ISSN: 2278-0181

PECTEAM - 2K18 Conference Proceedings

A Wireless Power Transmission using Cost-Effective System

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Abstract—In recent years, the notion of transfer of power using wireless techniques has attracted many researchers. In this paper, we have discussed the design of a simple and cost-effective system which can enable transmission of power over short distances. We have employed the H – Bridge Inverter configuration to convert DC power to high frequency (50 kHz) which is then radiated with the help of a suitable loop antenna. It is observed that this system can also be used as a induction heating unit. In this form it can be used to replace conventional convection heating based electric stoves.

Keywords- Induction heating; H-Bridge inverter; wireless power Transmission .

I. INTRODUCTION

The electrical energy can be transfer from power sources to electrical load without interconnecting the wires are called as wireless energy transfer or wireless power. Wireless transmission is useful in cases where interconnecting wires are complicate, inconvenient, hazardous, or impossible in few cases. Electromagnetic induction and Electromagnetic radiation are various methods of wireless power transmission.

II. SYSTEM DESIGN

The fundamental principle guiding this system is the use of a suitable inverter circuit to convert D.C voltage into an alternating supply. Such an alternating voltage would create a rapidly changing magnetic flux, as per the equation:

$$\varphi = B * A * \text{Cos}\ \theta$$

Where ‘φ’ is the magnetic flux, ‘B’ is the magnetic field density; ‘A’ is the cross sectional area of the loop and ‘θ’ is the angle between the magnetic field density and the surface of the loop. This flux change induces an e.m.f (electromotive force) in any wire loop or metal surface that cuts the magnetic flux lines. Such an e.m.f, if suitably tapped, can be used either for heating (where it manifests itself in the form of eddy currents in the vessel to be heated) or for wireless power transfer.

The power transfer efficiency of the inductor depends upon the coupling and the quality. The coupling is found out by the distance between the inductors and the relative size. The shape of the coils and the angle between them decides the coupling. The functional block diagram is shown in fig 1.

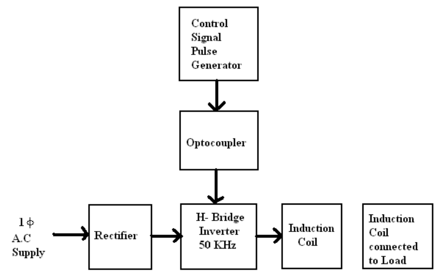

Figure 1. Block diagram

The electromagnetic induction wireless transmission technique is near field over a distance up to about one-sixth of the wavelength used. Some radioactive losses occur near the field energy even though non-radioactive.

A. Design of Control Signal Waveforms:

The SG3525A is a Pulse width modulator control circuits which offer improved performance and lower external parts count when implemented for controlling all types of switching power supplies, shown in fig 2.

To eliminate the external divider circuits an on-chip reference of 5.1V is accent to ±1% and the error amplifier has an input common–mode voltage range that includes the reference voltage. Using a single resistor between CT and discharge pins dead time range can be decided. For soft start circuit an external timing capacitor is used.

The soft–start circuit and the output stages are controlled by shutdown pin and simultaneously turn off through the PWM latch which makes the pulses to shutdown which also soft–start recycles with longer shutdown commands. The under voltage lockout decides the outputs and soft–start capacitor voltage varies when VCC is below the standard voltage

The SG3525A output stage is NOR logic where gets output low for an off-state. The output stages are totem–pole design with the source and sink current greater than 200mA.To minimize the large input current a Soft-start capacitor function is used which progressively increase the switch-current limit at startup, lagging the rate of rise of the output voltage and reduce the peak current when start up.

We have used a Timing Resistor and Capacitor of values 33KΩ and 0.001µF respectively. A dead time resistor of value 220Ω is used for dead time adjustments. The values are chosen such that we produce a oscillating frequency of 50 KHz by the formula

$$f = \frac{1}{C_T\ (0.7\ R_T +\ 3\ R_D\ )}$$

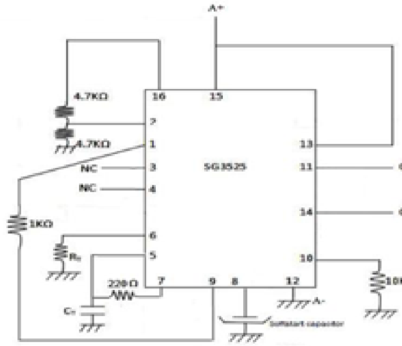

Figure 2. Control signal Pulse Generator

B. Physical isolation:

The H-bridge inverter employs high side and low side switches (four switches in all). The pulses used to drive the high side switches are derived from the pulses used to drive the low side switches. However, physical isolation using a suitable isolating technique needs to be implemented before these pulses are used to drive the high side MOSFETs.

This precaution is essential, for if the same signal is used to drive both the high side and low side MOSFETs in the circuit without physical isolation, a short circuit will result due to creation of a parasitic path between the ground and the source of the high side MOSFET. This can result in serious damage to the MOSFET switches.

Physical isolation of the high side drive waveforms can be implemented using several methods. One such method is to use an opto-coupler which is available from several manufacturers.

The output from the SG3525 is given to the pin 2 of the Optocoupler TLP250. The Pin 3 of the Optocoupler is grounded. The control signal for the MOSFET is obtained from the Pin 7 through a 100Ω resistor.

TLP250 is used for the circuit. It consists of a GaAlAs light emitting diode and a integrated photo detector. It is 8−lead DIP package. For IGBT or power MOSFET TLP250 is used as gate triggering pulse circuits shown in fig 3.

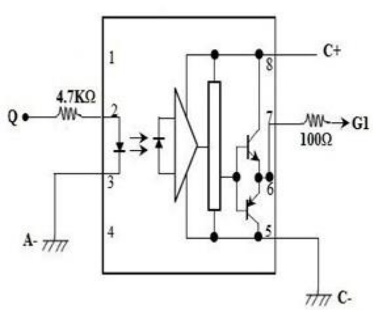

Figure 3. OptoCoupler

C. Inverter circuit:

The outputs from the secondary windings of the pulse transformers are sent to the H-bridge inverter circuit detailed in Figure 4.

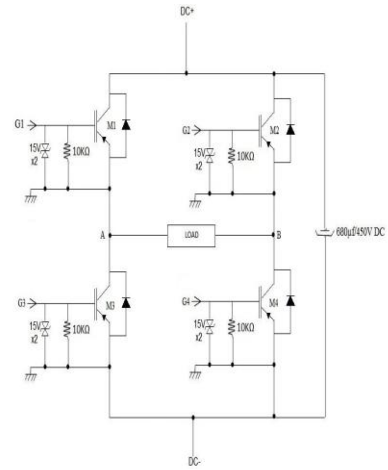

Figure 4. H-Bridge Inverter

One of the advantages of using an H-bridge inverter is that the load experiences a peak- to-peak voltage of 2Vcc. The inverter works in the required manner i.e. when Q is high, M1 and M2 are turned ON and current flows from Vcc to Gnd via the path M1- - A -- Load -- B – M2. At this stage, the other two MOSFETs will not be conducting because their input Q' will be low. When Q becomes low turning Off M1 and M2, Q' becomes high after sometime, which turns on M3 and M4. Now, the current flows from Vcc to Gnd via the path M3 -- B - - Load -- A -- M4. The power MOSFETs used to build the inverter are of type IRFPG50. As per [4], the VDS=1000 V, ID (max) = 6.1 Amp and on resistance Ron =2 ohms.

D. Load:

1) Induction coil design:

The inductor act as transformer primary and the work piece as the transformer secondary. So many characteristics of transformer is used for coil design. Important characteristic is coupling between the winding is square of the distance between the coil and work piece. To gain maximum energy transfer coils to be closely coupled. The Coupling efficiency can be increased by making largest number of magnetic flux line intersects in the secondary coil.

The denser the flux at this point, the higher will be the current generated in the receiving coil. A wide variety of coil designs are described in literature [4]. The choice of shape depends on the nature of radiation pattern to be established (if the application is wireless power transfer) and the shape of the vessel to be heated (if the system also to be employed as an induction cooking unit).

2) Core design:

The use of frequencies in the range of 10 kHz – 100 kHz requires special magnetic material for the pickup iron core. Laminated iron sheets as used in conventional line transformers leads to unacceptable high iron losses. A good choice for the material of the pick-up iron core is soft ferrite.

The geometric design of pick-up coils is restricted due to the limitations in the size of soft-ferrite cores used

The pick-up is magnetically coupled with the primary loop, but located on the secondary side of the inductive power transfer system and usually consists of a ferrite iron core and a coil. E-shaped pick up is used as shown in fig 5. Depending on the application of the power transfer system different geometric designs of the pick-up are known. The generated voltage is depending on the frequency, saturation of the ferrite core and the dimensions of the pick-up.

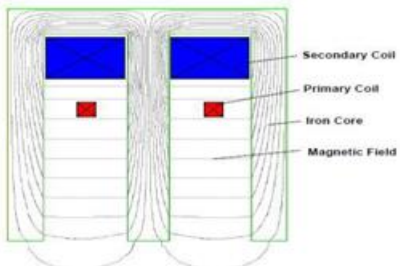

Figure 5. E-shaped pick up (Flux Simulation)

As the frequency increases the transferred power also increases proportionally so the use of line frequency is disadvantageous. For 10 kHz – 100 kHz frequency range single phase inverter used to convert the line power to higher frequency.

The limitation of the upper frequency is mainly given by the increase of inverter switching losses. The Hardware topology is shown in fig 6.

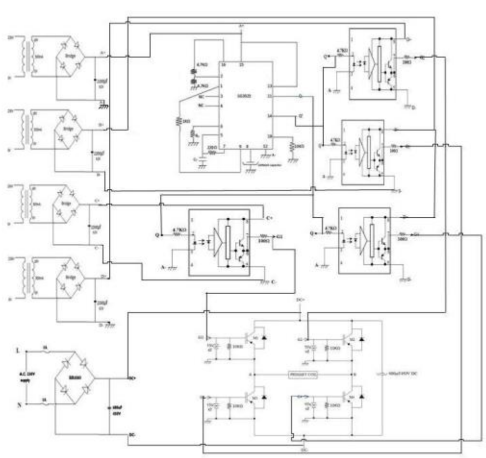

Figure 6. Hardware Topology

III. RESULTS

On connecting the circuit to the Induction Coil in series with a 60W bulb at an operating voltage of 60V, bulb glow as shown in fig 7.

A few observations were noted:

- On increasing the distance between the loop and the coil, the glow of the bulb gradually diminishes.
- By increasing the operating voltage through repeated testing; the Coil can be applied for use as a heating stove.

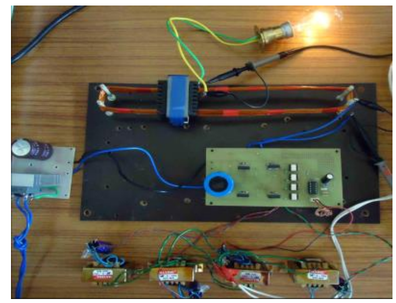

Figure 7. A 60W bulb glows when connected to receiving coil

IV. CONCLUSIONS

The system provides conclusive evidence that despite the absence of an antenna of suitable directivity, a sizeable amount of power can be wirelessly transmitted over short distances. The next step in the development of this system is to design and build a helical transmitter and receiver antenna system of suitable dimensions, which can increase the distance of transmission by improving directivity and gain. By increasing the operating voltage through repeated testing, the Coil can be applied for use as a heating stove.

From an efficiency point of view, wireless inductive power transfer is feasible for general power applications only if transmitter and receiver coils are in close proximity to each other. Inductive power transfer in a larger space is not feasible due to the very low efficiency.

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