Analysing An EV Solar Integrated Charging Station For Green Public Transportation In Jordan

*

Hassan S. Migdadi
Faculty of Engineering
American University of Madaba
Jordan
h.migdadi@aum.edu.jo

Husam Qutishat
Faculty of Engineering
American University of Madaba
Jordan
h.qutishat@aum.edu.jo

Iyad Mahmood Muslih
Energy Services Center
Jordan
info@energy4solution.com

Bilal Ali Abu Odeh
Faculty of Engineering
American University of Madaba
Jordan
Bilal.Odeh@std.aum.edu.jo

Rami Ass'ad Alsharif
Faculty of Engineering
American University of Madaba
Jordan
Rami.Alsharif@std.aum.edu.jo

Abstract **Solar power, rechargeable back-up battery system, electric vehicles (EV) are three technologies that are on the rise. Electric vehicles have started to be accepted globally as an accept replacement to gasoline- power vehicles as technology has improved the range and efficiency of electrical cars. In this paper, a study to upgrade a pre-existing parking lot to a large solar canopy was conducted in order to decrease the time needed to build a new structure and to reduce the initial costs for a green public transportation (GBT) charging station, the Northern Complex/ Amman-Jordan was found to be suitable with the pre-existing parking zones it already has installed. A solar station design was proposed using the net metering method to be accepted by local Jordanian laws. The simulation results show an output yield that covers the energy needed by EV charging station with reduced costs.**

Keywords—Solar Power, Electric Vehicles, Green Public Transportation, Net Metering

I. INTRODUCTION

The main driving force for solar energy is to trend towards cheaper solar cells that will help future projects become economically profitable. However, solar power still has to grow in many countries. A battery powered electric vehicle generates only one third of the emissions of an equivalent gasoline vehicle. This difference can only be increased as we move towards cleaner generation alternatives, as photovoltaic and wind generation have increased substantially during the last decade [1] Transportation is also responsible for approximately 14% of global greenhouse gas emissions, which was projected to increase to 50% by 2030 [2].

On the other hand, by 2020, 20 million EVs are expected to be on the road and 100 million by 2030[3]. Electric vehicles (EVs) are advancing the future of clean transportation. Unlike gas cars which have to be driven to gas stations for re-fueling, EVs charge when parked at a charging station, which can be as simple as a household or garage wall outlet.[4] The Greater Amman Municipality launched the first phase of the Electric Transportation Service in Amman, a project named Tawsila, comprised mainly of electrical taxi vehicles (Nissan Leaf) offering an alternative mobility options to citizens through the crowded areas in Downtown, Amman.[5] This paper investigates an EV solar integrated charging station to evaluate the technical feasibility and economic benefits of solar PV systems integration to the local transportation infrastructure. Installing PV solar panels on top of an existing public transportation's parking area and turning it into a big "Solar Canopy", is a great method to replace a relatively not useful structure and turn it into a useful system by laying out Photovoltaic Modules.

The Jordanian community tends to depend on private gasoline vehicles and the available public transportation system (buses and service cars). Because of this large dependency, the roads of Amman become crowded on a daily basis which produces dense rush hours and high rates of Greenhouse Gas (GHG) emissions. Public transportation sector need to be developed throughout Amman, due to the lack of served areas and the crowded available local transportation lines. One of the busiest bus stations over Amman city is the North Complex, which serves the most populated regions of Amman and a central connection point for all the main Provinces, Irbid, Zarqa, Salt, Madaba and Many other surrounding regions in Jordan.

This paper focuses on evaluating the impact of the added solar power through utilizing it into the local transportation system. An on-grid hybrid PV solar system with backup battery units is designed and selected to supply the charging units with electricity using the net-metering method. The net metering method allows the system to send extra power to the grid in exchange for banked energy credit that can be used when needed most. The system is investigated by performing simulations using PVSYST application and Sunny Design Web to study the entire systems energy production, shade analysis, losses analysis, GHG emissions calculations and the specifications of: the solar panels, inverters, wire sizing, yield outputs, profitability.

II. PROPOSED SYSTEM

A hybrid PV-Battery system takes the advantage of grid connectivity when its available or needed, and the PV productivity during day time, both providing the needed electrical power to charge a set number of electrical vehicles. The battery storage connected to the system provided as a backup system for any emergency case, such as, a shortage in the production of PV system during a day with no grid availability, that one of the main systems could not provide the needed power for any reason at any moment of day or night, such a backup system must be compatible with both charging methods, directly from the PV system

connected to the charge controller, or an interactive inverter that also works as a charger along with its functionality when the grid connectivity is unavailable.

During the day, most residential and commercial solar systems generate more electricity from solar power than they consume. Net metering allows these systems to sell the excess electricity back to the grid, which reduces the future electric bills. Even though it would generally cost electric utilities less to produce their own electricity, they are still required to buy this excess power. Depending on net-metering regulations, its benefits vary for solar customers in different areas of the country. Net-metering increases the demand for solar energy systems and allows the industry to thrive. Simply it was originally developed to encourage the introduction of small-scale power sources like rooftop solar panels. [6]

Harvested solar energy has two distinct flow paths in DC and AC-coupled systems. In DC-coupled systems, the harvested solar energy first flows to a battery bank via a charge controller and then to AC loads via a battery based inverter. In AC-coupled systems, harvested solar energy first flows to AC loads via a grid-tied inverter and then to a battery bank via a battery-based inverter. Further, DC-coupled systems, as the name implies are connected on the DC electrical system whereas AC-coupled systems are connected on the AC electrical system. Therefore, an AC coupled solar storage system is to be introduced along with the case study for its advantages in such case, as it will act as an additional system that could be installed initially in tandem with the entire solar system, or for future upgrade to the proposed solar system. Its ability to be separately connected without interfering with other components of the solar system,, gives it a unique feature that distinguishes it from DC coupled solar storage systems, which rather need prior planning and system interacting features such as its dependency on the main interactive inverter. The implemented structure of the system is shown in Fig.1.

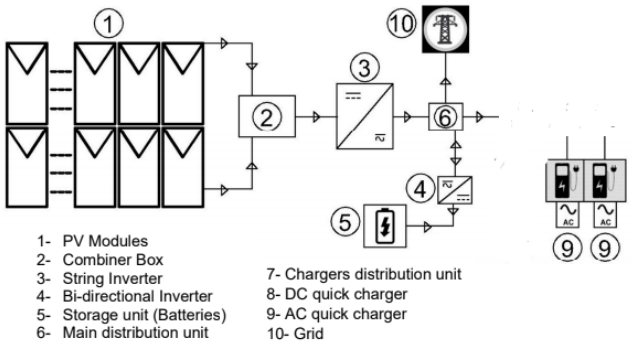


Fig.1. Implemented schematic structure of the system.

A. Solar Panels

Photovoltaic (PV) power systems convert sunlight directly into electricity. A PV power system enables its owner to generate some or all of the daily electrical energy demand, exchanging daytime excess power for future energy needs or night time usage. The number of solar panels is optimized to the determined number that fits taking the proper orientation, tilt angles and near shade analysis, resulting in using the following system connections shown in Tab.1.

Table 1

	Quantity	Pmax	VDC	IDC
Solar Panels	790	256 kWp	37.5 V	8.75 A
panels in series	17	5578.1	637.5	8.75
strings in parallel	46	256593.8	637.5	402.5

B. Inverters

The Inverters are considered vital when installing solar panels. The inverter's main objective is to convert DC power produced by the solar array into AC power, but that's not the only thing inverters accomplish; Inverters also make it possible to monitor how the system is performing by providing diagnostic information to help identify and fix system issues. With the growth of solar storage, inverters can also be responsible for battery management. [7]

C. Chargers

DC Quick charging station offers Electric Vehicles an opportunity to charge safely and quickly. As for the proposed charging system, a level 3 DC quick charger will be used (CHAdeMO protocol), that charges the car by delivering a DC electrical supply directly to the battery, bypassing the onboard inverter of a compatible electrical vehicle which leads to a faster charging time through a 400 VDC reaches 50 kW power input.

CHAdeMO 50KW EV charging station is combined with CHAdeMO connector. That can be fit for all CHAdeMO Electric Cars, Like Nissan Leaf and Mitsubishi iMiEV. DC Quick charging stations offers an opportunity to charge electrical cars safely and quickly. A typical electric car with 30kWh battery pack may be charged as quickly as 20 minutes to get up to 80% of its capacity. The Charger combines industry standardization with advanced charging technology to support next-generation electric vehicles. The CHAdeMO charger specifications are shown in Tab.2.

Table 2

Input	
AC power connection	3P + PE
Input voltage range	480 V_{AC} +/-10% (60 Hz)
Max. rated input current & power	75A, 60 kVA
	Power limiting options available
Power factor (full load)	> 0.96
Efficiency	94% at nominal output power
DC output	
Maximum output power	50 kW
Output voltage range	200 – 500 V_{DC} (Combo-1)
	50 – 500 V_{DC} (CHAdeMO)
Maximum output current	125 A_{DC} (Combo-1)
	120 A_{DC} (CHAdeMO)

D. Electrical Automobiles

Electric vehicles share a lot of similarities when it comes to the factors that influence charge speed, but the exact impact of each factor differs. For example the 30 kWh Nissan Leaf is able to charge to 90% in the same time as the previous 24 kWh version did.

Three major key components were taken into consideration while researching for electric vehicles, are: The charging power acceptance, battery capacity (range), credibility and

vehicle's price. It was found most suitable to use Nissan's leaf car, BYD's K9 buses and e6 cars, as they can be charged faster than rivaling vehicles. Charging time differs because of multiple reasons: rate of acceptance for the battery, type of electrical input (AC or DC), charging unit (wire connection and plug configuration), and circuit breaker type and delivery rate.

III. EV Solar Integrated Charging Station design

Google Earth gives a credible representation of the site survey and dimensions, provided as an add-on application to the main program (Sketch Up) used in modeling the PV system in 3D representation with the Help of another add-on application named Skelion, which creates the desired PV solar system parameters and orientations.

Dividing the parking lot into three zones as shown in Fig.2, and conducting the case study on zone C, with the dimension provided above yields a gross area of 1893.28 m^2. Furthermore, using the Skelion application, we can show the exact orientation and number of panels could be used on the provided area, south oriented with 11.5 degrees azimuth angle, a 10 degrees tilt angle and selected PV modules dimensions (2m x 1m) with an output of 325 Wp each. Every stack consisted of 5 rows of panels each. The worst shading pitch was taken in consideration when calculating the spaces between the stacks.

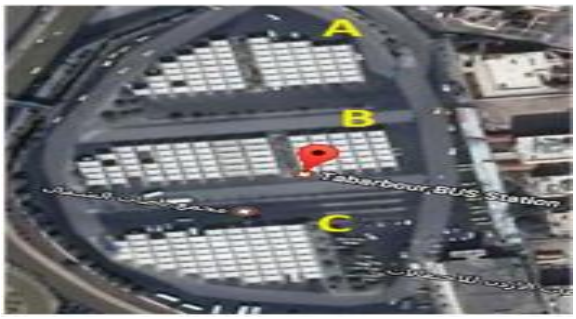


Fig.2. Google earth site divided zones.

Since the gross area is 1893.28 m^2 it was determined. With the help of Skelion, that the number of panels that will be mounted is 790 panels at an azimuth angle of 11.5 degrees from south, as shown in Fig.3.

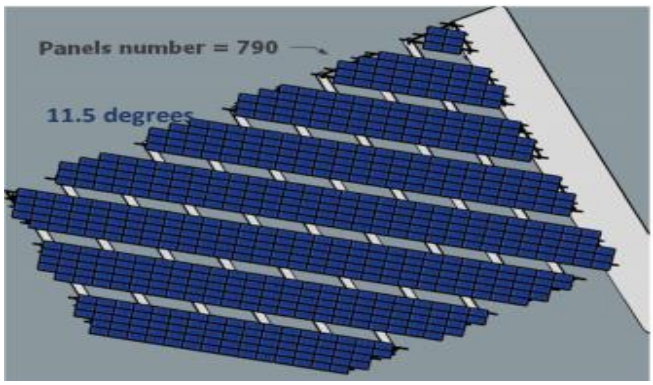


Fig.3. Number of utilized Panels at an azimuth angle of 11.5 degrees.

A. System Energy Production

The equation used to calculate the total DC output of the solar panels is given by Eq.1.

$$P_{DC} = N_P P_P \qquad (1)$$

Where P_{DC} is the total DC output power, N_P is number of solar panels and P_P is the output power of a single solar panel.

$$\frac{P_{DC}}{P_{AC}} = 1.1 \qquad (2)$$

The total AC output of the system (P_{AC}) can be calculated from the total DC output. The equation used to calculate the yearly yield of the system from the total AC output is given by Eq.3.

$$P_{AC} = \frac{Yearly\ Yield(KWH)}{1\ KWP\ (For\ 20\ Years\ For\ Jordan)} \qquad (3)$$

B. Charging Capacity

The expression given by Eq.4.represents full capacity charges per year for an EV $N_{full\ charge}$

$$N_{\text{Full Charge}} = \frac{Average\ Energy\ Yield}{EV\ Battray\ Capacity} \qquad (4)$$

The expression given by Eq.5.represents full capacity charges per day for an EV $N_{Charge\ Daily}$

$$N_{Charge\ Daily} = \frac{N_{Full\ Charge}}{Days\ Per\ Year} \qquad (5)$$

C. Suggested Route

The new designated route was planned as is a loop in the north-western region of Amman. The route is 28 kilometers long which goes through most of the northern region's hot spots. The route also takes 85 minutes while undergoing different types of traffic (heavy, moderate and light traffic). The route also includes the following elements of interest: 14 traffic lights, 5 main congestion points and 6 gas stations (Service stations). Fig.4. shows the suggested route.



Fig.4. the Suggested Route

D. Structure Saftey Analysis

Because the axial forces and the moment can't be measured each on its own, the interaction formula I_F given in Equ.6 will be used to ensure that the structure is safe.

$$I_F = \frac{Moment}{Allowed\ Stress} + \frac{\frac{Axial\ Force}{Area}}{Allowed\ Stress} \qquad (6)$$

If the interaction formula I_F is less than 1 then the system is safe.

IV. Simulation Results

PV system analysis on the EV solar integrated charging station is investigated by performing simulations of the system in Sunny Design Web and PVSYST is shown in Fig.5.and Fig.6. And it's required simulation parameters.

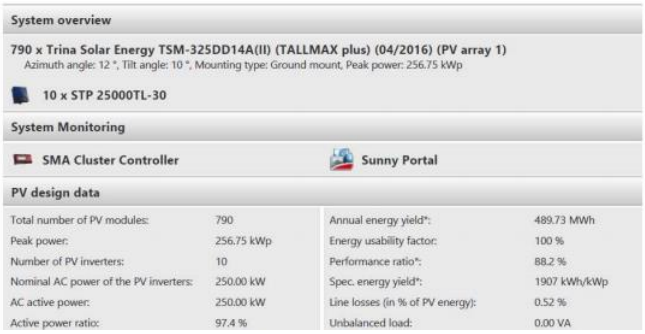


Fig.5. Simulation Parameters in Sunny Design Web

In the Sunny Design Web, 790 Trina solar energy (TALLMAX) solar panels were selected in order to simulate the solar system. Sunny design web determined that the peak power would be equal to 256.75 kWp and that the system would need 10 STP 25000TL-30 inverters. The annual energy yield calculated was found to be 489.73 mWh and the Spec. energy yield was 1907 kWh/kWp with only 0.52% PV energy losses due to the wire sizing.

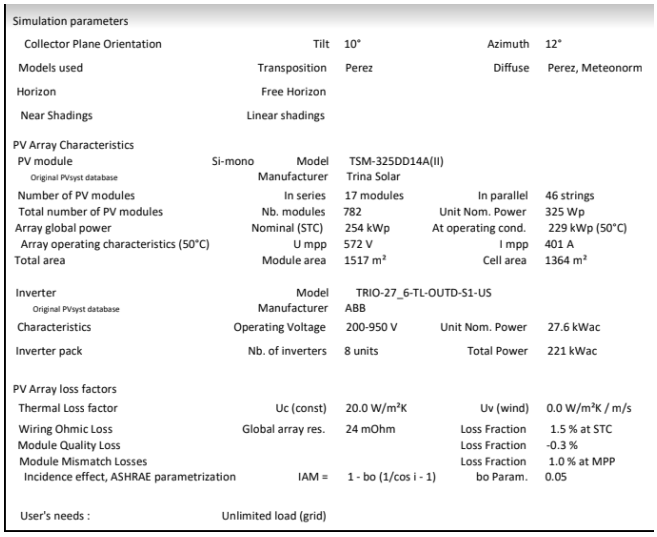


Fig.6. PVSYST simulation parameters

The maximum energy yield the system reaches is around the summer time of (June) with respect to the other months as shown in Fig.7.

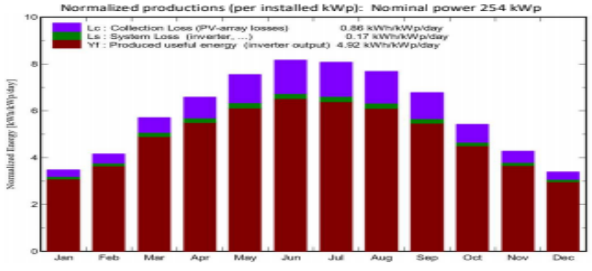


Fig.7. Energy yield per month

It shows that that the months with the least performance ratio produce the highest energy yield and that's because the heat reduces the performance ratio of the panels as shown in Fig.8

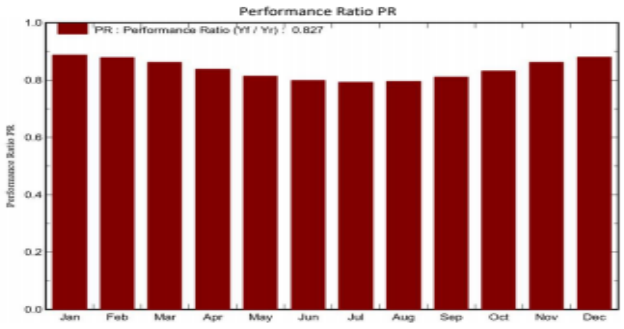


Fig.8. Performance Ratio (PR)

In the profitability analysis, the system calculated that the total revenue will be 4 million dollars and will have an expected amortization period of 2 years. The total investment was also calculated to be 308,100 dollars with an investment cost of 1,200 USD/kWp as shown in Fig.9.

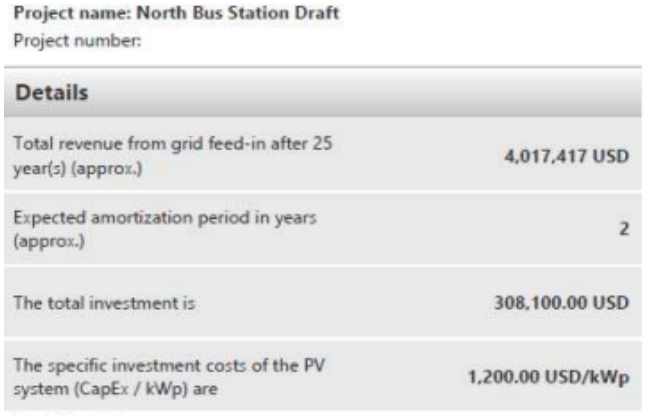


Fig.9. Profitability analysis

Also the aim of EV solar integrated charging station is to reduce GHG emissions with minimum shading losses. This is achieved as shown in Fig.10. And Fig.11

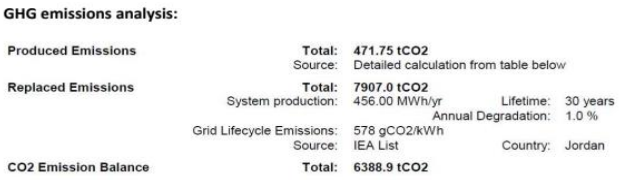


Fig.10. GHG emissions analysis

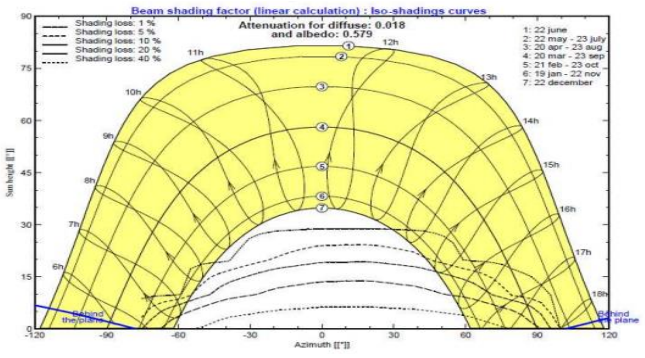


Fig.11. Shading analysis

CONCLUSIONS

An EV solar integrated charging station is proposed that connects solar energy to EV charging station on-grid using net metering method. The aim is to maximize the profit and lower the costs as much as possible. The solar integrated charging station includes PV panels installed in angles aligned with the existing structure, enabling for more panels to be installed on the new structure. One of the advantages of solar integrated charging stations is the capability of fast charging which adds a great value to the green public transportation.

The proposed solar integrated charging station is simulated with PVSYST application and Sunny Design Web application over a one year period to assess its ability of providing enough energy yields to cover the needs of the charging station. The desired energy yield is attained for the EV charging station and findings indicate a high reduction in GHG emissions.

REFERENCES

[1] Renewable Energy Policy Network for the 21st Century, "Renewables 2012 Global Status Report," available at http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx, 2012.

[2] O.Egbue and S. Long, "Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions,"Energy Policy, vol. 48, no. 2012, pp. 717–729, Sep. 2012.

[3] Global EV Outlook 2016 Electric Vehicles Initiative, 2016.

[4] Mdcleanenergy.org. (2018). EVs & Other Transportation Solutions | Maryland Clean Energy Center. [online] Available at: http://mdcleanenergy.org/all-about-energy/advanced-Technologies/transportation [Accessed 1 Jun. 2018].

[5] Alghad .Municipality Launches Electric Transport Service; "Tawsila", Today. [online] Available at: http://www.alghad.com/articles/940693-Municipality-Launches-Electric-Transport-Service-%E2%80%9CTawsila%E2%80%9D-Today [Accessed 1 Jun. 2018].

[6] SEIA. (2018). Net Metering | SEIA. [online] Available at: https://www.seia.org/initiatives/net-metering [Accessed 1 Jun. 2018].

[7] AG, S. (2018). Commercial self-consumption of solar power | SMA Solar.[online] Sma.de. Available at: https://www.sma.de/en/partners/knowledgebase/commercial-self-consumption-of-solar-power.html [Accessed 1 Jun. 2018].