Solar Powered Wireless Charging Station for Electric Vehicle

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***Abstract* - Wireless Power Transfer [WPT] using the magnetic induction technology which could avoid human from the hazardous accident caused due to the using of cables. By the using of MOSFET switches in the inverter, it creates the output with high frequency improves the efficiency of power transfer between the coils. Due to this creation of output with higher frequency the charging of battery will be very fast and efficient. By connecting the solar panel to the supply battery, it will be charged continuous sly using this panel. This will help the users for the non-stop driving. These advances make the WPT very attractive to the electric vehicle charging application in both stationary and dynamic charging. By introducing WPT in electric vehicle, the obstacles of charging time, range, and cost can be easily managed. WPT technology is developing rapidly in recent years.**

***Index Terms* - Charging station, Electric Vehicle, Inductive Coupling, Wireless power Transmission.**

I.INTRODUCTION

A lot of domestic, industrial, or commercial applications use solar energy. Moreover, sustainable energy is a key source to meet reduction of carbon emissions. On the contrary, standard vehicles are a big source of pollution, which makes the use of Electric Vehicles (EVs) a promising solution. However, because of range constraint and batteries cost, EVs have not developed too much so far. In this project, solar energy is used as a main source for charging station of EV. Inductive charging equipment, which uses an electromagnetic field to transfer electricity without a cord, has been introduced commercially for installation as an aftermarket add-on. Some currently available wireless charging stations operate at power levels through this technology is more common for transit or other fleet operations at higher power levels comparable to DC fast.

II. LITERATURE REVIEW

AbhijithNidmar et al (2019), has given the idea related wireless charging by using solar. Solar panel is used for the supply. The direct current by using 555 timers. Inductive coupling method is used for power transfer. Adel El-shahat et al. (2019) has given knowledge about essential requirements of electric vehicle charging and the various types of wireless charging methods compare to other methods, inductive power transfer has great power transfer efficiency prototype for inductive wireless power transfer is detailed. A.M. Alsomali et al (2017) has detailed the strategies of charging electric vehicles pulse width modulation is used to step down the voltage to a constant level. To reduce the charging time, time multiplexing method is used. Time multiplexing method is a successful charging method by simulation. BhuvaneshArulraj et al (2019) has given the idea of charging electric vehicle by using solar and wind system. Two separate batteries are used to store solar energy and wind energy. By comparing this two through voltage sensor, arduino decides which gives power to charge a vehicle by wireless charger. Dynamic charging method is the fastest charging method was the idea given by Carlos A.et al (2016). This charging method helps to charge the vehicle battery while it is moving.

III. PROPOSED SYSTEM

Solar based charging station is proposed in this research in fig.1. Here, the solar panels are kept at the roof of the charging station. It provides shades to the vehicles and generates the supply for this model. It uses solar energy and converts it into electrical energy through photovoltaic effect. The polarity control is used for the proper flow of the current to the battery.

The constant DC supply is stored in the battery, which is supplied to the inverter. The inverter generates high frequency AC current by using power electronic switches. According to Ampere's circuital law, this frequency AC current flowing in a primary coil produced variable flux in the vicinity. The primary coil is made up of copper wire, which is placed on the track below the parking station floor. The track consists of the aluminum shielding which concentrates the flux to the receiver. The receiver which is called secondary coil placed at the bottom of electric vehicle. Due to the Electromagnetic Induction Principle, emf is induced in the secondary coil. The secondary is connected to the full bridge rectifier which converts AC to DC. A regulator circuit is used to get constant DC supply, which charged the battery of electric vehicle.

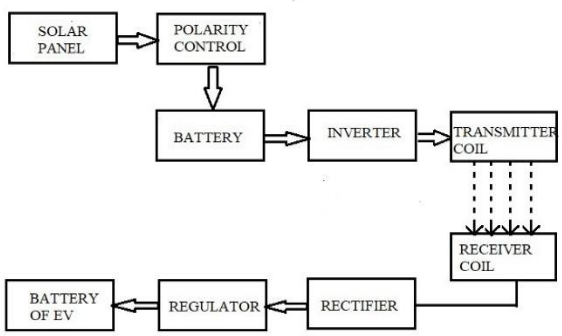

Fig.1. Block diagram of proposed system

IV. DESIGN CONSIDERATION

A. Coil Resistance

It is important to calculate the resistance of primary and secondary coils in Wireless Power Transmissions (WPTs), as they represent the main limitation for the power that can be transferred. Actually, if resistances were zero, the efficiency of the transformer would be 100%. Coil resistances generate joule effect, and this heat has to be remained at an acceptable level. Minimizing the joule losses is then a crucial point while designing WPTs, in terms of efficiency and transferable power.

$$R = \frac{\rho l}{A}$$

Where,
l is length of the coil,
A is area of the wire,
ρ is resistivity of the coil.

B. Helix coil

The arrangement of the helix coil (wire radius is not in scale with coil dimension). The turns are packed together in a rectangular section, having base b and height h, and their mean distance from the coil axis is R_m. The self-inductance of each coil can be formulated as

$$L_{Helix} = \frac{0.31(R_m)^2}{6R_m + 9h + 10b}$$

C. Quality factor

The quality factor (Q - factor) is a measure or the performance or a coil, capacitor, inductor in terms of its losses and resonance bandwidth. In resonance circuit, sharpness of the resonance can be measured by a term Q – factor.

$$Q = 2\pi * \frac{\text{Max. energy stored in the circuit}}{\text{Energy dissipated by the circuit in one period at resonance}}$$

In series circuit, the quality factor is given by

$$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 CR} = \frac{1}{R}\sqrt{\frac{L}{C}} \qquad \text{... ... ... (1)}$$

In parallel circuit, it is given by

$$Q = \frac{R}{\omega_0 L} = \omega_0 RC = R\sqrt{\frac{C}{L}} \qquad \text{... ... ... (2)}$$

When the circuit applied act as a voltage amplifier, the voltage produced as resonance circuit will be very high compared to the input supply voltage.

In series circuit, at resonance, the voltage across the inductor can be given by the equation

$$V_L = \frac{V_m}{R}\omega_0 L \qquad \text{... ... ... (3)}$$

We know that

$\frac{\omega_0 L}{R}$ is the quality factor (Q).

So, equation 3 becomes,

$$V_L = V_m Q \qquad \text{... ... ... (4)}$$

From the above equation, it is evident that the voltage across the inductor will be much larger than the input supply voltage. Hence this circuit can act as a voltage amplifier. The same concept can be applied for the voltage across the capacitor. By properly design the values or L & C in the resonance circuit, we can acquire higher voltages at high frequencies.Fig.2 shows that inductive coupling with resonant circuit.

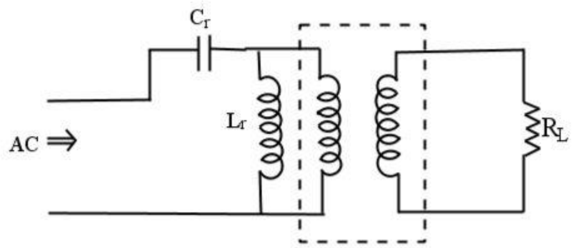

Fig. 2 Inductive Coupling with Resonant circuit

Where,

L_r → Resonant Inductor

C_r → Resonant Capacitor

R_L → Load Resistance

The values of these components are calculated using a few equations that are derived as follows. To simplify the calculation, the transformer can be eliminated by referring this load resistance as shown in fig.3

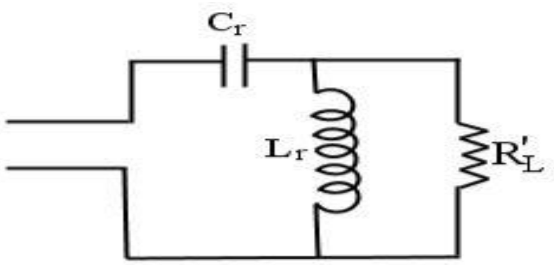

Fig. 3 RLC Circuit

The resistor that is referred to the primary side is addressed as R'_L.

At resonance condition, the imaginary components is the complex impedance are zero. Then we can solve for the circuit parameters as the resonance condition.

In figure, L_r and R'_L are parallel to each other.

So, Total impedance $Z = \frac{R' L_r}{R' + jL_r}$

$$Z = \frac{R' j\omega L}{R' + j\omega L}$$

C_r is series with the combination of L_r&R'_L.

So,

$$Z = \frac{1}{j\omega C} + \frac{j\omega L)}{R' + j\omega L}$$

$$Z = \frac{1}{j\omega C} + \frac{R'(j\omega L)}{R' + j\omega L} * \frac{R' - j\omega L}{R' - j\omega L}$$

$$Z = \frac{1}{j\omega C} + \frac{(R')^2(j\omega L) + R'(\omega L)^2}{(R')^2 + (\omega L)^2}$$

By separating Real and Imaginary part,

$$Z = \frac{(\omega L)^2 R'}{(R')^2 + (\omega L)^2} + j\left[\frac{(\omega L)\,(R')^2}{(R')^2 + (\omega L)^2} - \frac{1}{\omega C}\right] \quad \ldots\ldots\ldots (5)$$

From the equation, if we equate the imaginary component to zero, we can get the following equation.

$$\left[\frac{(\omega L)\,(R')^2}{(R')^2 + (\omega L)^2} - \frac{1}{\omega C}\right] = 0 \quad \ldots\ldots\ldots (6)$$

From the above equation, the resonant frequency is obtained as follows.

$$\left[\frac{(\omega L)\,(R')^2}{(R')^2 + (\omega L)^2} = \frac{1}{\omega C}\right]$$

$$\omega^2 = \frac{1}{LC - \frac{L^2}{(R')^2}}$$

$$\omega = \frac{1}{\sqrt{LC - \frac{L^2}{(R')^2}}} \quad \ldots\ldots\ldots (7)$$

From equation (7), we can get

$$C = \frac{1}{L\omega^2} + \frac{L}{(R')^2} \quad \ldots\ldots\ldots (8)$$

If the input voltage is given by V_{in}, at resonance, the relation between voltage & current is given by

$$V_{in} = I\left[\frac{(\omega L)^2 R'}{(R')^2 + (\omega L)^2}\right] \quad \ldots\ldots\ldots (9)$$

At resonance, the voltage drop in the resonant circuit will be only due to the real part of the total circuit impedance.

Then

$$I = V_{in}\left[\frac{(R')^2 + (\omega L)^2}{(\omega L)^{2'}}\right] \quad \ldots\ldots\ldots (10)$$

Quality factor (Q)

To find the voltage across the inductor and voltage across the capacitor, quality factor of this circuit is necessary. To find the expression of Q, the fig. 3 can be redrawn as shown in fig 4.

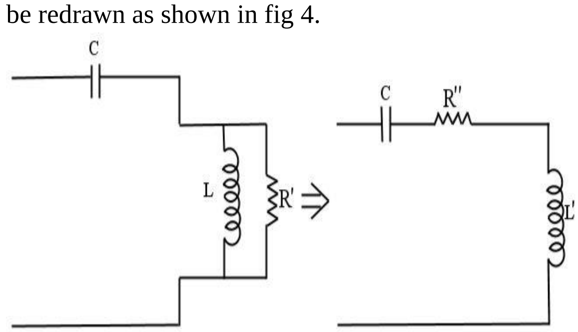

Fig. 4 Transforming to equivalent circuit

From figure 4,

$$\frac{1}{\frac{1}{j\omega L} + \frac{1}{R'}} = j\omega L' + R'' \quad \ldots\ldots\ldots (11)$$

$$\frac{j\omega L R'}{j\omega L + R'} * \frac{R' - j\omega L}{R' - j\omega L} = j\omega L' + R''$$

$$\frac{j\omega L R'(R' - j\omega L)}{(R')^2 + (\omega L)^2} = j\omega L' + R''$$

$$\frac{j\omega L (R')^2}{(R')^2 + (\omega L)^2} + \frac{(\omega L)^2 R'}{(R')^2 + (\omega L)^2} = j\omega L' + R''$$

By equating Real and Imaginary part

$$R'' = \frac{(\omega L)^2 R'}{(R')^2 + (\omega L)^2} \quad \ldots\ldots\ldots (12)$$

$$L' = \frac{L(R')^2}{(R')^2 + (\omega L)^2} \quad \ldots\ldots\ldots (13)$$

For series circuit, Quality factor (Q) is designed as

$$Q = \frac{\omega L'}{R''} \quad \ldots\ldots\ldots (14)$$

Substituting (12) and (13) in (14)

$$Q = \omega \frac{L(R')^2}{(R')^2 + (\omega L)^2} * \frac{(R')^2 + (\omega L)^2}{(\omega L)^2 R'}$$

From the above equation, we can get

$$Q = \frac{R'}{\omega L} \quad \ldots\ldots (15)$$

This quality factor is in terms of inductor L,

- For series circuit, the Quality factor in terms of Capacitance is given by

$$Q = \frac{1}{\omega C R''} \quad \ldots\ldots\ldots (16)$$

Substitute (12) in (16)

$$Q = \frac{1}{\omega C\left(\frac{\omega^2 L^2 R'}{(R')^2 + \omega^2 L^2}\right)}$$

By solving this equation, we can get

$$\frac{Q}{Q^2 + 1} = \frac{1}{\omega C R'} \quad \ldots\ldots\ldots (17)$$

- Voltage across the capacitor

$V_c = I\,X_c$

$$V_c = V_{in}\left(\frac{(R')^2 + (\omega L)^2}{(\omega L)^2 R'}\right)\left(\frac{1}{\omega C}\right) \ldots\ldots (18)$$

Substitute (8) in (18)

$V_c = I\,X_c$

$$= V_{in}\left(\frac{(R')^2 + (\omega L)^2}{(\omega L)^2 R'}\right)\left(\frac{1}{\omega C}\right)\left(\frac{L(\omega)^2 (R')^2}{(R')^2 + (\omega L)^2}\right)$$

$$V_c = V_{in}\left(\frac{R'}{\omega L}\right)$$

We know that $\left(\frac{R'}{\omega L}\right)$ in Q

So $V_c = V_{in}\,Q \quad \ldots\ldots\ldots (19)$

Voltage across the inductor

From equation (10)

Input current $I = V_{in}\left[\frac{(R')^2 + (\omega L)^2}{(\omega L)^2 R'}\right]$

The total current obtained from the resultant of the two vectors is equal to the current I.

$$\sqrt{(I_L)^2 + (I_R)^2} = V_{in}\left[\frac{(R')^2 + (\omega L)^2}{(\omega L)^2 R'}\right]$$

We know that

$$Q = \frac{R'}{\omega L}$$

So,

$$V_L\sqrt{1 + Q^2} = V_{in}(Q^2 + 1)$$

$$V_L = V_{in}\sqrt{1 + Q^2} \quad \ldots\ldots\ldots (20)$$

Current through the inductor can be calculated by

$$I_L = \frac{V_L}{\omega L} = I_C \quad \ldots\ldots\ldots (21)$$

The design consideration is used to design coils of transmitter and receiver for wireless power transmission.

V. HARDWARE IMPLEMENTATION

Fig. 5 shows the whole experimental setup which includes the solar panels and the various hardware parameters of the hardware setup. The solar energy as the input source for getting a quick result solar panel will exposed to the solar radiation for a certain time. The panel gets heated up and the power collected from the panel will be transferred to the inverter block. The inverter which helps to the power will be transferred from DC to AC. The AC supply will be given to the primary coil gets energize creates the magnetic field or flux in the primary side. Flux created in the primary side links the secondary coil and the EMF will be transferred wirelessly between the coils. Transferred power in the secondary coil will be indicated by using the LED after it will be moved to the rectifier circuit AC converted to DC will be injected to the booster circuit and the various harmonics will be neglected by the compensation networks and finally the power will be given to the Electrical Vehicle [EV].

Fig. 5 Hardware model

VI. CONCLUSION

Wireless Technology has emerged in the engineering domain which have been several problems associated with the wired charging such as power loss during transmission owing to the impedance of the conductors. Thus, a wireless mode of charging an electric vehicle is proposed. Solar energy is incorporated into the system in order to make it an independent power source, the use of Wireless power transmission proves to be useful and efficient when compared to wired transmission, furthermore, as demonstrated in the model, large scale setup of a wireless power station is possible in the near future.

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