Hybrid Solar RF modified

Abstract

This research focused on a potential application for a stationary sensor, which would combine the ever-present but low-power RF energy with the strong but variable solar power input. Moreover, the study confirmed that the two EH systems together produced more usable electricity when combined into a hybrid system than when operating independently.

Introduction

Recently, WPT concept has emerged as a promising technology to provide energy to battery constrained devices where the use of electric wires is infeasible [23].

In [1], the authors have shown the usefulness of LED DC Street Lights (SLs) rather than the traditional AC Street light. These are environment-friendly and offer better efficiency, lower maintenance costs and prolonged lifetime. In [3], the SLs were upgraded to LED where 64% energy saving is obtained. [6] and [7] focussed on Intelligent street lightning system where a Wireless Data Network based Street Lightning system is able to monitor and control a network with a number of street lights using Zigbee Protocol. EH technologies can be modified to harness energy not only from any single source but a combination of some suitable ambient sources which can be used as a supplement to power various electric operated systems such as low power consumption devices, unmanned aerial vehicles (UAVs)[8-10], robots, wheelchairs [11]. Authors in [],[] focuses on various hybrid energy harvesting mechanisms. Switching between two energy sources is established with the help of a multiplexer/electronic switch. Whenever both energy sources are present simultaneously, only one of the energy sources would be harvested based on the priority given by the power management circuit. One of the major tasks of WSN is continuous monitoring of environmental parameters such as humidity, temperature and its key limiting factor is continuous supply of required power. Generally, WSNs are battery-powered which are not suitable for long term operation due to limited lifetime problem and periodic replacement requirement. To resolve this issue various approaches have been proposed [],[]. Among those, the hybrid system which has the capability to harness energy from multiple energy sources instead of a single one which can be impractical due to the above issues can be an excellent solution for deployment of WSNs. Unlike solar energy that is available only during the day, RF energy can be harvested at both day and night. Hence integration of both RF and solar can definitely support each other to provide a stable and efficient energy source for any wireless sensor network.

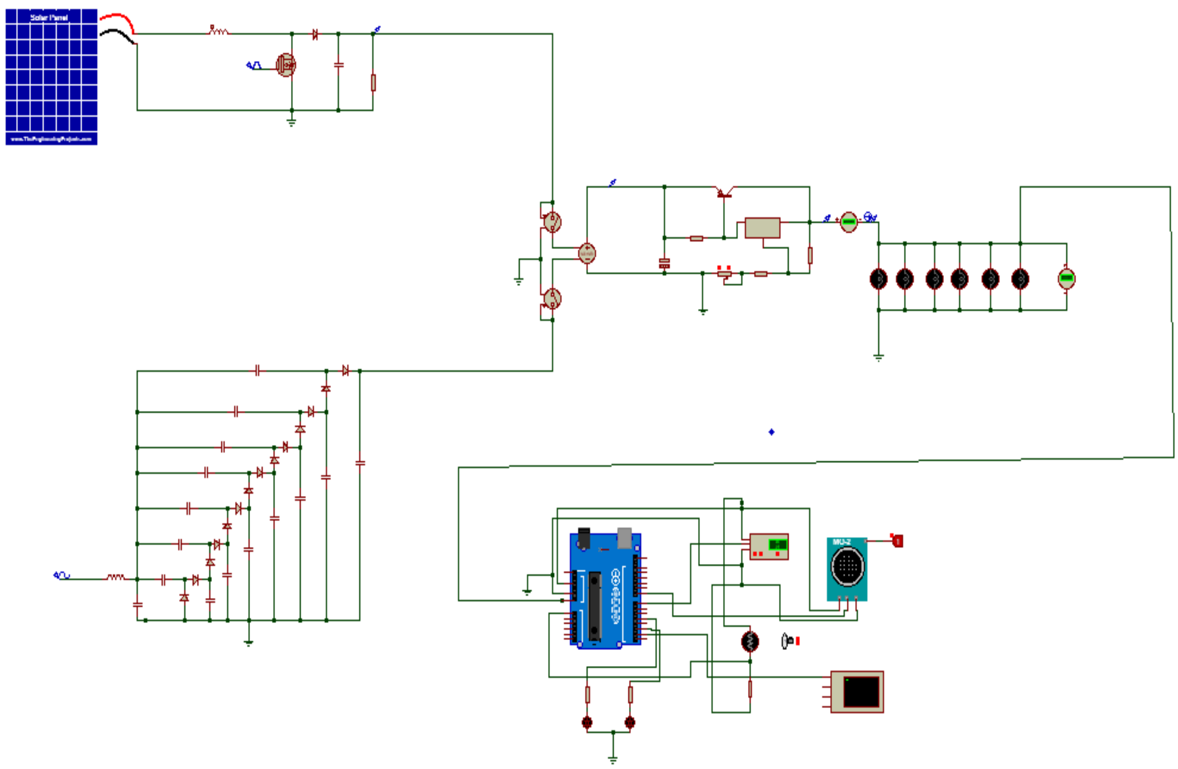
From the above perspectives, we design the system in three different scenarios of using Standalone, Serial and Parallel modes and compare the effectiveness of the systems. In Serial mode, the system will be able to harvest energy simultaneously from both the energy sources; whereas Parallel mode will be suitable for the condition that if one source of energy fails, the system will automatically switch over to its alternate source of supply depending on a fixed threshold. This will help in sustaining the operation of the system and save the batteries from overcharging as well as complete discharge condition. The key contributions of our work are as follows:

- A new hybrid Solar-RF system for garden lamp lighting system has been designed.
- Contribution 2
- Contribution 3

The rest of the paper is organized as: Section II demonstrates the energy harvesting technique for indoor wireless sensor node. Section III discusses how the solar and RF EH systems are combined using separate power electronic-based converters. Following that, the optimized HEH system using a single power management unit for indoor wireless sensor node prototype is illustrated in Section IV, which then ends with a conclusion and discussions in Section V.

System Model:

The system model is illustrated in Fig.1.



The proposed harvester is a hybrid solar/EM energy harvester that uses the solar antenna as well as harvests RF signals in the GSM 900 frequency band. The system is mainly composed of a 2.4 GHz custom dual-port antenna, an RF rectifier, a solar cell, a bq25504 Power Management Unity (PMU), a MSP430 Microcontroller (MCU), and a cc2500 transceiver. Here, the operation of the network is divided into four technology levels, i.e., sensing, computation, communication, and energy harvesting levels. The SEH unit includes an Energy

Source (i.e. Sun) and harvesting module (Solar Panel, MPPT and DC-DC Boost Converter). The RF EH unit includes an Energy Source (i.e. nearby Base Stations) and harvesting module (Rectenna). A SEH module consists of the following two main units: PV Cell, MPPT, Boost Converter. The RF energy harvesting unit contains an antenna to collect RF energy and appropriate peripheral circuitry for electrical to DC conversion. The computation unit consists of a microcontroller used here i.e. arduino uno. The arduino was used for detecting and showing the sensor readings. This detection was possible by using the digital pins to connect to the sensors and then interpret it, and consequently showing us the datas. The communication unit consists of The different sensors attached with the controller includes humidity sensor, temperature sensor and an analog LDR which is connected as well with the load (lamp) to control its brightness level according to the sun rays. The energy from the Sun is harvested by the solar module and converted to DC voltage. This can directly power the load or can be stored in a rechargeable battery for later use. A stabilizer is connected to control the unregulated voltage. An antenna, matching and rectifying circuits are the basic building blocks of a RF energy harvesting system. Each block of the energy harvesting system plays an important role.

Case 1: Standalone SEH/RF EH

The proposed system is designed in such a way that it will harvest energy even if only one source is available.

Case 2: Serial SEH-RF EH

The proposed system is designed in such a way that the system will be able to harvest energy simultaneously from both the energy sources. Here, the energy is collected from solar by means of solar panels and from EM source by means of a rectenna. Next is the DC combining circuit that combines the obtained DC outputs from both the harvesters to provide the necessary DC voltage and current.

Case 3: Parallel

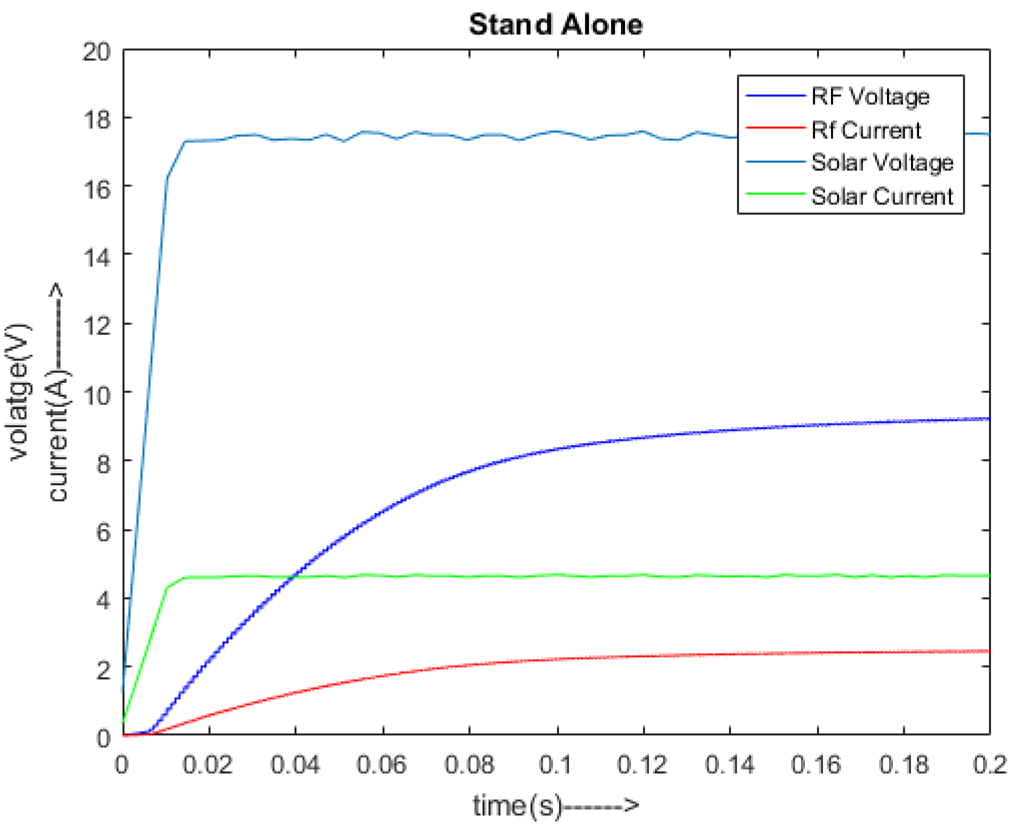
The proposed system is designed in such a way that if one source of energy fails, the system will automatically switch over to its alternate source of supply depending on a fixed threshold. The use of Parallel mode is more suitable under low irradiance conditions for low RF input power levels; if the irradiance is high the harvester could just be operated as a solar harvester else RF harvester will be utilized. The harvester should operate in hybrid serial/parallel mode only when there is not enough light and there is a demand of DC power. However if there is enough light it is more efficient to only operate in standalone solar harvester mode.

Simulation Results

Simulation Parameters:

4.1 Standalone

i) Standalone RF



No of Base Station	V(10s)	I(10s)	V(20s)	I(20s)	Voltage(30s)	Current(30s)
1	6.74	1.79	7.15	1.90	7.5	2
2	16.31	4.34	17.15	4.56	17.2	4.68
3	26.28	6.99	27.55	7.33	28.28	7.52

No of Base Station	V(10s)	I(10s)	V(20s)	I(20s)	V(30s)	C(30s)
1	9.46	2.52	9.46	2.52	9.46	2.52

2	21.82	5.8	21.82	5.8	21.82	5.8
3	34.35	9.14	34.35	9.14	34.35	9.14

For a fair comparison with the existing model, we have reduced the stages of voltage multiplier to five stages.

Method	Parameter	Solar	RF	Hybrid
[1]	V(V)	18.1	5.02	23.2
	I((A)	2.73	0.0005	6.62
Proposed	V(V)	17.60	5.96	24.12
	I(A)	4.68	1.58	6.42

The diode prevents the batteries from being discharged by the harvesting circuit at weak light conditions. It needs to have a low voltage drop and leakage current since the diode voltage drop decreases the minimum light intensity to recharge the battery, and the diode leakage current reduces battery charging current. Table 2 shows the measurement results of two samples from four diode models (BAX16, 1N4148FS, 1N4149, and FDH333) at a battery voltage of 3.6 V. The diode voltage drops are measured at three different lighting conditions such as 1 klx, 10 klx, and 100 klx, and the leakage currents are measured at 100 klx. The leakage currents of all diodes are negligible. BAX16 is selected for the proposed harvester due to the lowest voltage drop.

Table 2. Measured leakage current and voltage drop of four diode models (two units for each model) at different light conditions and VBAT = 3.6 V.

No. of stages	Voltage (in V)	Current (in A)	Schottky Diode	No. of stages	Voltage (in V)	Current (in A)
1	9.46	2.52		5	9.46	2.92
2	21.52	5.8		6	7.70	2.05
3	34.35	9.14		7	34.35	9.14

ii) Standalone Solar EH

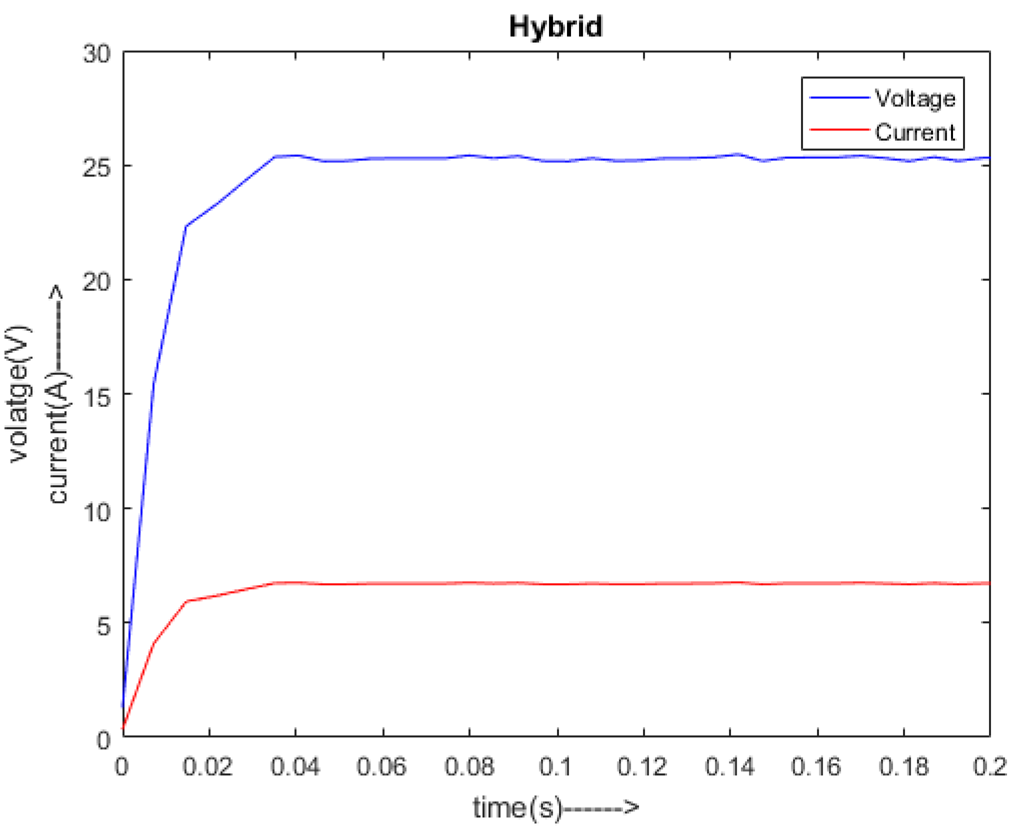
From the individual output of standalone systems, we have observed that the output of each source is not sufficient to meet the battery charging requirements.

<u>For standalone systems</u>:

The graphical depictions of the standalone system in both cases revealed that the energy output is higher when energy is harvested from the solar rays, but the RF energy harvested was not quite up to the mark. So in the long term using only RF as a viable source of EH is not possible .

Also the environmental factors like climate, terrains etc might affect the proper capturing of solar rays thus reducing output efficiency of the standalone solar EH thus making it very difficult to use everywhere

4.3 Serial (Hybrid)



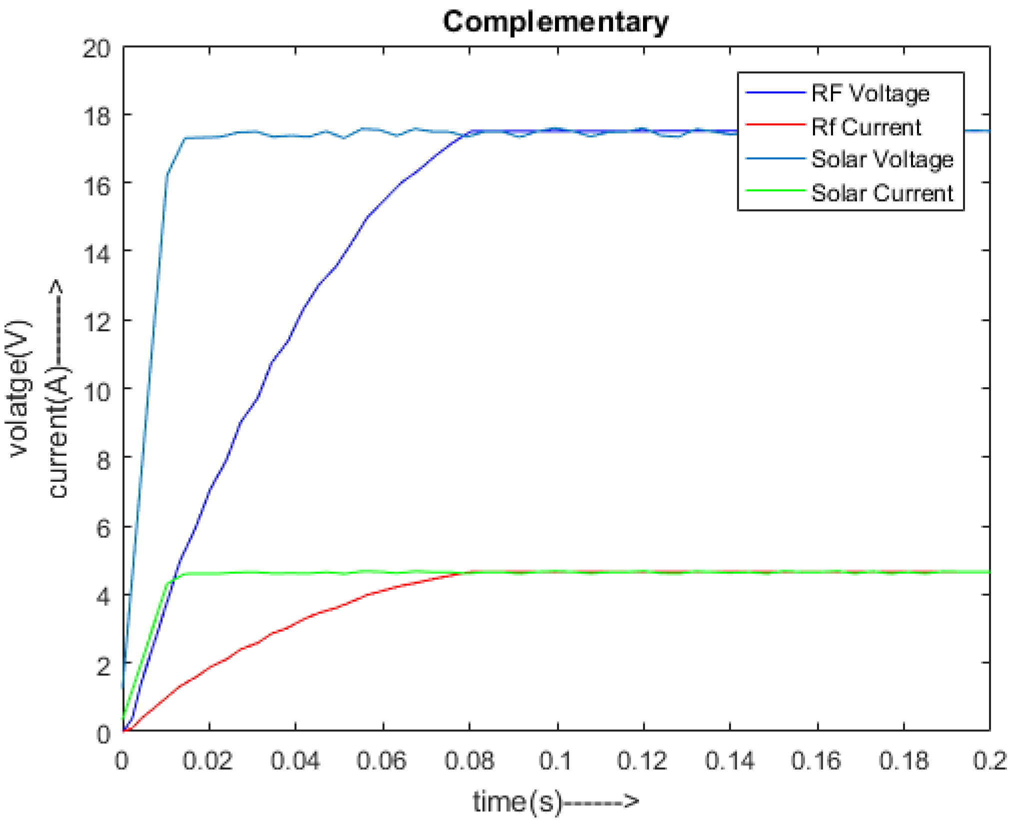
Parameters	Voltage (in V)	Current (in A)
Solar	18.1-19.2	4.8-5.1
RF	7.5	2
Serial	25.1	6.6

For hybrid systems:

The hybrid or the serial EH is far more power generating technique than the only standalone system, but usage wise the charging battery could only get charged up to a certain value and runs risks of overcharging as well as wasting of energy.

Even though it solves the problem of output efficiency by combining both the harvesters, but application wise it still results in wastage of power.

4.4 Parallel (Complementary)



For Complementary system:

The complementary system is the one which is combines the better qualities of hybrid system and as well standalone system. This model at a given time generates just sufficient amount of energy by jumping between different modes as the situation demands thus avoiding overcharging.