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# Design and Implementation of MPPT based Solar Powered Wireless Battery Charger

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**Abstract**

The solar power derived is monitored using a microcontroller to operate the PV panel at maximum power point. The power transmission circuit is a wireless charging circuit employing magnetic resonance coupling, which offers higher efficiency even with non-coaxial alignment. Wireless charging also eliminates the need for tethered cords, allows mobility, and synchronous frequency enables the charging of co devices at the same time.

**Keywords:** Resonance coupling, Maximum Power Point Tracking

## 1. Introduction

Today's world is only a limb short of absolute digitalization and it would be an injustice to exclude mobile phones and other hand-held electronic devices from the digital revolution. Although the semiconductor industry has seen a great leap in the past decade it had also become an industry to put a heavy pressure on the power sector, be in the form of load, quality or losses. The stress on the grid caused by the electronic loads alone amount to 10's of Gigawatts every year, a considerable fraction of annual global power generation. The growth in power sector, although not at sustainability, have rendered brilliant results in the lookout for renewable energy harvesting and could be the future power source for the entire humanity.

The main attraction of the past few years, solar energy could be the energy of tomorrow, with lesser pollution and no risk of running out, at least in the near future. Increase in need for electronics also increases their availability and constant usability, i.e., infinite charging. The above ideal charging setup is being realized via wireless charging which now can be used to charge very large loads like Electric vehicles. Wireless charging that could


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offer mobility to the devices is the state of art technology that would power the world, ideally, with no need to shut it down. With the above considerations in mind the utilization of renewable power sources, especially solar energy to power the wireless charging circuit, which when extended to the charging of all hand-held devices would be a critical contributor in improving the mobility and remove the limitations that come with cords and charging ports. The magnetic field synchronous coupling employed in tapping the power for the load enables the system to operate at maximum efficiency, directly following the MPPT (Maximum Power Point Tracking) algorithm employed. The method also keeps open the future enhancements in universalizing the operating frequency of the transmitter-receiver pair, thus creating a universal charger for all kinds of handheld devices. The design and testing were formulated based on these objectives.

a) Execution of MPPT Algorithm for efficient charging of the battery, implemented by using Arduino logic.

b) To synchronize the transmitter and receiver coils at their resonance frequency [1, 2] thus effectively improving the range of quality power transmission and improved efficiency after conversion.

c) To provide an extended range of charging distance whilst no co-axial [1] alignment is feasible.

d) Scaling the receiver circuit as a mobilizable dongle for universal use of the wireless charger.

e) To expend the prospects of power source from solar to dual source, i.e., Solar and Conventional.

## 2. Proposed Work

The charging system has two units, the MPPT and the transmission unit. The conversion, rectification and control units assist in the integration and operation of the main blocks. Figure 1 depicts the overall block diagram. MPPT Charge Controller achieves MPP through DC-DC optimizers and Localized control of panel voltage and current can also be achieved, and each panel Operates at its independent maximum power point (MPP), thus improving the energy Extraction of the overall system. The series connection of the outputs provides an Inherent voltage stacking that enables each DC-DC converter [2] to operate at a relatively

Low voltage conversion ratio (enabling high conversion efficiency), while still achieving High overall output voltage, which is desirable as it enables the use of a central, high-Voltage, high-efficiency inverter. Figure 2 depicts the block diagram of the MPPT Charge Controller.

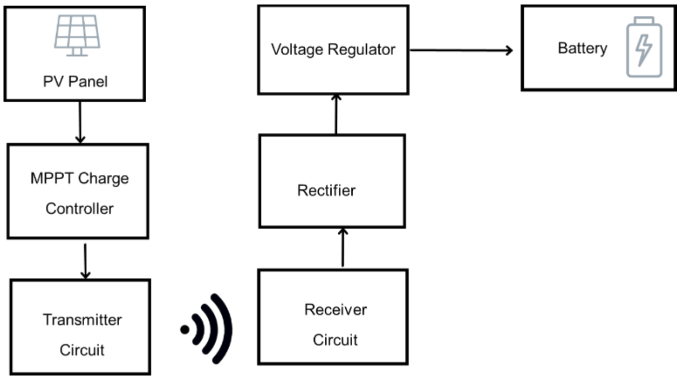


**Figure 1.** Overall block diagram

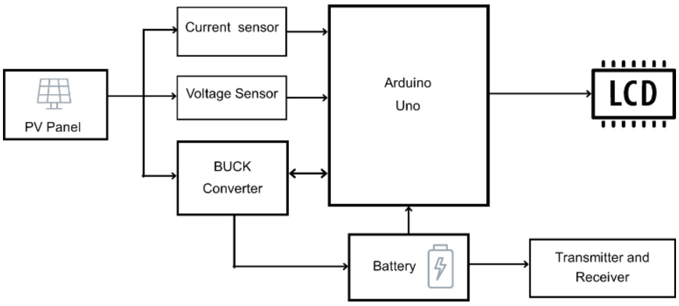


**Figure 2.** Block Diagram of MPPT Controller

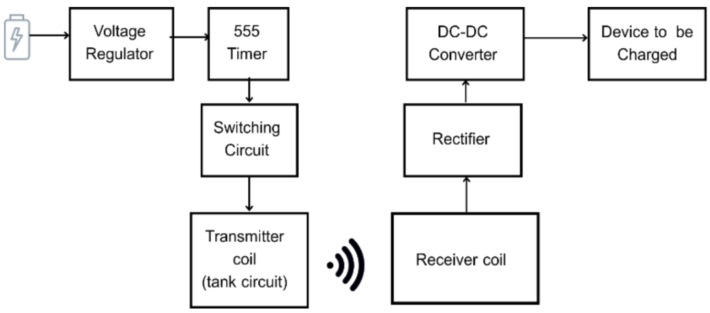


**Figure 3.** Block Diagram of Power Transmission

The wireless charging circuit is the circuit being loaded where the battery Voltage to converted to high frequency pulses by the use of a MOSFET (Metal Oxide Semiconductor Field Effect Transistor) switch. The Battery charged from MPPT algorithm in the previous step powers the transmission Circuit, that would then be used to charge the loads. The battery voltage is regulated to the threshold of the 555 timer and the maximum output voltage is tapped from the Battery for powering the resonantly coupled circuit. Figure 3 depicts the block diagram of the Transmission Circuit.

## 3. Simulation and Results

The MPPT battery charger circuit is realized in MATLAB – Simulink as depicted in the Figure 4, with blocks that emulate the dynamic programming environment, enabling us to cut close to hardware replication. The PV (Photovoltaic) array block in Simulink allows the user to select one of the available panels with pre-determined characteristics or to customize the ratings.

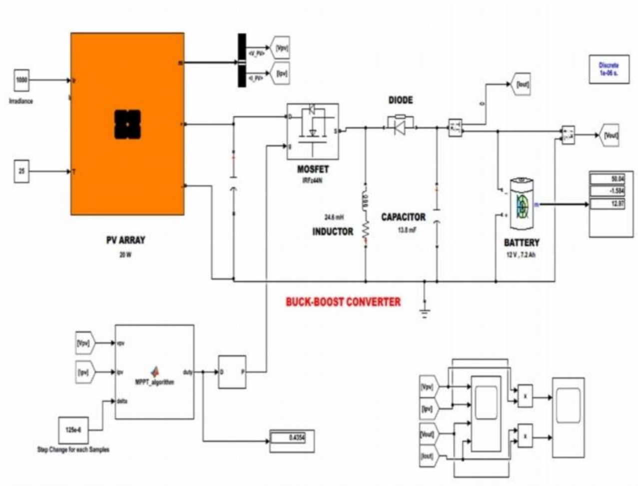


**Figure 4.** Simulink model of MPPT Controller

The primary half of the circuitry is the DC-DC converter design to draw maximum output from the PV array. The buck-boost converter adopted for executing the MPPT algorithm retains the operating point near the Maximum Power Point in conditions where the PV panel output falls above or below the required output voltage with the help of MPPT algorithm block, which functions in place of a microcontroller in real time. The algorithm enables both buck and boost mode, consistently tracking the operating point and adjusting it by altering the duty cycle. To imitate real time, the PV panel takes both irradiance and temperature as input. The depicted circuit takes a constant irradiance input but can be modelled to accept variable irradiance to mimic an available dataset. The converter circuit charges the battery, which is essentially an ideal, lossless load in the simulation and the system achieved MPPT in both buck and boost modes. The battery attains steady state voltage in constant charging mode and retains it till 80% of its charging capacity and enters constant current mode for the rest 20%.

The power transmission unit shown in Figure 5, for the wireless transmission using resonance coupling is realized with the help of MATLAB – Simscape to replicate the real-world conditions. Simscape is a physical modelling environment that provides the user with the option to create non-ideal version of the components used and a wide range of customization parameters.

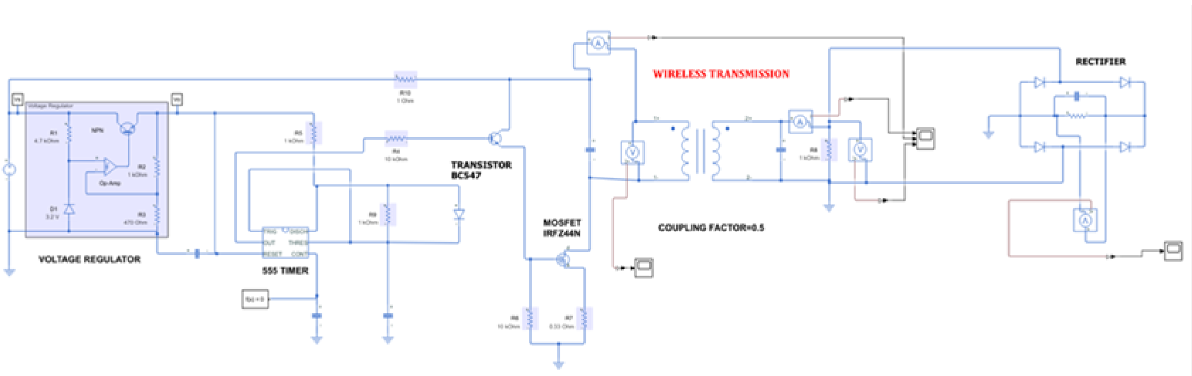


**Figure 5.** Power Transmission Unit

The panel output voltage waveform depicted in Figure 6 is the voltage at maximum power point of the solar panel. It is fed as input to the DC-DC converter employed to step down or step up the voltage accordingly, monitored and regulated by the Arduino logic fed into the controller for adjusting the PWM duty cycle.

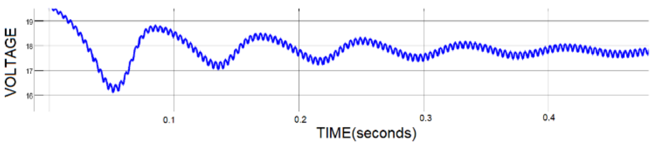


**Figure 6.** Panel Output Voltage Characteristics

The panel output current, which is also the current at Maximum Power Point as indicate in the chosen panel rating. The Figure 7 depicts the steady state current at Maximum power point and held at the Ipp value for the entirety of power production as soon as it reaches the peak value. Table 1 shows the VI characteristics of the PV panel used as the power source under STP (Standard Temperature and Pressure) and the maximum power delivered by the panel at its MPP value. Figure.8 shows the PV-curve plotted from the table explaining the operation of the panel at its rated values but unable to deliver maximum power at those rating. This supports the implementation of P&O (Perturb and Observe) algorithm [13], to track the voltage and current to deliver maximum power.

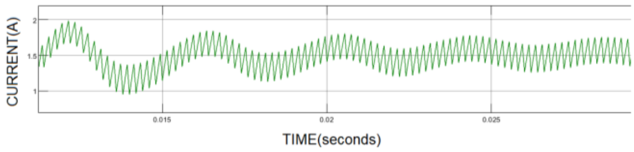


**Figure 7.** Panel Output Current Characteristics

**Table 1.** VI characteristics of PV panel

| S. No. | Voltage(V) | Current(A) | Power(W) |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 0 |
| 2 | 3.40 | 1.28 | 4.352 |
| 3 | 6.60 | 1.27 | 8.382 |
| 4 | 16.15 | 1.22 | 19.703 |
| 5 | 16.80 | 1.19 | 19.992 |
| 6 | 17.90 | 1.01 | 18.079 |
| 7 | 19.40 | 0.40 | 7.76 |

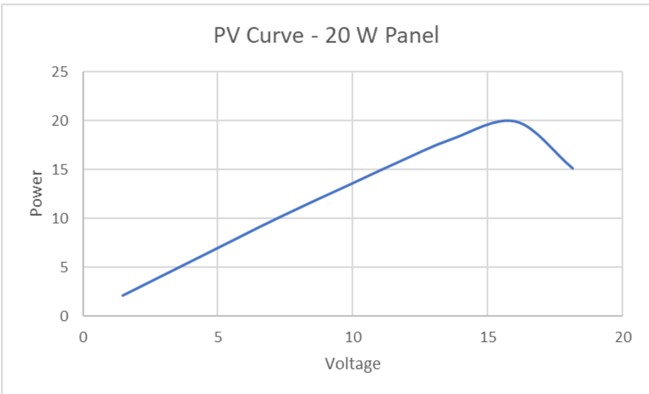


**Figure 8.** PV-Curve

The battery is charged to 80% in constant voltage mode and the float percentage is charged in constant current mode to ensure the safety of the device and the longevity of the battery. Figure 9 represents the current drawn from the battery after it is fully charged by the converter circuit. The 7.2Ah battery allows the user to draw a steady current of 1.1A at its fully charged condition and stabilizes to its steady state value fairly quickly, with a very short transience.

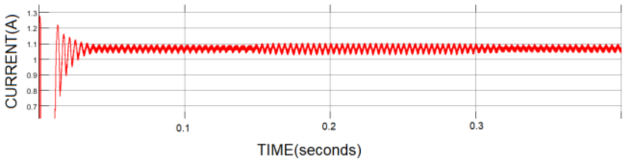


**Figure 9.** Battery Current Characteristics

The voltage output of the 12V battery cuts close to its rated value as represented in Figure 10. The discharge experiences a brief transient period before it stabilizes around 12V and supplies a steady state voltage for considerable period of time. This battery output powers the entirety of Transmission-Receiver unit and the stable charging and discharging enables the efficient operation of the secondary unit.

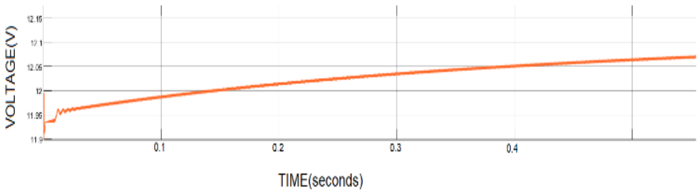


**Figure 10.** Battery Voltage Characteristics

## 4. Hardware Implementation

Solar battery charger with MPPT tracking has been implemented in real time with the help of a DC-DC converter. The converter adopted for the realization is a DC-DC buck converter, whose maximum power point has been achieved with the help of a solar emulator under lossy condition. The Solar PV panel is of polycrystalline variety and is suitable for use in rugged conditions with life as long as its monocrystalline counterpart. It also pulls close to its maximum operating capability even under low light conditions. The hardware setup visualized in Figure.11 is the buck converter with gate driver circuit implemented in its simplest form with a use of LM741 IC operating in the inverting mode. The driver setup turns on the MOSFET and holds the Vgs at the rated maximum, thereby reducing the Vds drop, and allowing the MOSFET to operate as a switch and not slip into linear region. Since the driver circuit employs an Op-Amp (Operational Amplifier), there is no loading effect due to its high input impedance.

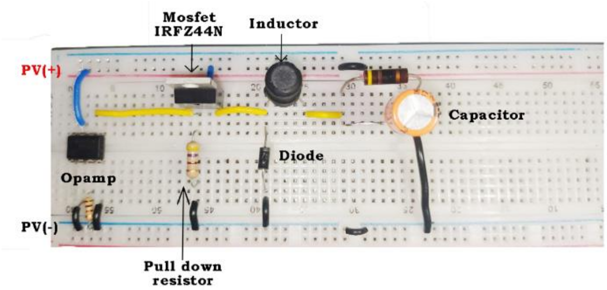


**Figure 11.** Hardware assembly of Buck Converter

The pull-down resistor attached to the source terminal plays a crucial role in turning the MOSFET off as soon as the Vgs is removed. The inductor and capacitor are designed to match the impedance of the PV panel, thereby achieving MPPT [12] by the principle of Maximum power transfer theorem. The battery at the end of the buck unit is the load and acts as the voltage-controlled voltage source. As depicted in the Figure. 12 the switching circuit comprises of a power MOSFET, driven by an operational amplifier which in turn is powered by the solar PV panel, making the entire set up operating on renewable energy. The Arduino Uno module provides the required PWM (Pulse Width Modulation) pulses in accordance with the Maximum Power Point Tracking.

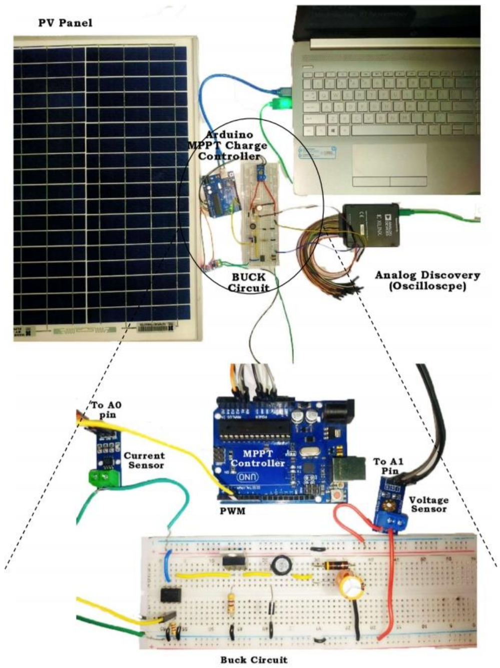


**Figure 12.** Hardware assembly of MPPT Controller

The PWM pulses are then amplified to saturation by the Op-Amp which acts as the gate driver. Since the Solar PV output is sufficient to drive the MOSFET at its maximum gate-source potential, the RDS drop becomes almost negligible and the power conversion remains close to ideal conditions. This also eliminates the need for a complicated gate driver circuitry cutting down on the cost. The MOSFET IRFZ44n was chosen for its high-power withstanding capability. It is worth mentioning that since this model is an N-channel MOSFET it has comparatively lower loss characteristics and optimizes the circuit operation. The high input impedance of the MOSFET prevents the loading of Op-Amp and thus the need for resistance grounding in the Op-Amp output.

## 5. Conclusion

The insufficient power supply and power outages in remote areas has been addressed by the implementation of Maximum Power Point Tracking to monitor the solar power generation. A battery backup has been provided to stabilize the powering of transmission-receiver circuit and as a power source for times of insufficient irradiation or night time. Wireless charging utilized greatly improved the chances of uninterrupted usage of mobile phones and other hand-held devices. The resonant coupling adopted instead of conventional inductive coupling comparatively reduced the coupling factor required for effective transmission in the transmission-receiver unit.

The magnetic field synchronous coupling has tremendously reduced power loss due to misalignment of device and charger, while the resonant operation of the coupled coil has eliminated the need for devices specific ports or charger cables. Wireless charging has also allowed the user to function effectively without the need to be tethered to a cord. In order to reduce the magnetic interruptions between multiple receivers, the resonant peak associated with the receiver has been designed to be coil pair specific, thereby charging multiple devices from same transmitter.

## 6. Future Scope

Wireless power transmission using resonant coupling could be extended to accommodate a number of receiver units by designing appropriate LC circuits to operate at multiple Q points. The standardization of frequency in receivers could enable such circuits to have predetermined Q values and thereby reduce losses occurring in idling mode or during coupling with a single receiver. A key issue for powering of multiple receivers is the coupled mode frequency splitting that occurs when two receivers are in close enough proximity that their magnetic fields are relatively strongly coupled. Control circuitry to track the resonant frequency shifts and to retune the receiving coil capacitances is a potentially viable strategy for addressing this issue.

## 7. Acknowledgement

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