A Wireless Approach For Powering Of Solar Power Satellite

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Abstract

Wireless power transmission and reception is an underdeveloped field of study. There are many promising applications for the ability to transport power over great distances and boundaries without the need for transmission lines. Wireless power transmission is a useful and convenient technology that can be employed to collect solar energy (Renewable energy) and concentrate on earth surface without the need for a wire connection. Overall, WPT will support both future energy production and the environment. This paper provides an analysis of wireless power transfer with an assessment of its practical applicability in terms of power range. There are two types of satellites are accessed ,one is primary and other is secondary .This assessment is obtained through the design and construction of a resonant inductive wireless powering system(in secondary) suited to supply a satellite transceiver(primary) including OOK techniques for data communication to improve efficiency .It consists two main parts for implementation (i) Power train & (ii) Control loop. The Power train is Implemented in MATLAB code environment with distance of 2 meters with efficiency of 70-75% for power range 80-120W.

Keywords-Introduction; Solar Power Satellite; Proposed system block diagram; Result; Conclusion

1. Introduction

One of the major issues of present day power system is the loss of electrical power due to resistance in the wire during transmission and distribution of electrical energy. The resistance of the wire may cause a loss of 26%-30% of the total generated energy. This loss decreases the efficiency of power transmission. Nikola Tesla is best known for his remarkable statements regarding the wireless transmission of electrical power. His first efforts towards this end started in 1891 and were intended to simply "disturb the electrical equilibrium in the nearby portions of the earth ... to bring into operation in any way some instrument." In other words the object of his experiments was simply to produce effects locally and detect them at a distance. Again, recent climate change due to “Green-house Effect” from burning fossil fuels has gain brought alter-native energy sources to public attention. Therefore, the time has come to move our attention to Solar Power Satellite (SPS). SPS is a concept to collect solar power in space and then transport it to the surface, where it is converted into electrical power for terrestrial. Throughout the history of science and technology, the possibility of supplying power wirelessly has held a prominent place in the mindset of scientists as well as the general public. The concept of wireless electrical power is far from new and has been heavily exploited throughout the 20th century, e.g. in applications employing electromagnetic waves as means of transporting very low power over vast distances for communication purposes (radio transmission).Although the prospect of transmitting high power levels over similarly great distances has been subject to a lot of scientific research over the course of the last 121 years, a practically implementable and commercially viable solution has yet to be presented due to the losses associated with the large distances of interest. Recent year’s technological advances have however led to the introduction of battery powered portable equipment with different logistical requirements in terms of power and distances than have previously been the case. The subsequent change in use, from long range powering to short range charging has altered the premise on which Wireless Power Transfer (WPT) was previously discarded as a no feasible solution. Furthermore the prospect of gaining valuable early shares of emerging markets has respired interest from the scientific community and led to serious commercial efforts towards bringing forward a solution to wireless charging of products ranging from smaller portable devices to electric vehicles. Some of the more notable recent contributors in the growing field of WPT include MIT and Intel, whose R&D efforts have led to the coining of nifty terms such as WiTricity and WREL2 respectively.

2. Solar Power Satellite (SPS)

The concept of the Solar Power Satellite energy system is to place giant satellites, covered with vast arrays of solar cells, in geosynchronous orbit 22,300 miles above the Earth's equator. Each satellite will be illuminated by sunlight 24hoursa day for most of the year. Because of the 23"tilt of the Earth's axis, the satellites pass either above or below the Earth's shadow. It is only during the equinox period in the spring and fall that they will pass through the shadow. They will be shadowed for less than 1% of the time during the year. The solar cells will convert sunlight to electricity, which will then be changed to radio-frequency energy by a transmitting antenna on the satellite and beamed to a receiver site on Earth. It will be reconverted to electricity by the receiving antenna, and the power would then be routed into our normal electric distribution network for use here on the Earth. Figure 2 illustrates the concept. Capacity of a large Earth-based power plant. The great advantage of placing the solar cells in space instead of on the ground is that the energy is available 24 hours a day, and the total solar energy available to the satellite is between four and five times more than is available anywhere on Earth and 15 times more than the average location. Testing has demonstrated that wireless energy transmission to the Earth can be accomplished at very high efficiencies. Tests have also shown that the energy density in the radio-frequency beam can be limited to safe levels for all life forms. The concept is simple; the technology exists.

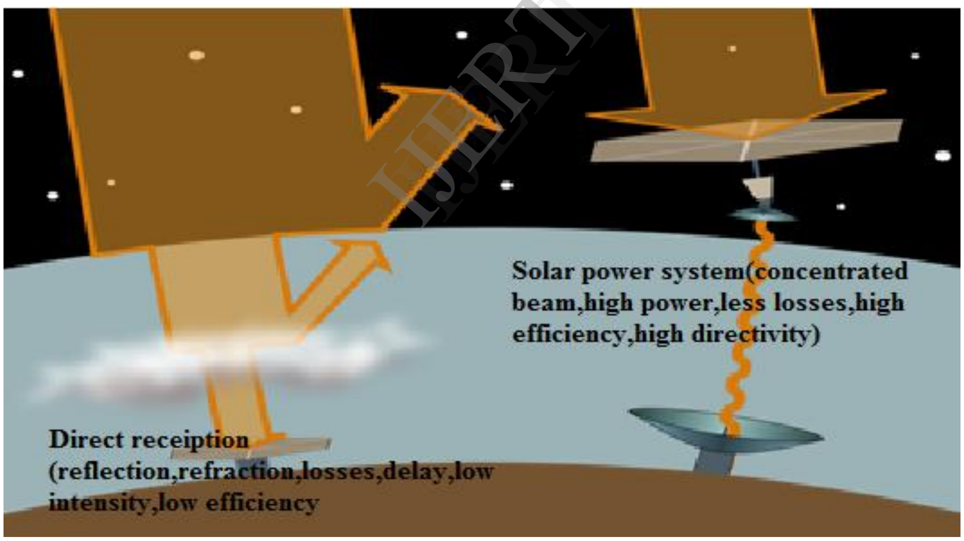

Fig 1. Direct reception and SPS reception

3. Proposed System Block Diagram

Although larger amounts of power can be transferred using the simple system by increasing input power and coil dimensions, it is desirable to make the circuit compatible with an AC power signal from an electrical outlet, to identify the power requirements of the device being charged, to store power in the receiver for later use, and to shutoff the transmission of power to a receiver that is out of range of the transmitter. To accomplish all this, a bi-directional coupling system must be implemented to transmit power across certain frequencies and data across separate frequencies without interference. Fig. 2 depicts the block diagram for such a system. This design has not been tested in the lab and improvements to it are still being considered. Conceptually, however, the block diagram properly reflects the intentions of the system.

3.1. Summary of Block Diagram Functionality

The circuit in Fig. 2 passes the incoming AC power waveform from a standard electrical outlet through an AC-DC rectifier. This DC signal is then distributed to a low-dropout (LDO) regulator that is suitable for use with the multi-constant output voltage for the MCU. The MCU at the transmitter also reads data from the RF receiver that is in communication with the RF transmitter at the receiver in order to control the switch S1 and the DC-DC converter. The RF receiver tells the MCU two pieces of information: whether or not the load is out of range of the transmitting coils, and the power requirements of the load if it is in range. Basically, if a load (like a cell phone) is out of range, then the switch S1 will open, zero power will reach the DC-DC converter, and the transmitting coils will not transmit power wirelessly, thus minimizing wasted power. If the cell phone is in range, then S1 closes, and the MCU relays the power requirements of the load to the DC-DC converter, which is inverted to an AC signal at the resonant frequency of the inductively coupled coils. At the receiver, the incoming AC signal is converted back to DC. The current sensor then determines how much current is received by the load device (i.e. a Resistive load). If this current is below a predetermined threshold, meaning that the loads is out of range of the transmitting coil, then the MCU pings the RF transmitter to relay an "out of range" signal back to the RF data receiver. An out of range signal also means that switch S2 opens and any power still being transmitted by the transmitting coil (until it shuts off) is stored in a storage unit, and switch S3 closes to still provide power to the load. Due to the improving capabilities for supercapacitors to store larger amounts of voltage, a supercap is shown in Fig. 2 as this storage unit. If the load device is in range of the transmitting coil such that it receives sufficient current, switch S2 closes and the load is directly connected.

3.2. Current Detector for Wireless Power Communication

To implement the current detector – essentially an intelligent ammeter – first consider how a similar issue is handled with LEDs. Very often an LED will receive sufficient current to light up; however, this current may be so small such that the light is unnoticeable. The same affect is reproduced by the current detector and MCU at the receiver in Fig. 2. The MCU receives data relaying the minimum current and voltage required to charge the load device. The MCU controls switches S2 and S3 accordingly, which either power the load device or store power for later use – much like a battery.

3.3. Data Communication

Although the data communication components will require supply voltages that take away from some of the power transmitted wirelessly, the overall efficiency will improve and the total wasted power will decrease because the data communication allows for the power transfer to be completely halted as soon as a load device is out of range.

There are several techniques that can be implemented for this data communication. In this case, the two MCUs handle all the data signal reading and writing, and for simplicity a single channel RF wireless data transmitter and receiver are used in Fig. 2. Another strategy that is currently part of ongoing research involves using the transmitting and receiving coils for bidirectional data and power communications using On-Off keying (OOK). This technique will eliminate the need for a separate data communications mechanism because OOK will allow the coils to transmit data at one frequency, and power at a separate frequency without interference.

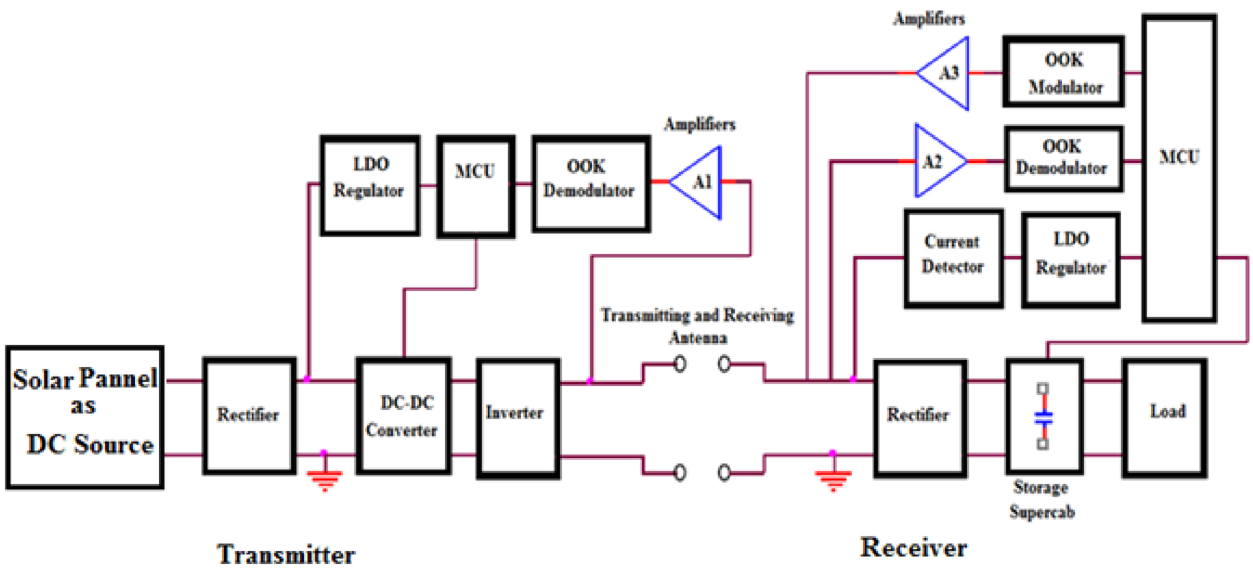

Fig 2.Block diagram of wireless power transfer system using RF receiver and transmitter antennas for Satellite Transceiver.

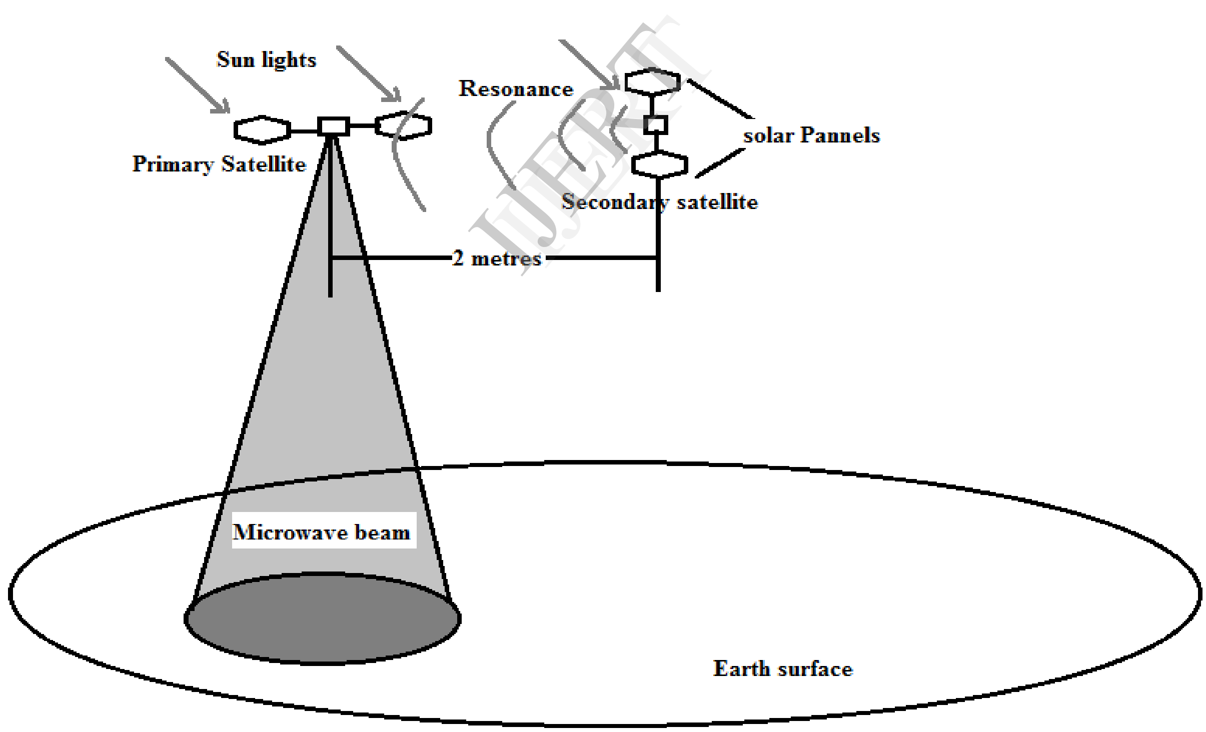

Fig 3 Basic Concept

4. Software Implementation

MATLAB R2012a is used for evaluation of proposed system. The function of each block is processed with MATLAB Coding. The microcontroller interfacing is done using C language code in MATLAB environment. First all required Parameters are initialized and the power train (source,dc-dc converter,inverter,rectifier,filter & load) is evaluated in terms of efficiency.

5. Result

The proposed system is evaluated in terms of efficiency with MATLAB coding, and the result is representing in Figure 4. The three graphs depict the efficiencies of both the buck converter, and the coils including the full bridge rectifier, as well as the overall efficiency. The overall efficiency of wireless Satellite transceiver at maximum power (120 W) is in range of 70-75% with distance upto 2 meters .

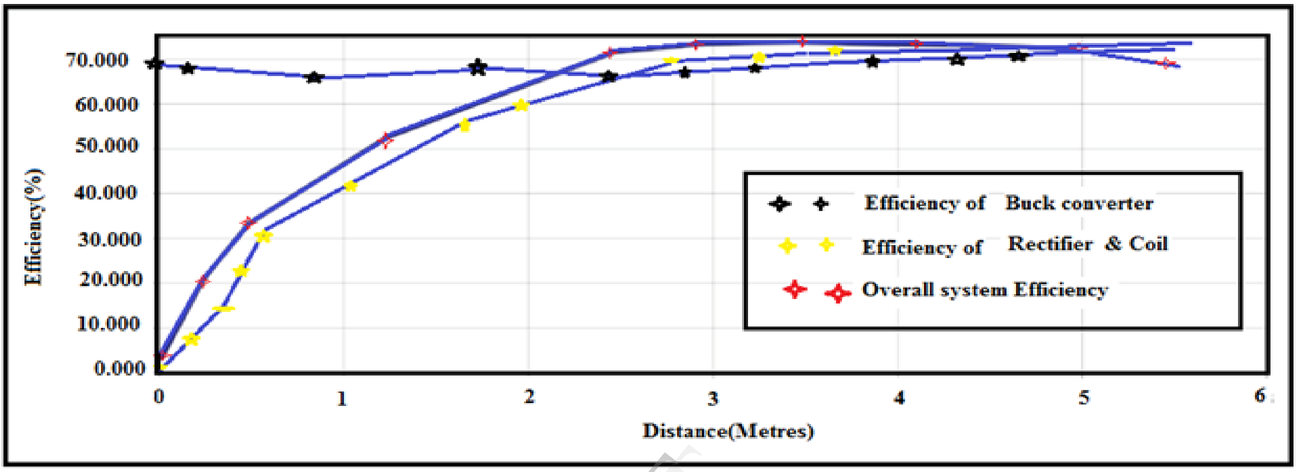

Fig 4. Efficiencies of subsystems of wireless satellite transceiver (buck, coil rectifier and overall efficiency)

6. Conclusion

The concept of Wireless Power Transceiver system for Satellite which offers greater possibilities for transmitting power with negligible losses and ease of transmission is presented here. The system block diagram is discussed. Through the development of this system, a noteworthy realization was made. A scheme for such a feedback channel (Control Loop) was proposed .This possibility should be investigated, since this would make possible the omission of the secondary side converter and the losses it inflicts on the overall performance. The following components are all part of ongoing research, and can be added to the system to improve energy efficiency, minimize transmission power loss, and explore alternative methods for wireless power transfer:

- A controlling unit at the transmitter and receiver for maintaining efficiency with increasing distance.
- A controlling unit at the transmitter and receiver including a current monitor to detect when a device is “out of range” of the transmitter.
- Protection against interfere with Resonance.
- An energy storage unit at the receiver using a super capacitor.
- An RF-DC converter that can replace the inductively coupled coils as the wireless power transfer mechanism between the transmitter and receiving device.

With all the challenges that face wide-scale deployment of this new technology wireless powering for satellite transceiver is still considered as a next-generation power transmission system.

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