International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN: 2395-1990 | Online ISSN : 2394-4099 (www.ijsrset.com)
doi : https://doi.org/10.32628/IJSRSET

Design and Implementation of Wireless Charging System Using Sandwich Coil and LCC Converter for Smart Electric Vehicle

R. Manimegalai[1], G. Sanjaidharan[2], N. Keerthika[2] , P. Yuvaraj[2]
[1]Assistant Professor, Department of Electrical and Electronics Engineering, RAAK College of Engineering & Technology, Puducherry, India
[2]UG Scholar, Department of Electrical and Electronics Engineering, RAAK College of Engineering & Technology, Puducherry, India

ARTICLEINFO

Article History:
Accepted: 05 April 2023
Published: 28 April 2023

Publication Issue
Volume 10, Issue 2
March-April-2023

Page Number
703-710

ABSTRACT

Wireless power transfer (WPT) is emerging as the preeminent way to charge electric vehicles, but there appears to be no fair way to measure the power transfer. In this article, Faraday coil transfer-power measurement (FC-TPM) is presented. FC-TPM employs non-contact, open-circuited sense coils to measure the electromagnetic field from WPT and calculates the real power propagating through the air gap between the transmitter and receiver coils. What is measured is the real electromagnetic power, representing the pure dispensation of energy that unambiguously demarcates the losses on either side. FC-TPM was demonstrated to be 0.1% accurate in hardware over an Rx coil sandwich of up to 10 cm using a 1-kW WPT system. Fair metering incentivizes businesses and individuals to make choices that conserve energy and advance technology by providing more information and by properly assigning the financial loss. This article is accompanied by a video highlighting the essential contributions of this article.

Keywords : Sandwich coil, LCC Converter

I. INTRODUCTION

The Indian government announced plans to ban the sale of internal combustion propelled vehicles by 2040 in an attempt to decarbonize the transport sector. Countries including France have already announced plans to remove petrol and diesel vehicles from the road with the intention of reducing fumes released and improving air quality. The air quality issue is one of the largest environmental health risks currently facing the UK. It is anticipated that Railway Applications (RA) will provide the main alternative to these vehicles. One of the potential charging infrastructures for this uptake of RA is wireless charging. Wireless charging will aid in mitigating issues faced by existing EV users. These issues include the users need to plug the vehicle in, the vast array of adapters required for the number of different chargers across GB, the number of different smartphone applications and the diminished need for large, valuable cables to be installed in public areas. Wireless charging may also pay a large role in the development autonomous vehicles. These vehicles should not need a user to plug in the vehicle when an operator is not required for the operation of the vehicle. In this scenario, automated cars will

simply park directly over a wireless charger and begin. Wireless charging may also aid in street charging. This is an issue that worries a number of potential users without a personal driveway. Without the access to a private driveway, for example in city's or flats, the plugging in of an EV can become a difficult challenge. With the growing interest in decreasing the fossil fuel utilization and pollution, Railway Applications (RA) have emerged as an applicable alternative to conventional gas engine vehicles. The development and increasing utilization of RA requires widely distributed charging stations due to the limited EV battery capacity.

However, large scale of directly grid-connected charging stations, especially fast and super- fast charging stations, stress power grid stability and reliability with peak demand overload, voltage sag, and power gap issues. Some researchers have been integrating photovoltaic (PV) generation with EV charging infrastructure however, the PV integration is still considered as a minor portion of power source for EV charging stations in researches. As for the higher demand of fast-speed. charging during daytime, the rapid development of PV generation optimizes power consumption at peak hours with its adequate daytime generations. With respect to the intermittency of solar energy, a battery energy storage (BES) can be employed to regulate the DC bus or load voltage, balance power gap, and smooth PV power.

Considering the high-power density and high efficiency merits of the multiport power converters, a multiport DC/DC converter is employed in this paper for the EV charging station instead of using three separate DC/DC converters. Among the above mentioned research, the charging station architectures can be classified into two topologies: using AC bus or DC bus. Compared with isolated multiport converters, non isolated multiport converters that are usually derived from buck or boost converters may feature a more compact design, higher power density, and higher efficiency compared with isolated multiport converters. Accordingly, a DC bus non isolated structure with Sic switches is leveraged in this paper, to improve efficiency and minimize the power losses.

II. OBJECTIVE

The Main aim of the project is to design and Implement a Smart wireless charging system for the purpose of electric Vehicle using the Sandwich coil based LCC Converter Circuit. The key of the design is to use the distinct sandwiched topology in both the transmitter and receiver coils, whose operating frequency of 160 kHz is significantly lower than the existing WPT system up to megahertz.

III.PROPOSED SYSTEM

A. METHODOLOGY

Sandwich Coupling technology, when a transmitting coil sends electromagnetic waves tuned to a frequency matching the resonance of a circuit holding a receiving coil, it will transfer energy to it very efficiently. We propose a Hybrid Coupling compensated coil into a Hybrid Coupling main coil system. As it is shown in Figure, five extra coupling effects appear after the integration and the coupling effect of the two Sandwich coils at the same side of the wireless charging system are studied.

A sample battery wireless charging system with 95.3 % efficiency was designed and tested in. Further detailed analysis on both the coupling effect of the same-side coils and the coupling effect of the cross-side coils can be found in. successfully make the system more compact and highly efficient; however, the method of integration complicates the design of a wireless charging system using High Gain LCC converter topologies. In order to simplify the design and analysis while keep the advantages of compactness and high efficiency.

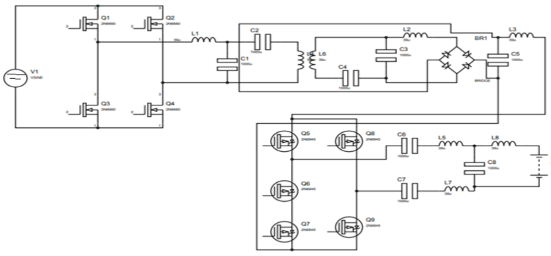


Fig.1 Proposed system circuit diagram

Topologies are very important for wireless charging systems, for they are the major power transfer carrier and affect the system transfer characteristics. LC series and LC parallel are the basic two topologies, and their combinations derive four topologies, including LC series-LC series, LC series-LC parallel, LC parallel-LC series and LC parallel-LC parallel. To ensure the reflected impedance of LC parallel topology is purely resistive, an additional inductor is employed to compensate the imaginary part, which derives the LCL-LCL topology [11].

According to the Norton's law, we can easily deduce that the LC parallel topology and LCL topology have the CC characteristic. Additionally, LC series-LC series topology also has a CC characteristic when the load is a strong voltage source, like the battery. So, we can use these topologies to charge the battery directly, which can remove the cascade DC/DC part in the receiver, and thus improve the efficiency. CC/CV strategy is widely used due to the requirements of many commercial power batteries. The battery is at first charged by a constant current. Once its terminal voltage arrives at a predesigned value, the CV stage begins. At this time, the charging instrument works as a voltage source to clamp the terminal voltage of the battery. Then, the internal resistance and OCV (open circuit voltage) of the battery increase continually until the charging current reduces to a threshold, which indicates that the charging process is over. Obviously, we can find that the CC stage is realized easily in wireless charging systems, but for the CV stage, it needs an additional control algorithm as well as some other sensors at high speed. Initially, CV stage is used to charge the lead- acid battery, which aims to avoid the electrolysis of the water at the end of the charge, and hence, to prevent excessive gaseous emissions. As we know, both the component material and electrochemical mechanism of the lithium-ion battery is apparently different from that of the lead-acid battery; thus, we are going to study whether the CV stage is necessary for the lithium-ion battery charging. First, the contributions of CV stage to the battery are studied, then the CC/CV strategy is compared with the CC strategy, and three evaluation criterions, including the charging time, the charging capacity and the charging energy efficiency, are adopted in order to evaluate them. The specific parameters of the test battery. The charging current rates and temperatures often affect the battery characteristics, for they influence the electrochemical reaction speed;

thus, we consider their effects on the three criteria in the following experiments. The charging and discharging equipment are MACCOR model 4300 (MACCOR, Tulsa, OK, USA), and the thermostatic equipment is MACCOR model 4300 (MACCOR, Tulsa, OK, USA), and the thermostatic equipment is Votsch C4-180 (VötschIndustrietechnik, Stuttgart, Germany).

B.LCC CONVERTER

Converters only need to buck or boost the voltage and can simply use the corresponding converters. However, sometimes the desired output voltage will be in the range of input voltage. When this is the case, it is usually best to use a converter that can decrease or increase the voltage. Buck-boost converters can be cheaper because they only require a single inductor and a capacitor. However, these converters suffer from a high amount of input current ripple. This ripple can create harmonics; in many applications these harmonics necessitate using a large capacitor or an LC filter.

This often makes the buck-boost expensive or inefficient. Another issue that can complicate the usage of buck- boost converters is the fact that they invert the voltage. Cúk converters solve both of these problems by using an extra capacitor and inductor. However, both Cúk and buck- boost converter operation causes large amounts of electrical stress on the components, this can result in device failure or overheating. LCC converters solve both of these problems.

C.LCC CONVERTER OPERATION

All dc-dc converters operate by rapidly turning on and off a MOSFET, generally with a high frequency pulse. What the converter does as a result of this is what makes the LCC converter superior. For the LCC, when the pulse is high/the MOSFET is on, inductor 1 is charged by the input voltage and inductor 2 is charged by capacitor 1. The diode is off and the output is maintained by capacitor 2. When the pulse is low/the MOSFET is off, the inductors output through the diode to the load and the capacitors are charged. The greater the percentage of time (duty cycle) the pulse is low, the greater the output will be. This is because the longer the inductors charge, the greater their voltage will be. However, if the pulse lasts too long, the capacitors will not be able to charge and the converter will fail as

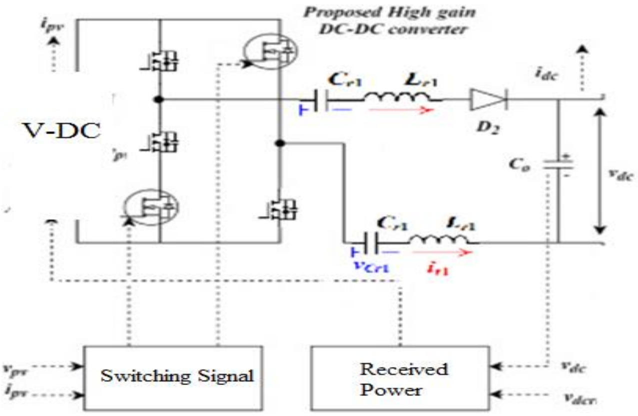


Fig.2 Proposed system LCC Converter

D.SANDWICH COIL BASED POWER TRANSFER

WPT well fits with the idea of a "Bi-Directional" power transfer, meaning that the power is able to flow from the grid to the load or, alternatively, from the load to other users of the grid. A Bi-Directional Inductive Power Transfer (PROPOSED) system is therefore exploitable to accomplish the Vehicle-To-Grid (V2G) concept, consisting in the possibility to use the EV battery as storage element for other users of the grid or other vehicles as well, in the scenario of a multi-parking area. The V2G idea belongs to the philosophy of the active demand, where the user plays the double role of consumer and producer of electrical energy.

III. VI.PRODUCT DEVELOPMENT

A.DESIGN OF THE EACH SUB SYSTEM

The Wireless Power Transfer (WPT) can be exploited for Railway Application (EV) battery charging. The WPT consists of a wireless power flow between two magnetically coupled coils. Therefore, through WPT the battery charging can occur wirelessly. The lack of wires brings some benefits in terms of comfort and safety: the vehicle could be automatically charged without the need of a plug-in operation and no electrocution risk would involve the user. Depending on whether the vehicle is stationary or in motion, and whether the driver is inside the vehicle or not, there are three types of WPT-based battery charging: static, semi-dynamic and dynamic [25].

The static WPT occurs when the vehicle is stationary and nobody is inside it, i.e. during the parking time; the semi-dynamic WPT occurs when the vehicle is stationary and the driver is inside it, i.e. during the stop at traffic red lights for cars or during the bus stop for electric buses; the dynamic WPT occurs when the car is in motion, i.e. along motorways. Yet the dynamic wireless battery charging features some drawbacks. The motion of the vehicle implies a widespread infrastructure of power transmission buried inside the road in order to have adequate charging times and therefore for an efficient dynamic charging high costs are required is cheaper in static and semi-dynamic options, since the same charging time is covered by the use of a minor number of coils in comparison with the dynamic case, due to the stationary state of the vehicle.

Static WPT is feasible for private RA which could stay stationary for some hours, whereas semi-dynamic WPT is particularly appropriate for public electric means of transportations, such as cabs or buses, needing to continuously move across the day and therefore requiring frequent charging operations if a proper autonomy is wanted without increasing the battery size. Considering that the wireless battery charging is inherently less efficient than the conventional wire-based battery charging, the benefits brought by the wireless method in terms of comfort and safety need to be notable in order to make the static WPT really attractive for EV battery charging. The frequent movements of a vehicle may require to charge its battery many times across the whole day.

This particularly fits with the case of electric bicycles, being very smart and comfortable to be driven in the congested traffic, typical of the urban scenario. The Vehicle is potentially an ideal means of transportation for frequent transfers throughout the day. Furthermore, the E-Vehicle represents a smart, green and light solution of urban mobility.

More and more people are supposed to be driving electric bicycles in the next future. WPT would therefore represent a brilliant solution of battery charging for parked E-Vehicles, due to different reasons. First of all, every time the cyclist parks the E-Vehicle, it would be automatically recharged without the bothersome and potentially dangerous plug-in operation. Later, in case of multiparking areas for E-Vehicles, each bicycle could be recharged and no wire would be visible.

IV. PRACTICAL IMPLEMENTATION

For the designed IPT system a laboratory prototype has been assembled and several experimental tests have been carried out to test the proper working and to measure the power efficiency and the produced magnetic field. The application target for this prototype corresponds to a (100÷250) W power range, useful for the charging `of an electric bicycle battery. In the next subparagraphs, the different parts of the assembled IPT prototype will be described.

V. Winding coils

The Inductive Power Transfer is implemented through the magnetic coupling between two coils. For the experimental prototype, two circular coils have been used, whose features are listed in Tab. VI.1 and Tab. VI.2:

Table VI.1

Material	**Value**
PCu	$1.68 \cdot 10^{-8}\ \Omega \cdot m$
μr,Cu	˜1
Wire geometry	**Value**
D	3mm
L	3.48mm
Coil geometry	**Value**
Dout	15mm
N	15cm
Maximum air gap	3mm

Table VI.2

Element	Value
L1 = L2 = L	13 µH
M	4.9 µH
K	0.377
R_{dc}	8.2 mΩ

VI. SIMULATION RESULTS

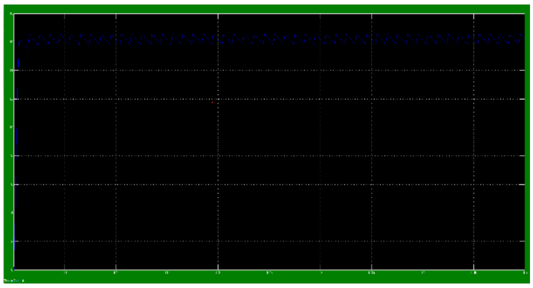


Fig.3 Input voltage of proposed system

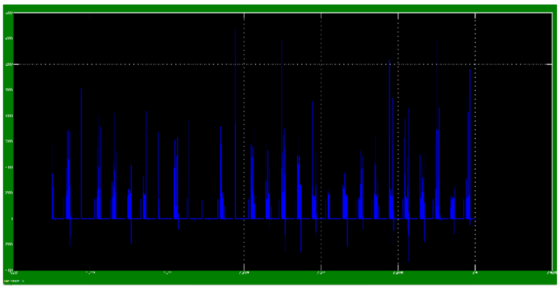


Fig.4 Winding output wave form

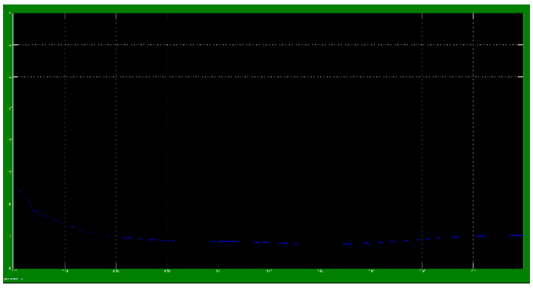


Fig.5 proposed system output voltage discharge wave form

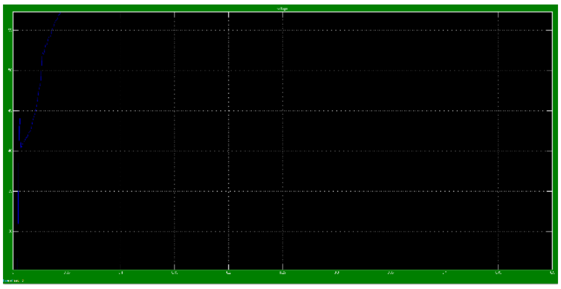
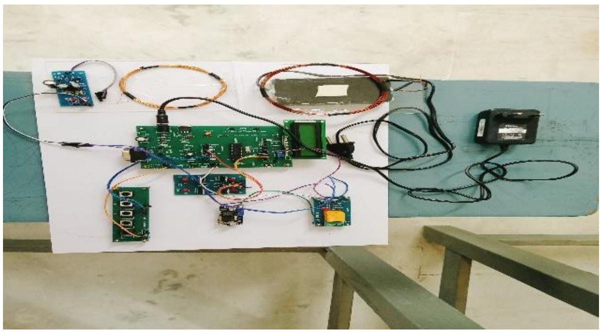
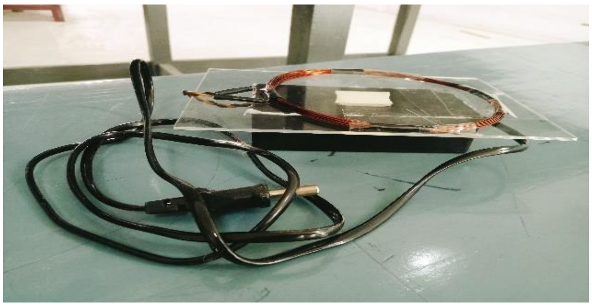


Fig.6 proposed system output voltage

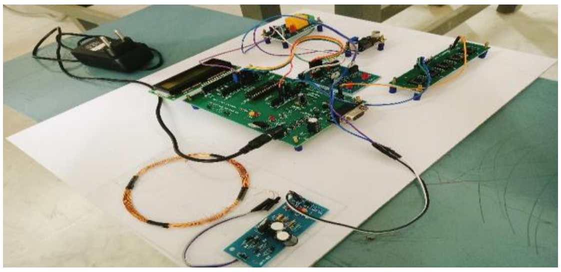
VII. HARDWARE IMPLEMENTATION



a) Over all hardware kit



b) Primary coil



c) Secondary coil

- A DC voltage source, which is used to supply the half-bridge and the MOSFET drivers of the transmitter board;
- A function generator which is used to produce the AC waveform driving the MOSFETS, in order to power the primary coil;

- an electrical load, representing RL according to Fig.8.3.1 and consisting in an electronic load or in a rheostat, depending on the type of measurements;
- A measuring system composed by two voltmeters connected to the terminals of the coils and two current probes, used for the current measurement of both coils;
- A power scope, which is used for the real-time waveform detection and measurement of the main electrical quantities involved in the proposed system; a magnetic probe for the magnetic field characterization of the system.

VIII. CONCLUSION

The proposed sandwich coil design further eliminates or minimize the extra coupling effects to a negligible level, making it more straightforward to design a wireless charging system using the double-sided LCC converter topology. The detailed design procedures to improve system efficiency are also introduced. Both the MATLAB simulation results and the experimental results verify the proposed idea. The compact and highly efficient wireless charging system is able to deliver DC-DC efficiency of 95.5% with an air gap of 150 mm when fully aligned.

IX. REFERENCES

[1]. [Online]:http://home.howstuffworks.com/question292.htm.

[2]. V. Boscaino, F. Pellitteri, L. R. R., and C. G., “Wireless battery chargers for portable applications: design and test of a high-efficiency power receiver,” IET Power Electronics, vol. 6, pp. 20–29, 2013.

[3]. S. Segan. (2015) First Look at Intel’s Laptop Wireless Charging. [Online]. Available: http://www.pcmag.com/article2/0,2817,2490600,00.asp.

[4]. [Online]: http://www.wirelesspowersupply.net/tv-that-uses-wireless-powersystem.

[5]. H. Z. Z. Beh, G. A. Covic, and J. T. Boys, “Wireless Fleet Charging System for Electric Bicycles,” Emerging and Selected Topics in Power Electronics, IEEE Journal of, vol. 3, no. 1, pp. 75–86, Mar. 2015.

[6]. S. Asheer, A. Al-Marawani, T. Khattab, and A. Massoud, “Inductive power transfer with wireless communication system for electric vehicles,” in GCC Conference and Exhibition (GCC), 2013 7th IEEE, 2013, pp. 517–522.

[7]. G. Jung, B. Song, S. Shin, S. Lee, J. Shin, Y. Kim, C. Lee, and S. Jung, “Wireless charging system for On-Line Electric Bus (OLEB) with series connected road-embedded segment,” in Environment and Electrical Engineering (EEEIC), 2013 12th International Conference on, 2013, pp. 485– 488.

[8]. Y. Shi, L. Xie, Y. T. Hou, and H. D. Sherali, “On renewable sensor networks with wireless energy transfer,” in INFOCOM, 2011 Proceedings IEEE, 2011, pp. 1350–1358.

[9]. J. Li, P. Li, H. Liu, D. Li, and J. Tang, “A contactless battery charging and monitoring system for wireless sensor network nodes,” in Computer Science and Network Technology (ICCSNT), 2011 International Conference on, 2011, vol. 3, pp. 1923–1926.

[10]. L. Xie, Y. Shi, Y. T. Hou, W. Lou, H. D. Sherali, H. Zhou, and S. F. Midkiff, “A Mobile Platform for Wireless Charging and Data Collection in Sensor Networks,” Selected Areas in Communications, IEEE Journal on, vol. 33, no. 8, pp. 1521–1533, Aug. 2015.

[11]. R. W. Porto, V. J. Brusamarello, I. Muller, and F. R. de Sousa, “Design and characterization of a power transfer inductive link for wireless sensor network nodes,” in Instrumentation and Measurement Technology Conference (I2MTC), 2015 IEEE International, 2015, pp. 1261–1266.

[12]. C. Park and P. H. Chou, “AmbiMax: Autonomous Energy Harvesting Platform for Multi-Supply Wireless Sensor Nodes,” in Sensor and Ad Hoc Communications and Networks, 2006. SECON ’06. 2006 3rd Annual IEEE Communications Society on, 2006, vol. 1, pp. 168–177.

[13]. F. I. Simjee and P. H. Chou, “Efficient Charging of Supercapacitors for Extended Lifetime of Wireless Sensor Nodes,” Power Electronics, IEEE Transactions on, vol. 23, no. 3, pp. 1526–1536, May 2008.

[14]. Y. Yu, H. Hao, W. Wang, and L. Li, “Simulative and experimental research on wireless power transmission technique in implantable medical device,” in

[15]. Engineering in Medicine and Biology Society, 2009. EMBC 2009. Annual International Conference of the IEEE, 2009, pp. 923–926.

[16]. A. Pandey, F. Allos, A. P. Hu, and D. Budgett, “Integration of supercapacitors into wirelessly charged biomedical sensors,” in Industrial Electronics and Applications (ICIEA), 2011 6th IEEE Conference on, 2011, pp. 56–61.

[17]. Q. Xu, H. Wang, Z. Gao, Z.-H. Mao, J. He, and M. Sun, “A Novel Mat-Based System for Position-Varying Wireless Power Transfer to Biomedical Implants,” Magnetics, IEEE Transactions on, vol. 49, no. 8, pp. 4774–4779, Aug. 2013.

[18]. S. C. Nambiar and M. Manteghi, “A simple wireless power transfer scheme for implanted devices,” in Radio Science Meeting (USNC-URSI NRSM), 2014 United States National Committee of URSI National, 2014, pp. 1–1.

[19]. P. Aqueveque and J. Barboza, “Wireless power system for charge supercapacitors as power sources for implantable devices,” in Emerging Technologies: Wireless Power (WoW), 2015 IEEE PELS Workshop on, 2015, pp. 1–5.

Cite this article as :

R. Manimegalai, G. Sanjaidharan, N. Keerthika, P. Yuvaraj, "Design and Implementation of Wireless Charging System Using Sandwich Coil and LCC Converter for Smart Electric Vehicle", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 10 Issue 2, pp. 703-710, March-April 2023.
Journal URL : https://ijsrset.com/IJSRSET23102112