UNDERWATER WIRELESS POWER TRANSFER SYSTEM

[1]Shardul Kamble, [2]Shruvi Pandey, [3]Purva Chawda, [4]Saili Surve, [5]Prof. Bhavna Thakur

[1]B.E. Student, [2]B.E. Student, [3]B.E. Student, [4]B.E. Student, [5]Professor of Electronics and Telecommunication Engineering,
Department of Electronics and Telecommunication Engineering,
Shivajirao S. Jondhale College of Engineering, Dombivli, India.

Abstract: This project has been worked upon in the context of the time when there is surge in demand of power usage due to increase in electronic devices rapidly; power transfer (known as charging in simpler terms) is the need of the hour. There is significant development in the field of wireless power transfer with applications in various domains. However any technology can be made even more practically successful by increasing its efficiency to an optimum level. In this project we aim to develop a prototype model where we try to increase the efficiency of the underwater wireless power transfer. To achieve this we try to minimize the losses occurring in the transfer. The goal of the project is to devise an Underwater Wireless Power Transfer system prototype from scratch and understand the fundamental concepts utilized in this system while improving it for a better efficiency.

***IndexTerms* - electronic, wireless, power, efficiency, underwater.**

I. INTRODUCTION

In today's time of technological advancement, human desire to explore and understand various concepts in all fields is at its epitome. Extensive research projects are being carried out in the oceans to understand it better. Underwater vehicles such as Autonomous Underwater Vehicles (AUVs) and Remotely Operated Vehicles (ROVs) are widely used to collect large volumes of data from underwater wireless sensor nodes and networks on the surface or in Deep Ocean. These vehicles are mostly battery-powered and charging the on-board batteries of underwater vehicles is considered as a challenge. Various electronic devices are being brought into use to facilitate this research and study which eventually results in increase in demand of power and its transfer. In this project we try to increase the efficiency of the charger by using a ferrite c core with a toroidal winding. This combination helps us minimize the hysterical losses thereby increasing the efficiency.

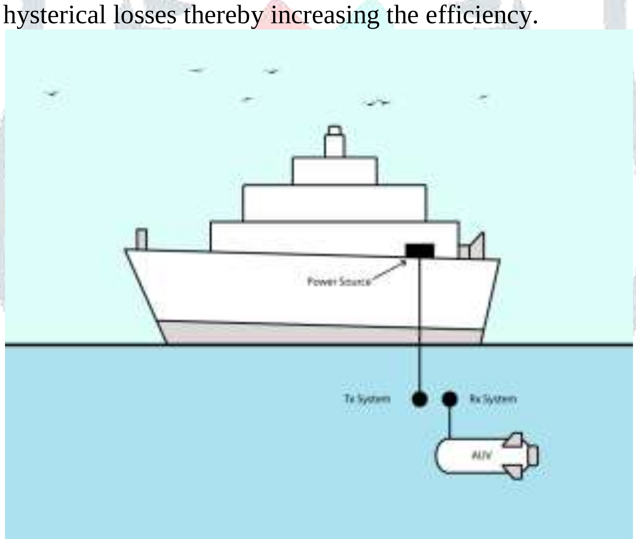

Fig.1. Underwater Wireless Charging Mechanism of Proposed System

II. LITERATURE SURVEY

The paper, "Design of a 1kW Underwater Wireless Charging Station for Underwater Data Gathering Systems" states that design and evaluation of an indigenously designed 1kW Underwater Wireless Charging Station is proposed, which enables the underwater vehicles to come near the proposed charging station and get charged. In order to evaluate the performance of proposed system designed, various experiments are carried out and the results are reported. The proposed system can charge wireless sensor nodes and networks too [1]. In paper, "Underwater wireless power transfer for ocean system applications." the field of wireless power transfer (WPT) has been revitalized since the development of resonant induction technique. For WPT in the ocean environment, it is still very much in the research portion of its development. The results from the study is expected to provide guidelines to improve the efficiency and transmitting distance between the coils in underwater and also that proper coil winding and the addition of resonator circuits increase transmission efficiency. As the properties of the coils contribute to the efficiency of the WPT system, a detailed study of the system is analyzed to determine the self-inductance, capacitance, parasitic resistance, and the best coil shape for WPT [2].The paper, "Design and development of contactless battery charger for underwater vehicles." propose the performance of 300W contactless underwater battery charger system design, which is tested under various conditions and then the results are compared. After comparing the results, it is observed that out of all the systems class E based system produces best results and is simpler. The authors aim to design system for recharging the maritime surveillance and security systems such as battery-operated wireless sensor nodes, autonomous underwater vehicle, wireless network systems as well as which can be easily extended for various domestic applications [3].The paper, "Underwater wireless power transfer for maritime applications." demonstrates the ability to model the transfer of power and shows that at frequencies below 250kHz, there is little difference between transferring power between water and air. It also presents the development and implementation of an inductive, underwater wireless power transfer system used with unmanned underwater vehicles (UUVs). Specifically, the design and fabrication of power transfer coils and power electronics is provided for a system capable of providing 75W to a load [4]. The research paper, "Wireless charger for underwater vehicles fed from a constant current distribution cable." states the existing conductive power supplies for such systems use voltage-fed series resonant converters (SRCs) and parallel resonant converters (PRCs) to minimize switch stress and 6 achieve zero voltage switching (ZVS). This work presents a modification of the resonant tank so that the above-mentioned inverter can be used for wireless charging of small autonomous underwater vehicles (AUVs). The tanks behave as coupled resonant tanks with inter-dependent quality factor relationships, consideration for which is necessary for underwater IPT systems owing to the frequency dependent eddy current losses in seawater [5].

III. WORKING

The transmitter design consists of dc power source, gating inverter circuit and class E amplifier inverter circuit. The receiver design is of bridge rectifier and regulator which are connected to the battery. 12 V, 20mA dc power source (battery) is used as input to the system. This is then passed through the gating (inverter) circuit which is then fed to the class E amplifier.

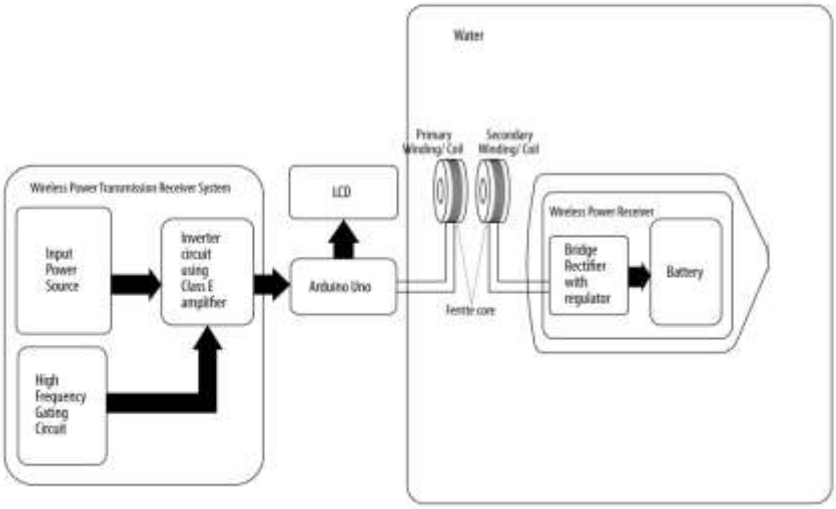

Fig.2. Block diagram of proposed system

The most important block of the proposed contactless power transfer system is high frequency inverter. The circuit which is used in order to transform the DC voltage input into an AC voltage output is called as an inverter, High frequency (HF) inverter is used to generate AC signals at high frequency, here we convert our 12V 20 mA DC power output into 12V 50hz AC power output. In this section, we are using class E amplifier is used for contactless underwater power transfer application.

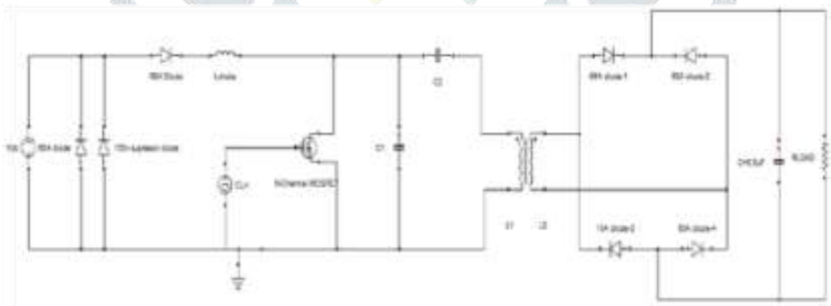

Fig.3. Circuit diagram of the proposed system designed using Class-E amplifier

Class-E amplifier circuit is simple to design and use. It uses only one MOSFET and possesses enhanced reliability. These advantages motivate the use of Class E amplifier based inverter for proposed system. Hence we are using Class-E amplifier circuit in the system. The circuit diagram for contactless underwater battery charger using class-E circuit is shown in Fig.3. IRFP360 MOSFET is used for the proposed design. The wireless power transmitter module shown in image comprises of the design as in Fig.3.and an oscillator to generate the gating signal.

Fig 4.a.Copper Coil

Fig 4.b. Bridge Rectifier module

The proposed system is powered up using a 12V, 20mA DC power supply. Wireless power receiver modules designed as shown in Fig. 4.a. and 4.b. which comprises of a secondary coil and bridge rectifier that charges a 5V, 20mA battery.

Fig.5.a. Arduino Uno

Fig.5.b. LCD

The arduino uno in configuration with LCD is used to display the value of input power supply. The power is then transmitted from primary winding to the secondary winding.

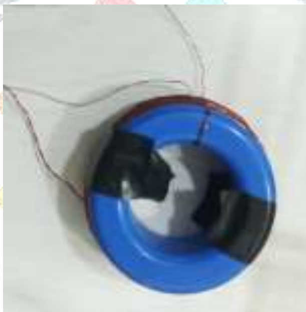

Fig.6.Ferrite core

The copper coil on each side is wounded on the ferrite core as shown in Fig.6. Ring configuration is used in the system having 100 turns in around each winding. The average efficiency of the magnetic resonant coupling wireless power transfer (MRC-WPT) system can be improved by 80% using ferrite core. The ferrite core have been designed and optimized for efficient power transfer. Copper coil are used as they are good conductor of electricity and are easily available. This copper coil wounded on ferrite core on both the sides and is used to transfer power; it works on the principle of mutual induction. Dimension of ferrite core are 5cm outer diameter, 3.5cm inner diameter and height 2 cm and the length of the copper coil around each winding is 1800cm.

The AC voltage induced in the secondary is converted into DC voltage using a bridge rectifier circuit which is then passed through the regulator to give a stabilized dc output of 5V, 20mA. This output is stored in a 1200mAh battery and the further used to power n devices.

IV. EXPERIMENTAL RESULTS

Details about the performance evaluation and hardware results of the contactless power transfer system designed are reported in this section.

The hardware setup used to experiment the contactless power transfer system is designed using Class E amplifier-bridge. The system designed is powered using 12V, 20mA DC power supply. The various power receiver modules designed are placed above the power transmitter module. The proposed system is capable of powering the various receiver modules upto a maximum distance of 50mm.

The proposed system is tested for150mW output. The performance of this contactless power supply system is calculated using different distances between primary and secondary coils, and the optimum combination is Lp=423microH and Ls =141microH. Details about the performance of the system with Lp=423microH, Ls=141microH and changing the value of capacitor C, which in-turn changes the frequency of operation. It is observed from Table 1. that maximum Pout is obtained at 9.53 kHz and maximum **η** is obtained at 8.37 kHz. The performance of the system designed is then evaluated by slowly moving the receiver away from the primary and the results obtained are reported in Table 2.a. and 2.b., where d denotes the distance between primary and secondary coil in mm.

Lp	Ls	f (kHz)	Pin	Pout	η
423 microH	141 microH	7.86	243.87mW	86.72	35.56
424 microH	142 microH	9.11	256.41mW	194.58	75.89
425 microH	143 microH	10.47	259.65mW	175.36	67.54
426 microH	144 microH	12.93	235.49mW	76.86	32.64
427 microH	145 microH	14.18	251.36mW	59.17	23.54

Table 1. System performance for different frequencies

Air							
Gap	V1	I1	PIN	V2	I2	POUT	η
0cm	12.2 V	19.1 mA	233.02mW	8.9V	20.03 mA	178.26mW	76.52
2cm	11.7 V	18.9 mA	221.13mW	9.1V	15.14mA	137.77mW	62.34
5cm	11.9 V	20.1 mA	239.19mW	8.5V	14.3mA	121.55mW	50.83
10cm	12.3V	19.7mA	242.31mW	4.5V	12.6mA	56.7mW	23.4

Table 2.a. Distance vs. Power transfer of system in Air

Water							
Gap	V1	I1	PIN	V2	I2	POUT	η
0cm	11.8 V	19.7 mA	232.46mW	8.7V	20.26mA	176.26mW	75.85
2cm	12.1 V	19.5 mA	235.95mW	8.6V	16.35mA	140.61mW	59.54
5cm	12.3 V	20.2 mA	248.46mW	8.8V	7.51mA	66.08mW	26.63
10cm	12.2V	20.3mA	247.66mW	3.1V	4.6mA	14.26mW	5.75

Table 2.b. Distance vs. Power transfer of system in Water

This hardware setup is used to experiment the 150mW contactless power transfer system underwater is shown in figure. The system is powered using a 250mW power supply source with output voltage set at 12VDC 20mA and have been tested in air and underwater. The contactless underwater battery charging systems demand the capability of the system to charge the batteries when the secondary receiver is not aligned and the cases of receiver placed at an offset when compared with the primary. It is observed from Table 2.a. and 2.b., at the **η** is almost same upto a distance of 5cm under water and beyond that distance, **η** gets reduced. Similarly it may be observed from Table 2.a. and 2.b. that as the distance between primary and secondary increases, the Pout decreases, concluding that the secondary receiver coil should be properly aligned with the primary transmitter coil for best results.

V. Conclusion

This paper presented design, fabrication and testing of wireless power transfer under water. We have demonstrated the model with ring winding along with ferrite core for power transfer in air and under water which give efficiency of around 75 % in water and a slight difference in air .This power transfer is also applicable to underwater sensor nodes, ROV, AUV to charge battery with maximum power transfer.

VI. Acknowledgement

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