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Design Of Standalone Photovoltaic (PV) Integrated Charging Of Lithium - Ion Battery Using MATLAB/Simulink

(7th Semester Project Report - 18EEP107L)

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ABSTRACT

The world today is steadily moving towards an era of sustainable energy. In this fast changing world it is important to keep in mind the resources one has at the hands and how one uses them. One such crucial resthece available at the disposal is ‘fuel’. one needs fuel to run the factories, power the electrical grid, automobiles, etc. So for the project one has narrowed the domain to the field of automobiles and electric vehicles (EV) in particular. The project aims to achieve at least 75% SOC of an EV vehicle of battery built Li - Ion using a photovoltaic system integrated standalone with the battery. The project is therefore centered around this problem and presents a solution statement that if one could integrate the charging of EVs using solar power it would spread out the load on the grid used by EV chargers. Using the data published by Power Magazine (Issue 2020), using PV integrated EV chargers will save the cost required/sector of demand by $1500 (Rs, 1,11,577) per month. This is a simulation based project and one has used MATLAB/Simulink for the work.

INTRODUCTION

Now the electrification of transport is increasing day by day, which is a greener and cleaner innovation in the automotive industry. Global warming and the impending disappearance of fossil fuels have given the electric vehicle a great opportunity (EV) to be part of the automotive industry. Transport industry, which is the means of reducing vehicle emissions, which in turn reduces the risk of climate change, but at the same time places an additional burden on the grid systems, i.e. renewable energy sources, in particular solar or photovoltaics (PV), which are available in abundance during business hours , is a preferred energy source for charging electric vehicles (EV) with improved energy efficiency, fuel consumption, but also the additional load on the network. System that would be able to redirect rapid changes in photovoltaic power to the direct load on the photovoltaic.

It was 115 years since Edmond Becquerel discovered the photovoltaic effect in 1839 before Chapin and his colleagues announced a practical device in 1954 at Bell Laboratories in Murray Hills, New Jersey. Due to the increasing efficiency of solar cells and the improvement in manufacturing technology for solar modules, installations have been carried out in recent years. Photovoltaics is still in the evolutionary phase and is expected to grow in the next few decades. The interest in photovoltaic energy is increasing both in the public and in the planning arenas of the electricity communities. A photovoltaic solar energy source is one of the most interesting technologies among the other renewable energy sources, with an annual growth rate of 25 to 35% over the past decade. Photovoltaic modules, commonly known as solar cells, are simply converters. Solar cells are able to generate electricity when exposed to light without damaging the environment or the device, which means that energy can be generated over many years with minimal maintenance and operating costs. The number and variety of batteries of electric vehicles connected to the grid continues to increase sharply, which leads to a large load on the grid, so that photovoltaic charging stations will be very helpful in reducing this load. Some preliminary criteria need to be considered during the initial planning phase of the photovoltaic system. The establishment of photovoltaic charging stations will also be a very good platform for future research on photovoltaic charging of electric vehicles.

LITERATURE REVIEW

Electric vehicles (EVs) have received a lot of attention recently due to their sustainable use of energy. The advancement of lithium-ion batteries has accelerated the development of electric vehicles. However, the increasing number of electric vehicles creates a large demand for electrical energy, which increases the pressure on the electricity system. This leads to a search for alternative and clean energy sources to power electric vehicles. This project implements a solar energy system for the construction of a charging station for the use of electric vehicles. The charging station uses a constant voltage DC bus to allow charging through multiple ports. Charge regulators work on the principle of equalizing current and charging with constant current / constant voltage. Experimental and simulation results are used to validate the performance of the charging system. In a survey done by Global EV outlook done in 2020 it was found that there are over 6.5 million private chargers in the world, the major consumers being:

Name of the Country	**No. of private chargers**
United States of America	15,00,000
China	24,00,000
Japan	2,00,000

PV energy, on the other hand, fluctuates with changes in irradiance and hence cannot create consistent energy. As a result, an energy storage device is necessary to match the energy demand and increase the charging station's long-term viability. As a result, a system containing an energy storage system (ESS), as onell as a PV source and an EV charger, has been proposed. The EV and ESS have been charged and discharged using the BDC. When the energy provided by PV is insufficient to fulfil demand due to a lack of or reduced amount of sunlight, the ESS can be used to meet the need. An off-grid charging station (OGCS) is important for increasing the use of electric vehicles (EV) in rural regions while reducing grid burdening in urban areas. The OGCS aims to obtain energy from renewable stheces (RES). Photovoltaic (PV) is the most ideal renewable energy among all RES due to its abundance and ease of installation. Due to falling electricity prices and rising electricity costs, the self-consumption of photovoltaic electricity is becoming more and more important. Instead of reselling the electricity produced at a low profit[2], it has to consume or temporarily store as much electricity as possible. Today, the kilowatt can be up to 24 ct, as you neither have to obtain expensive electricity from the grid (electricity costs: 21 to 30 ct / kWh) nor temporarily store the photovoltaic electricity you have generated yourself.

With a median consumption of an electrical vehicle, the illonerke will conceal up to 310,000 metric linear units annually with self-generated solar energy 100 percent emission-free. With 15,000 kilometers driven per electric vehicle, up to twenty one electric vehicles per annum may be operated strictly with self-generated star power. CED Greentech did a survey in 2019 where it was published that the majority of EV chargers onere grid powered and contributed to 11.33% of USA's annual electricity demand.The current battery capacities of electric vehicles range from just 17.6 kWh in the Smarteq For two with a range of only 58 miles to 100 kWh in the Tesla Model S and Model X, which can drive more than 300 miles. This leads to considerable cost savings, as the electricity generated is not fed into the grid (remuneration in June 2021 approx. 77 ct / kWh), but is used to charge electric vehicles (approx. 21 ct / kWh for charging on the electricity network).These aforementioned problem statements could be onell tackled using a standalone solar power approach where using the data published by power Magazine (Issue 2020), using PV integrated EV chargers will save the cost required/sector of demand by $1500 (Rs, 1,11,577) per month.

METHODOLOGY & ANALYSIS

The project is divided into stages. The 1st stage is Data Collection. In this stage two kinds of data are collected namely quantitative and qualitative. Quantitative data is further divided into two types namely Primary and Secondary. Primary data is the data that is not already available and needs to be created/collected firsthand. For the project this includes the circuit diagram, the data parameters for the buck converter (incl. calculations), assumptions for theoretical calculation and load side power consumption. The secondary data on the other hand is the data that has already been collected by someone else and is available open source and data that is pre defined in terms of specifics and cannot be altered in the project. This includes the PV array type and specification, PV built, MPPT algorithm, and Perturb and Observe algorithm.

The qualitative data on the other data is the data that deals with the technical and economical feasibility of the project and methods. It is divided into two parts namely Technical feasibility and economic feasibility. The technical data for this includes the socio - economic barriers in the society, sustainably driven consumers, supply chain production of PV and Li - ion batteries, cost per sector. The economic data includes long term cost factoring, infrastructure cost, buying power of the mass and material and garbage cost. The next stage i.e. 2nd Stage is the data analysis part. This includes the simulation part and the model calculation along with the code for writing the algorithm used in Perturb and Observe. The specification for the buck converter is calculated and the value for filter capacitor and filter inductor is calculated using the following formula (found from Power Electronics by Mohammed H. Rashid): Then for the 3rd stage the code for MPPT is written in a separate MATLAB function block and is fed the input parameters (V and I) from the PV array via unit delay blocks with sample time 1e-4. Then the output of the MATLAB function block is fed to a comparator along with a repeating sequence and the combined output is fed back to the mosfet (buck converter). The output of battery charging and solar output is then finally compared.

It is to be noted here that as far as the scope of this project is concerned, the parameters namely 'aging effect' and 'temperature decay' of the Li - ion battery are ignored and assumed to be not present for maintaining an ideal environment.

FINDINGS

Input Irradiation	Input Temperature	PV Output Voltage	PV Output Current	PV output power	Battery Voltage	Battery Current	Battery Power Output	Duty Ratio block output
Watt/m^2	*Celcius*	*Volt*	*Ampere*	*Watts*	*Volt*	*Ampere*	*Watts*	*N/A*
0	0	12.91	-3.47E-08	4.62E-07	13	4.60E-08	5.97E-07	0.9449
50	1.25	30.68	0.3629	11.13	13.01	0.008728	0.11355128	0.394
100	2.5	31.98	0.7068	22.62	13.01	-1.188	-15.45588	0.4264
150	3.75	30.58	1.115	34.28	13.02	-0.8182	-10.652964	0.4262
200	5	30.78	1.485	45.89	13.02	-2.765	-36.0003	0.4232
250	6.25	32.42	1.76	56.93	13.03	-3.198	-41.66994	0.4256
300	7.5	30.78	2.228	68.75	13.03	-3.643	-47.46829	0.4296
350	8.75	31.21	2.572	80.18	13.03	-3.999	-52.10697	0.4334
400	10	31.52	2.901	91.46	13.04	-5.912	-77.09248	0.4318
450	11.25	30.8	3.323	102.5	13.04	-8.655	-112.8612	0.4386
500	12.5	30.69	3.69	113.2	13.05	-7.173	-93.60765	0.4378
550	13.75	30.17	4.096	124	13.05	-7.715	-100.68075	0.4452
600	15	30.66	4.394	134.7	13.05	-8.209	-107.12745	0.4484
650	16.25	30.47	4.762	144.5	13.06	-9.608	-125.48048	0.453
700	17.5	30.35	5.117	154.8	13.06	-10.5	-137.13	0.4544
750	18.75	30.27	5.462	164.8	13.07	-10.62	-138.8034	0.46
800	20	29.19	5.977	175.2	13.07	-11.12	-145.3384	0.4654
850	21.25	29.37	6.292	184.9	13.07	-12.21	-159.5847	0.4668
900	22.5	29.31	6.634	194	13.08	-13.12	-171.6096	0.4756
950	23.75	28.59	7.102	203.7	13.08	-13.24	-173.1792	0.4784
1000	25	28.7	7.414	212.3	13.08	-14.33	-187.4364	0.4858
1050	26.25	27.59	11.14	221.3	13.09	-14.61	-191.2449	0.5126
1100	27.5	28.1	8.195	230.2	13.09	-15.13	-198.0517	0.4918
1150	28.75	27.72	8.602	238.9	13.09	-15.61	-204.3349	0.4996
1200	30	27.85	8.886	247.4	13.1	-16.14	-211.434	0.5046
1250	31.25	27.48	9.298	255.2	13.1	-17.09	-223.879	0.5078
1300	32.5	27.39	9.627	263.2	13.1	-17.26	-226.106	0.5156
1350	33.75	26.79	10.11	271.5	13.11	-17.71	-232.1781	0.52
1400	35	26.75	10.42	278.8	13.11	-18.41	-241.3551	0.5246
1450	36.25	26.37	10.84	285.8	13.11	-19.02	-249.3522	0.5334
1500	37.5	26.36	11.14	293	13.11	-19.37	-253.9407	0.54

After running the simulation for 30+ irradiation level and temperature the output data was obtained in terms of PV voltage, PV current, PV power, Battery voltage, battery current, battery output power and duty ratio.

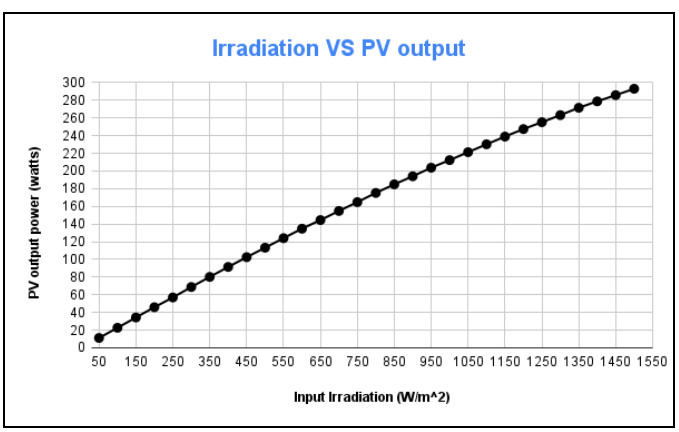
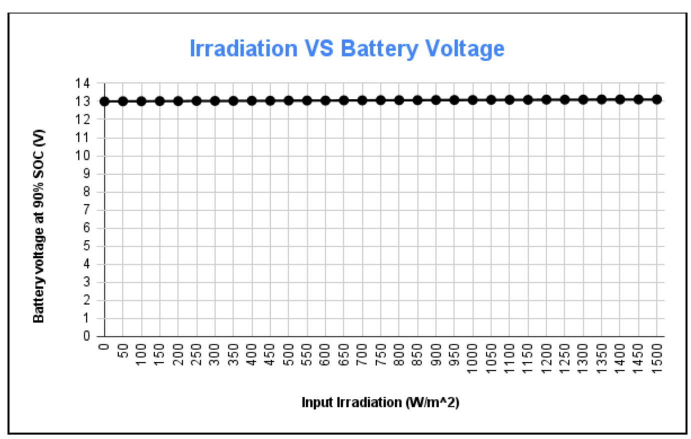


Figure 1



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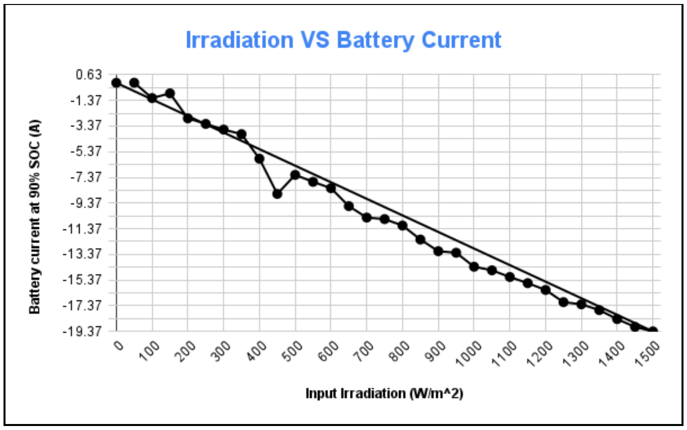

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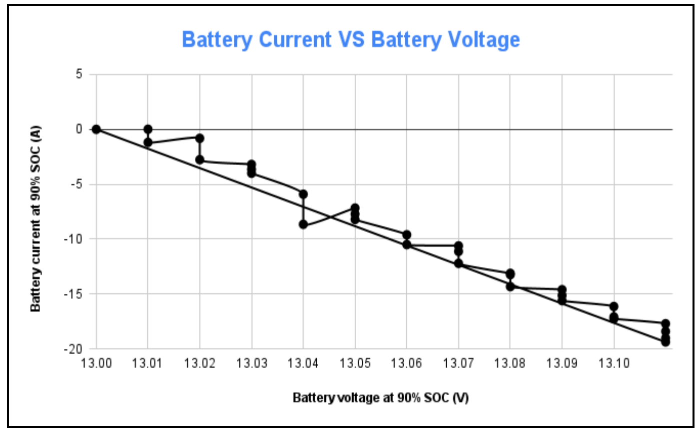


Figure 4

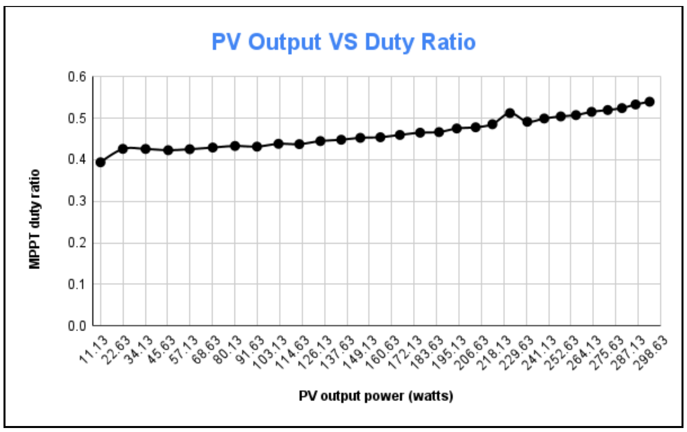
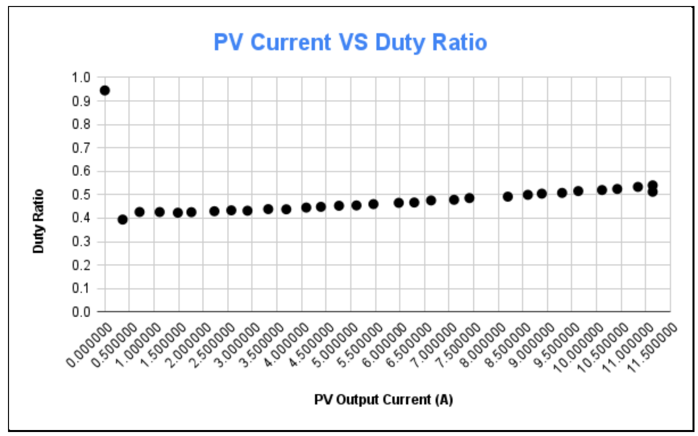


Figure 5



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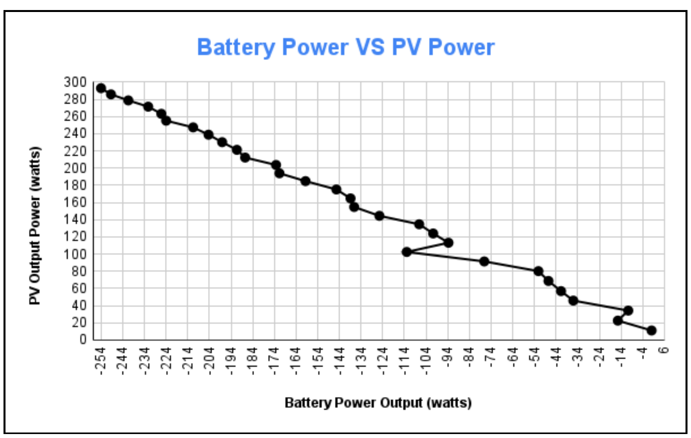

Figure 7

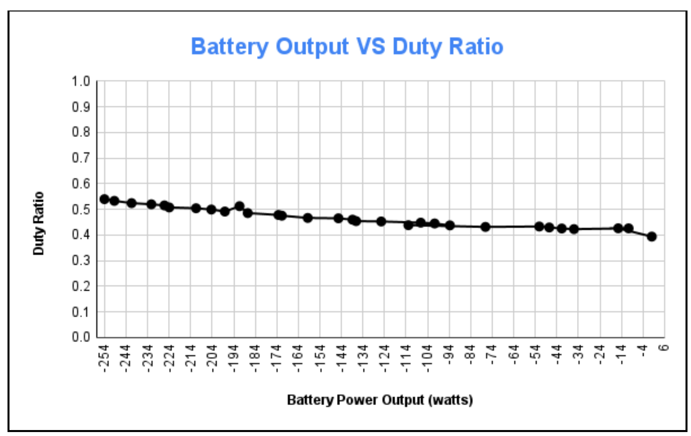

Figure 8

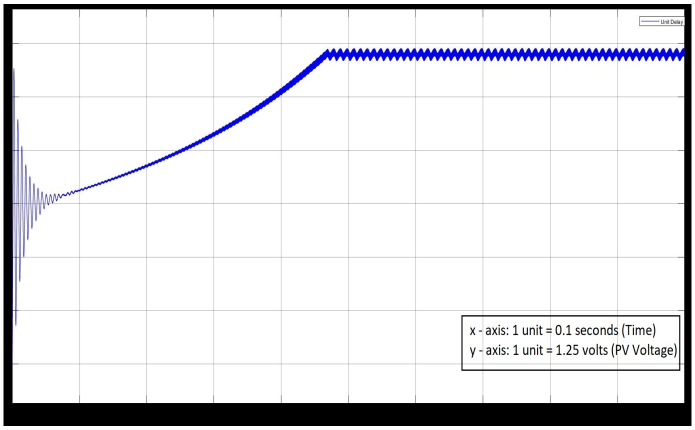

Figure 9

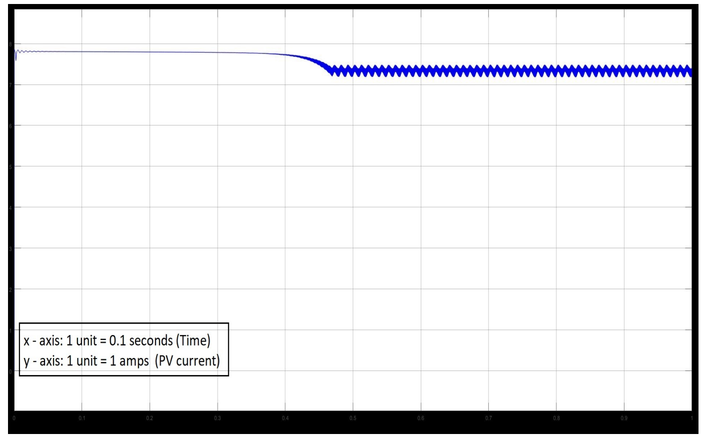

Figure 10

INFERENCE & ANALYSIS

In Figure 1 study the trend of *Irradiation VS PV output* and as expected see that as the irradiation increases the output power of the PV also increases. The relationship is directly proportional with a linear trend with a slight curve at (650, 134.7). **In Figure 2** study the trend of *Irradiation VS Battery Output voltage* and one see that even though the irradiation is increasing, the output voltage at the battery side after attaining 90% SOC stays approx. constant. Therefore one can conclude that the relationship is independent. **In Figure 3** one studies the trend between *Irradiation VS battery current* and one sees that as the irradiation increases (after 100 irradiation) the battery begins to charge and the charging current keeps on increasing as the irradiation increases. Therefore one concludes that the relationship is directly proportional. **In Figure 4** one study the trend between *Battery current VS Battery voltage* and expect to see that the trend is directly proportional. **In Figure 5** one plots the *PV output power VS Duty ratio* and one sees that the change in duty ratio (increase) is there but very slight compared to the increase in power output of the PV array. From this one infer that the relationship is directly proportional with a constant value of less than one. **In Figure 6** one plots *PV output current VS Duty Ratio* and sees that there is a strong dip in duty ratio during the first change in output current but after that the remaining step increase in PV output current shows a very slight increase in duty ratio. **In Figure 7** one plots the trend between *Battery power VS PV power* and see that the trend is linear with a sharp decrease at (-107.12, 134.7) and it trends back to its original trend after that till battery output reaches 253 watts. **In Figure 8** one studies the relation between *Battery output power VS Duty Ratio* and see that even though the battery output is increasing, the change in duty ratio is very slight. **In Figure 9** one looks at the trend in PV voltage with increase in time and see that there is a slight periodic fluctuation in the first part with a steady increase in the next half and a steady voltage output in the final time. **In Figure 10** one looks at the trend in PV current with increase in time and see that there is a steady output in the first half of the simulation with a trickle oscillation in the next half.

CONCLUSION

Considering the world population and electricity demand, there is a need to use solar energy and get more energy from it. MPPT is one of the techniques to do this efficiently, it is argued that the parasitic capacitance technique works for both PandO and Incremental goods . Conductivity method according to output power. Therefore, as the population increases, there is a need to use renewable energy. Hence, solar energy is gaining popularity. In order to extract the maximum performance, it is desirable to use the MPPT algorithm to develop different types of algorithms. from MPPT, so that the maximum power can be obtained from solar energy with good efficiency. A comparative analysis is performed based on the pros and cons, voltage ripple, average power obtained, and response time. So, finally one can conclude that by using a module 1Soltech-1STH-215 P PV array rated at 25 deg C for 1000 irradiation one can charge a Li - Ion battery rated at 1.3KWh at 90% SOC with a nominal voltage at 12V - 14V.

LIMITATIONS

Now that one has concluded the project it is worthwhile to mention that the approach has some limitations that one would like to mention. It must also be noted that these limitations are by no means to undermine the field of EV but to bring up the challenges one think will be faced by integrating a standalone PV integrated charging. Firstly by using a PV module the max battery capacity that can be efficiently charged is rated at 1000Ah or 12kWh whereas the current world leader at EV vehicles, Tesla has Li - Ion batteries that are rated at 13.5kWh at level 1 charging. Moreover the PV installation could add extra cost to the car and will increase the total number of movable parts installed on the car as the PV module would require to be aligned with the sun.

So, it is advisable to use this form of charging on smaller rated vehicles such as Electric Rickshaws, Electric Autos, etc i.e. vehicles that are not built for high end uses.

FUTURE SCOPE

It is documented that numerous styles of strategies are used for generating the electricity like Thermal Power plants (Nuclear, Coal, fossil oil etcetera), Hydro (water) power plants, however they're non-renewable resources and also harmful for humans as well because of the environment. As many sorts of alternative charge controllers like PWM etc. also are available, but thanks to low potency it can't be used utterly by the consumers. There's a requirement to develop a lot of other low cost and effective MPPT algorithms, in order that virtually 100% efficiency will be achieved.

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