this system, the chosen topology is a Series-Series (SS) compensation because it is the most suited topology for dynamic wireless charging as analyzed in [21].

3.2.4 Implementation

The implementation of DWPT system can be achieved by means of either of the two arrangements of the transmitting side such as segmented coil arrays (multiple power sources are applied in order to transfer energy to the vehicles) or single long transmitter track (single power source transfers energy to the receiver side). In case of single-track transmitter pad, it is easier to implement and control power output, however there is a huge leakage of power and low coupling coefficient associated with this approach, which results in harmful exposure. Therefore, segmented coil array transmitter side has been applied for the construction of this dynamic wireless charging system as this configuration is more efficient in terms of power transfer.

3.3 Smart Highway Lighting System

In this proposed system, Arduino Uno has been used as the main controller of the entire circuit because with it programs can be directly loaded into the device without the need of a hardware programmer to burn the program. The lighting system consists of LEDs which are cheap and efficient as well. BJT (2N1711) have been used for switching purpose because it is a silicon Planar Epitaxial NPN transistor in Jedec TO-39 metal case which is intended for use in high performance amplifier, oscillator and switching circuits. Hence, this transistor is useful for optimum switching to provide desired results. A low cost yet reliable LDR model has been used for light detection so that the simplicity of the circuit can be maintained while increasing efficiency of the circuit by employing intensity variation based on the Pulse Width Modulation (PWM) technique. At night, when motion is detected, the lights glow with maximum intensity, otherwise they still do remain on but at minimum intensity. So, our proposed system is not only cheap but its efficient functioning helps in conserving energy in a more reliable manner.

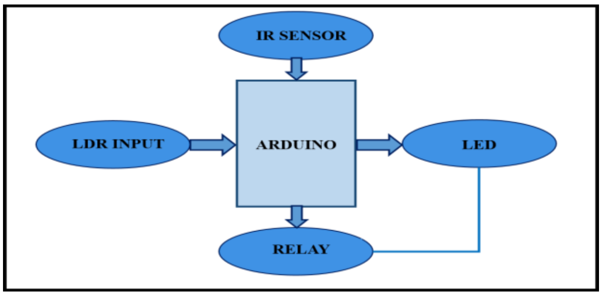

Figure 2: Block diagram of smart highway lighting system

4. MATHEMATICAL MODELLING

The effect of resonant frequency on the system transmission efficiency and output power, effect of transmission distance on system transmission efficiency and the output power as well as the effect of load resistance on system transmission efficiency and output power has been evaluated correctly using the equations mentioned in [22]. Calculation of various important parameters has also been done using the formulae mentioned in [23].

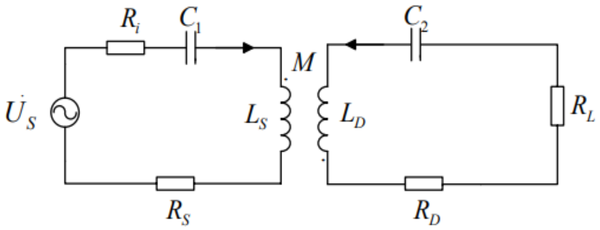

Figure 3: The simplified circuit diagram of DWPT system

The following parameters with their respective values have been considered in the mathematical modelling of our project to obtain optimal result:

1. N=Number of turns(25)
2. D=Diameter of coil (7.6cm)
3. r=Radius of wire in coil(3.5mm)
4. ρ=resistivity of material(Ω·m)(1.72x10^-8)
5. L=length of coil(750cm)
6. A=cross-section area of wire in coil(πr^2)
7. Resistance(R)=ρ L/A(ohm)
8. R1=resistance of primary coil(0.0714ohm)
9. R2=resistance of secondary coil(0.0714ohm)
10. Rm=mutual resistance of coil(Rm=R1+R2)(0.1428ohm)
11. k=mutual coupling(between 0.1 to 0.5)
12. Lm=k√L1L2(k=0.2)
13. L=Inductance of coil

Calculation of L1 and L2:
L1=N1^2 R1 u0 ur [ln(8R1/r)-2]=(73.43uH) (1)
L2=N2^2 R2 u0 ur [ln(8R2/r)-2]=(73.43uH) (2)
The value of C1L1 and RL can be calculated as follows:
C1L1=C2L2 where, (C1 or C2=0.2uF) (3)
RL=100 ohm

Calculation of resonance frequency can be done as shown below:
Resonance frequency, fr=1/(2π √LC) (4)
Here, L=73.43uH and C=0.2uF, then
fr= 1/(2π √(73.43x10^-6)(0.2x10^-6))
fr= 41530 hz (nearly 41.5khz)
Vs= (R1+Rs+jwL1+1/jwc1)I1+jwMI2 (5)
0= (RL+R2+jwL2+1/jwc2)I2+jwMI1 (6)
Now consider,
Z1=R1+Rs+jwL1+(1/jwc1) (7)
Z2=RL+R2+jwL2+(1/jwc2) (8)
Vs= Z1I1+jwMI2
I2=-(jwMI1)/Z2
Vs= Z1I1+jwM(-jwMI1/Z2)
I1=VsZ2/(Z1Z2+w^2M^2) (9)
I2= -jwMVs/(Z1Z2+w^2M^2) (10)
Now for input power,

P_{input}= $(Z2Vs)^2/[Z1Z2+(wM)^2]$ (11)
Now for output power,

P_{out}= $w^2M^2Vs^2RL/[Z1Z2+(wM)^2]^2$ (12)
Now for efficiency, η= (P_{out}/P_{input}) x100 (13)

η= $[w^2M^2RLx100]/[Z2\{Z1Z2+(wM)^2\}]$% (14)

At resonance frequency, capacitive reactance cancels out the effect of inductive reactance:
Z1=R1+Rs=0.0714 ohm (15)
Similarly, Z2=100.0714 ohm (16)
RL=100 ohm; F=41500 Hz
M=k√L1L2=1.468x10^-5 H (17)
η=$[w^2M^2RLx100]/[Z2\{Z1Z2+(wM)^2\}]$% (18)

$$\eta = \frac{[(2\pi\times41500\times1.468\times10^{\wedge}-5)^2\times(100)]\times100\%}{100.0714[(0.0714\times100.0714)+(2x\ \pi\ x\ 41500\ x\ 1.468\ x\ 10^{\wedge}-5)]}$$

$$\eta = \frac{(1465.23)x100\%}{(2181.07)}$$

η=67.18%

5. SIMULATION AND RESULT

5.1 Accident Detection and Alert System

5.1.1 Simulation

The simulation of circuit diagram of the proposed accident detection and alert system has been done using Proteus software whereas the coding part has been done in Arduino software.

In case of the software-based simulation, when an accident occurs, it is detected by the vibrational sensor module and the LCD display shows the message "Accident Detect alert system" i.e. accident detection has been completed and a virtual terminal appears on the screen as well as shown in figure 4.

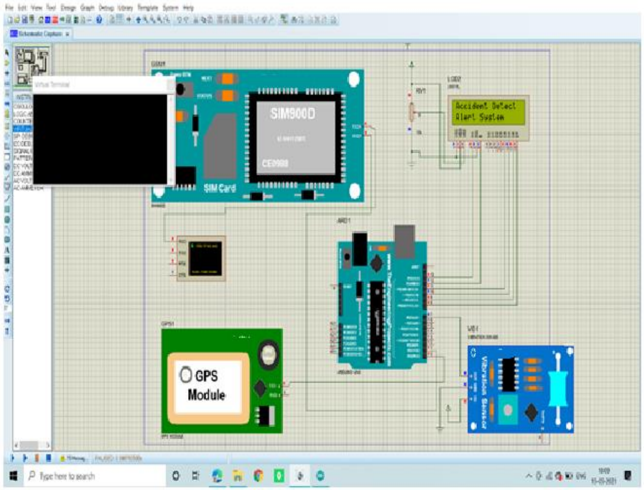

Figure 4: Accident has been detected successfully

Simultaneously, the GPS module and GSM module gets activated and the LCD display shows the message "Sending SMS" when the accident area's coordinates are being sent to the pre-stored number as shown in figure 5.

The virtual terminal then shows the message that pops up on the screen of the pre-stored numbers of the family members and necessary services, containing the coordinates of the accident area and a Google map link as well directly guiding to the accident location, so that medical aid can reach the victim without any delay as shown in figure 6.

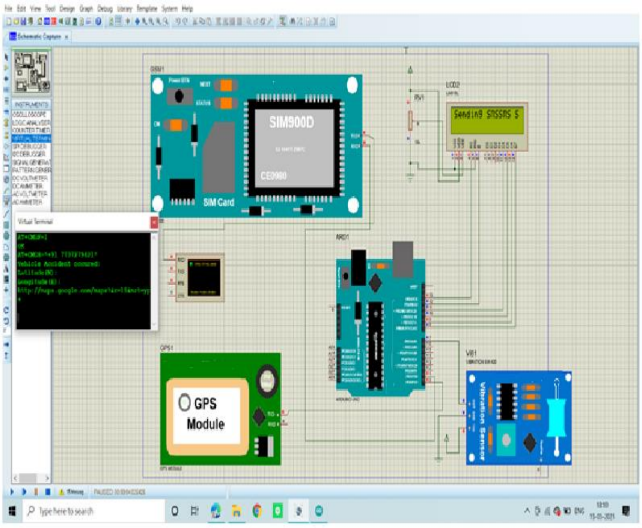

Figure 5: Accident alert message being sent to the pre-stored numbers

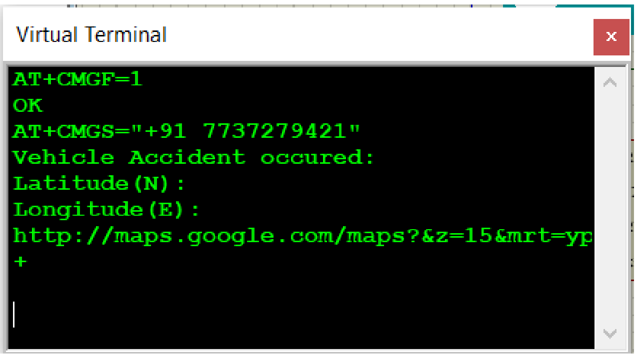

Figure 6: Virtual terminal depicting successful execution of the program

5.1.2 Result

The expected performance is achieved through implementation of the proposed system. The sensor and other required components are distributed throughout the car providing more optimal results to detect accidents. A Google-map link along with the accident area's coordinates is also sent to the pre-stored numbers using GPS and GSM modules resulting in the reduction of the response time of emergency services which reduces the casualties to a minimum and prevents loss of life to its maximum. Overall, this low-cost system helps in saving various assets, out of which human life is the most valuable one.

5.2 Dynamic Wireless Power Transfer System

5.2.1 Simulation

Simulation of the optimized DWPT system with desired characteristics has been done on MATLAB software as shown in the following figures.

The rectifier module has been designed properly and simulated as well as shown in figure 7.

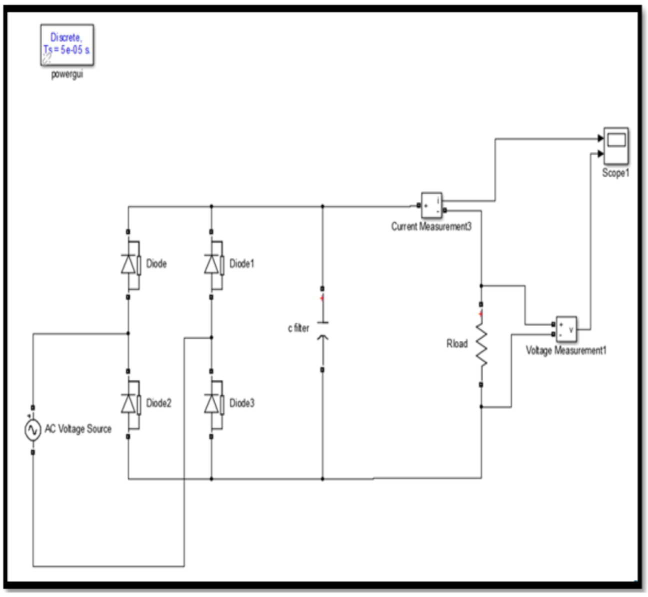

Figure 7: Simulation of rectifier circuit of DWPT system

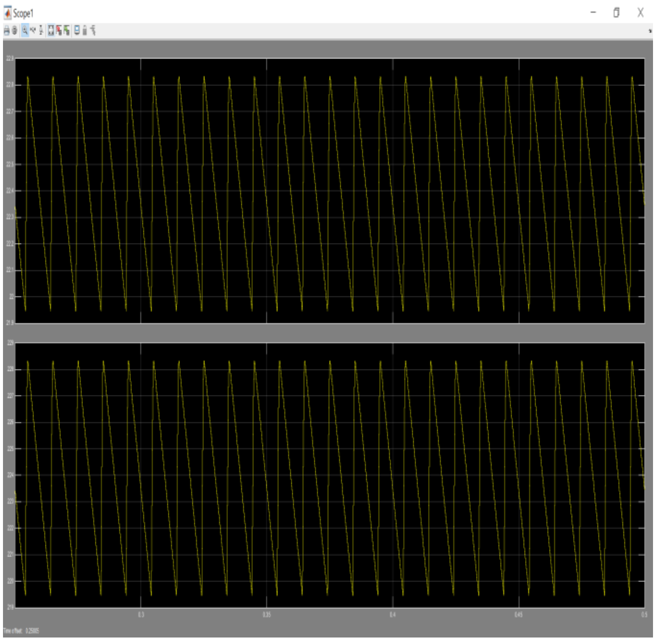

Figure 8: Waveform at rectifier scope 1

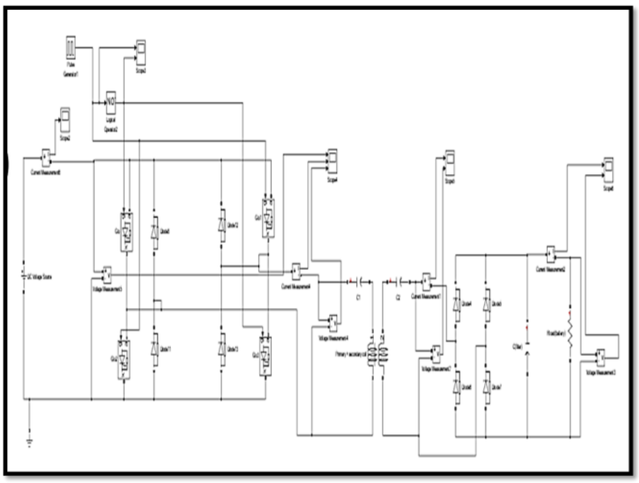

Figure 9: Simulation of entire circuit diagram comprising of primary and secondary circuit

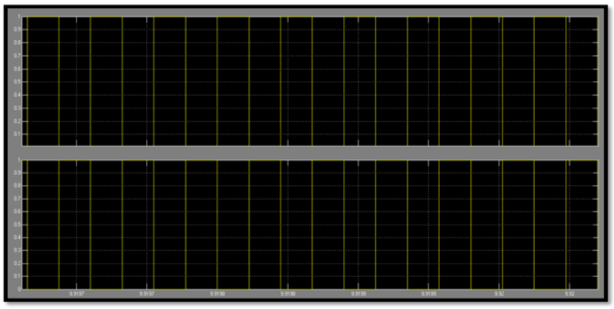

Figure 10: Waveform at pulse generator scope3

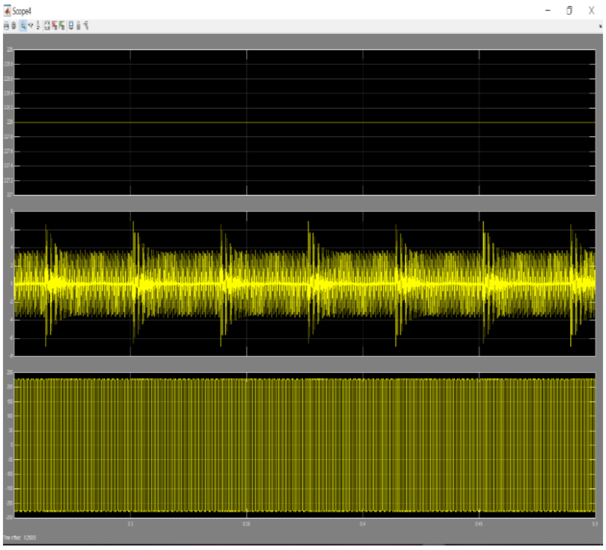

Figure 11: Waveform at primary side scope4

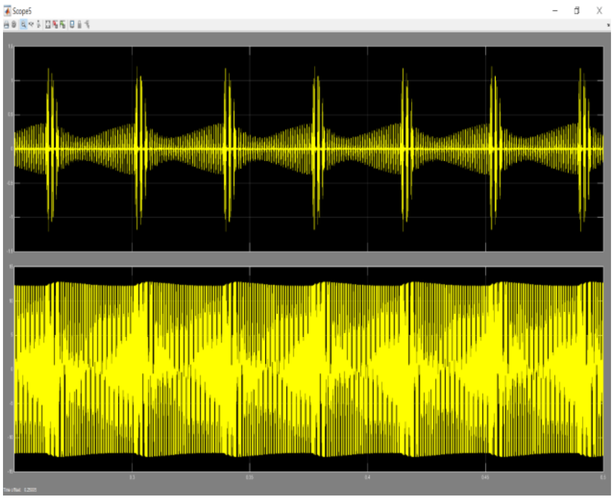

Figure 12: Waveform at secondary side scope5

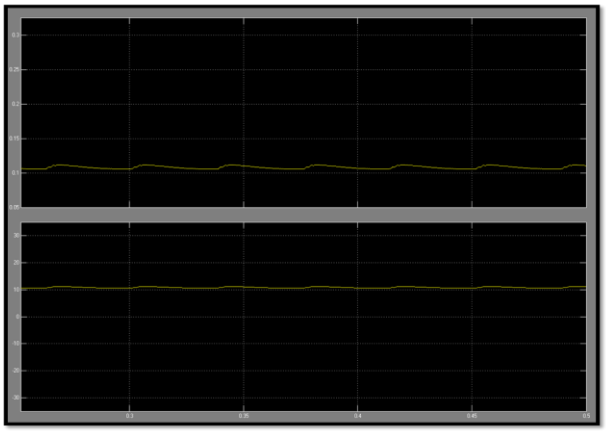

Figure 13: Output waveform at scope6

Table 1: Obtained measurements of various parameters

PARAMETER	VOLTAGE LEVEL
SUPPLY AT RECTIFIER	230V,AC
OUTPUT VOLTAGE AT RECTIFIER	228V,DC
INPUT TO THE INVERTER	228V,DC
OUTPUT OF THE INVERTER	228V,AC
VOLTAGE TO PRIMARY COIL	228V,AC
VOLTAGE AT SECONDARY COIL	16V,AC
FINAL OUTPUT VOLTAGE AT RECTIFIER	12V,DC

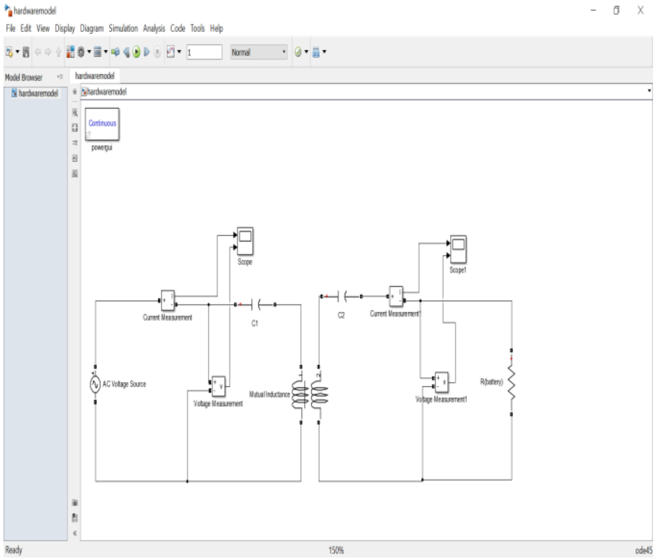

Figure 14: Small-scale model of the proposed DWPT System

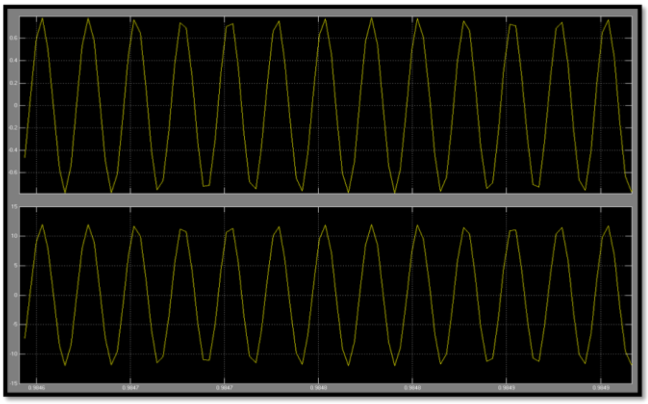

Figure 15: Waveform at primary side scope

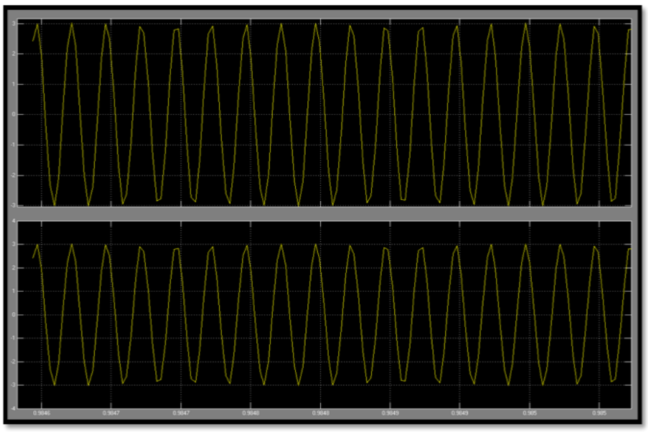

Figure 16: Waveform at secondary side scope1 at resonance frequency

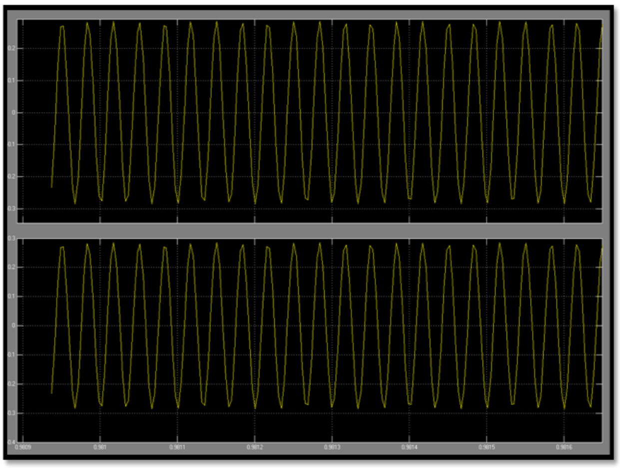

Figure 17: Waveform at secondary side scope1 at non-resonance frequency (39926 Hz)

5.2.2 Result

A segmented dynamic wireless charging system of electric vehicle has been analysed as well as designed properly, and a small scale model including resonant network module, rectifier filter module and primary as well as secondary circuit has been established. Various parameters like maximum transmission efficiency have been measured and calculated in an error-free manner. The simulation and model calculation results are basically the same, which verifies the accuracy of the established model. The results of the designed model are consistent with the simulation results, indicating that the established DWPT model is reliable.

5.3 Smart Highway Lighting System

5.3.1 Simulation

The coding part of the project has been done in Arduino software whereas the simulation of circuit diagram of the proposed smart highway lighting system using Proteus software has been shown in figure 18.

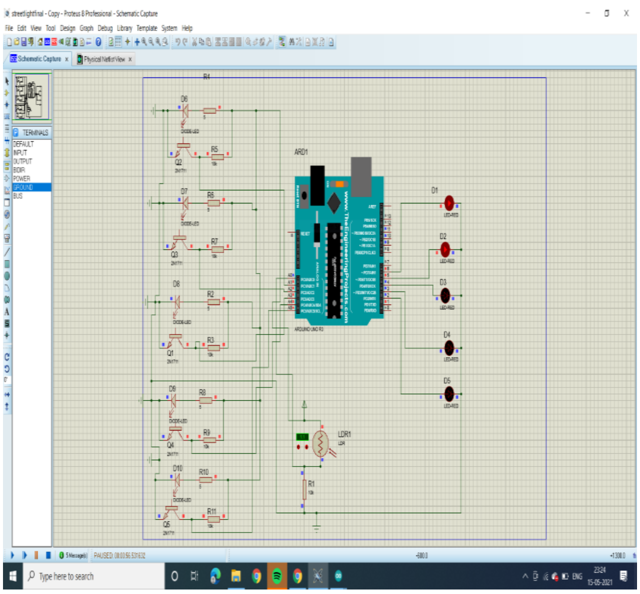

Figure 18: Simulation of circuit diagram of smart highway lighting system in Proteus

5.3.2 Result

To overcome the energy wastage occurring at general highways due to complete switching of lights, we have introduced a circuit with PWM at its pinnacle, via this improvisation one can maintain minimum intensity without completely switching off the lights and switching them on to maximum intensity whenever it detects motion. The simulation results achieved by our project are in accordance with the desired characteristics. Hence, optimization of smart highway lighting has been done successfully.

6. CONCLUSION

The project SACHET (Smart Automated and Connected Highway Engineering Technologies) has proposed various software-based methodologies for the optimisation of electrified highways. All of the proposed models (accident detection and alert system, DWPT based model for charging of EVs and smart highway lighting system) have been successfully simulated and the results are in accordance with the desired characteristics, thus leading to successful optimization of highways by employing these systems altogether. Moreover, mathematical modelling of the DWPT based charging system of EVs resulted in an efficiency of 67.18% at a resonant frequency of approximately 41.5 kHz by regulating the load resistance to an optimal value which was verified by simulation of the system in MATLAB as well. Hence, a proper connected set-up has been established which has resulted in optimisation of highways using diverse engineering technologies to save time and energy in a more efficient and environment friendly manner; thus making project SACHET a success.

REFERENCES

[1] N. Kattukkaran, A. George and T. Haridas, "Intelligent accident detection and alert system for emergency medical assistance", 2017 International Conference on Computer Communication and Informatics (ICCCI), 2017. Available: 10.1109/iccci.2017.8117791 [Accessed 13 June 2021].
[2] Tan, Linlin et al. “Research on an EV Dynamic Wireless Charging Control Method Adapting to Speed Change.” Energies 12.11 (2019): 2214. Crossref. Web.
[3] M. A. Rahman, A. T. Asyhari, M. S. Obaidat, I. F. Kurniawan, M. Y. Mukta and P. Vijayakumar, "IoT-Enabled Light Intensity-Controlled Seamless Highway Lighting System," in IEEE Systems Journal, vol. 15, no. 1, pp. 46-55, March 2021, doi: 10.1109/JSYST.2020.2975592.
[4] Sharma, Shivani, and Shoney Sebastian. "IoT based car accident detection and notification algorithm for general road accidents." International Journal of Electrical & Computer Engineering (2088-8708) 9.5 (2019).
[5] Liang, G. "Automatic traffic accident detection based on the internet of things and support vector machine." Int. J. Smart Home 9.4 (2015): 97-106.
[6] Bhatti, Fizzah, et al. "A novel internet of things-enabled accident detection and reporting system for smart city environments." Sensors 19.9 (2019): 2071.
[7] Agarwal, Nimish, et al. "Camera-based Smart Traffic State Detection in India using Deep Learning Models." 2021 International Conference on COMmunication Systems & NETworkS (COMSNETS). IEEE, 2021.
[8] Nasr, Elie, Elie Kfoury, and David Khoury. "An IoT approach to vehicle accident detection, reporting, and navigation." 2016 IEEE International Multidisciplinary Conference on Engineering Technology (IMCET). IEEE, 2016.
[9] Zhou, J.; Zhang, B.; Xiao, W.; Qiu, D.; Chen, Y. Nonlinear Parity-Time-Symmetric Model for Constant Efficiency Wireless Power Transfer:

Application to a Drone-in-Flight Wireless Charging Platform. IEEE Trans. Ind. Electron. 2019, 66, 4097–4107.
[10] Zhang, Z.; Tong, R.; Liang, Z.; Liu, C.; Wang, J. Analysis and control of optimal power distribution for multi-objectivewireless charging systems. Energies 2018, 11, 1726.
[11] Liu, F.; Chen, K.; Zhao, Z.; Li, K. Analysis of transmitter-side control methods in wireless EV charging systems. Sci. China Technol. Sci. 2018, 61, 1492–1501.
[12] Dai, X.; Jiang, J.-C.; Wu, J.-Q. Charging Area Determining and Power Enhancement Method for Multiexcitation Unit Configuration of Wirelessly Dynamic Charging EV System. IEEE Trans. Ind. Electron. 2019, 66, 4086–4096.
[13] Sun, Y.; Jiang, C.; Wang, Z.; Tang, C. Optimal Planning of Dynamic Wireless Supply System for Electric Vehicles Based on Particle Swarm Genetic Algorithm. Automation of Electric Power Systems. Autom. Electric Power Syst. 2019, 43, 125–131.
[14] Jiang, Y.; Wang, L.; Wang, Y.; Liu, J.; Li, X.; Ning, G. Analysis, design, and implementation of accurate ZVS angle control for EV battery charging in wireless high-power transfer. IEEE Trans. Ind. Electron. 2019, 66, 4075–4085.
[15] Doan, V.-D.; Koseki, T.; Kishi, H.; Fujimoto, H.; Yasuda, T.; Fujita, T. Simultaneous optimization of speed profile and allocation of wireless power transfer system for autonomous driving electric vehicles. IEEJ J. Ind. Appl. 2018, 7, 189–201.
[16] M. F. Pinto, T. R. Mendonca, F. Coelho, and H. A. Braga, “Economic analysis of a controllable device with smart grid features applied to LED street lighting system,” in Proc. IEEE Int. Symp. Ind. Electron., Sep. 2015, vol. 2015, pp. 1184–1189
[17] F. Leccese, M. Cagnetti, and D. Trinca, “A smart city application: A fully controlled street lighting isle based on Raspberry-Pi card, a ZigBee sensor network and WiMAX,” Sensors, Switzerland, vol. 14, no. 12, pp. 24408– 24424, 2014.
[18] P. Elejoste et al., “An easy to deploy street light control system based on wireless communication and LED technology,” Sensors, vol. 13, no. 5, pp. 6492–6523, 2013.
[19]] F. Marino, F. Leccese, and S. Pizzuti, “Adaptive street lighting predictive control,” Energy Procedia, vol. 111, pp. 790–799, 2017.
[20] A. M. Mustafa, O. M. Abubakr, A. H. Derbala, E. Ahmed, and B. Mokhtar, “Evaluation of a traffic-aware smart highway lighting system,” in Proc. Appl. Future Internet, 2017, vol. 4, no. 1, pp. 2–9.
[21] S. Guerroudj, H. Boulzazen and Z. Riah, "New approach for the evaluation of magnetic fields in dynamic wireless charging for electric vehicles," 2018 IEEE International Conference on Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles & International Transportation Electrification Conference (ESARS-ITEC), 2018, pp. 1-5, doi: 10.1109/ESARS-ITEC.2018.8607456.
[22] Y. Liu, J. Fan, T. Zuo, Y. Zhang, L. Dong and J. Liu, "Simulation study on series model of wireless power transfer via magnetic resonance coupling," 2017 IEEE 3rd Information Technology and Mechatronics Engineering Conference (ITOEC), 2017, pp. 191-195, doi: 10.1109/ITOEC.2017.8122409.
[23] M. Kavitha, P. B. Bobba and D. Prasad, "Comprehensive mathematical modelling and experimental analysis of a wireless power transfer system for neighborhood electric vehicles," 2015 IEEE International WIE Conference on Electrical and Computer Engineering (WIECON-ECE), 2015, pp. 275-279, doi: 10.1109/WIECON-ECE.2015.7443916.