# *Parking Areas at BUT for energy use*

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***Abstract*— The article focuses on the concept of solar carports in parking lots for energetic utilization and charging electric vehicles (EVs), describes their structure, components, configuration, also paper presents an overview of the analysis of selected parking areas at Brno University of Technology (BUT) for energy utilization, finally a designed project of solar carports in these areas are highlighted.**

***Keywords*— Solar energy, PV system, Electric vehicle, Car parking lots, EVs charging, Solar carport**

## I. Introduction

The concept of solar parking lots aims to coupling the development of clean solar electricity and electric mobility [1].

Solar carports are multifunctional structures that turn everyday parking spaces into sustainable power sources. They do not only protect vehicles from weather conditions but also harness solar energy, leading to monetary benefits. They offer a variety of designs that cater to different needs, whether it is for a home or a vast commercial space. Besides their economic and environmental benefits, they offer smart charging which has many optimizations on grid and the power storage in the case of smart solar carport.

This paper is divided into two basic parts. Chapter 1 outlines the definition, structure, configuration and overview of the solar carport. An overview of designed carports in selected parking areas at BUT are presented in chapter 2.

## II. An Overview of the solar carport

The solar carport is defined as a parking area provided with an overhead canopy that offers shelter for vehicles besides generating electricity from the solar PV system. Since is similar to the ground-mounted panels, that are installed on the ground, it differs from the ground-mounted panels not just in structure but also in space efficiency, whereas the solar carports are taller and more space-efficient [2].

### *A. Design and structure*

Solar carport could be classified depending on the next points:

**Size:** A solar carport could cover one, two or more rows [2], and can be for one car (single carport), two cars (solar carport double) or many cars (solar carport multi) fig.1 [3], these types match residential, commercial and industrial settings.

**Frames:** Frames may be wooden or metallic from Aluminum or steel [2], designs L, T, Y, W, N. [4]

**Shape:** Carport roof can be tilted in one direction upwards, tilted and curved in one direction, extremely slightly tilted, tilted in two directions like east-west, double row [5].

Fig. 1. Solar carport multi, pitch, single column, T structure [6]

### *B. The configuration and operation of solar parking lots*

The solar parking lots could be off-grid or on-grid, providing PV charging alone or PV-grid charging, the second one is more frequent, Conceptually, the layout of an Electric Vehicles Solar Parking Lots (EVSPL) is as mentioned in Fig.2. Vehicles are connected to a DC link after a DC-DC converter. Or an AC link after a DC-AC inverter a Control Center (CC) is responsible for managing the system, system can be with battery system or without it [1].

The energy production of the PV system is variable. On the other hand, the charging requirements of the EVs vary according to the behavior of the users, this makes the coupling of the two a problem. To avoid this, many variables must be considered with a minimal time-step:

Solar generated electric power, distribution in time of cars arriving, the parking duration of each car, state-of-charge of the batteries at the time of vehicles arrival, energy demand of each vehicle [1].

For maximizing solar EV charging, PV production must be matched as much as possible to the EV load profiles. This is considering in the controlled charging.

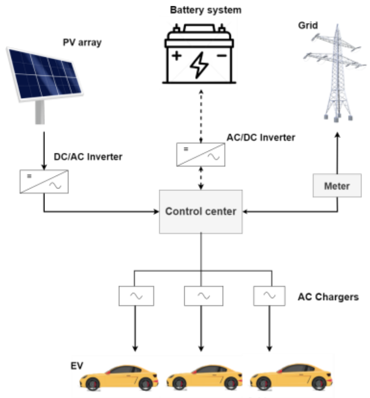


Fig. 2. Configuration of a PV EVSPL (AC charging)

## III. Analysis of selected parking areas at BUT for energy utilization

### A. *The selected parking areas for the solar carport at BUT*

The selection was between four parking areas near faculty FEEC, for the solar carport the parking areas Technická 12 (T12), Technická 14 (T14), and Centre of Sports Activities of BUT (CESA) are suitable. The largest one is T12; however, the shading analysis indicates that not the entire area is suitable for PV installation.

Fig. 3. Location of the selected parking areas for solar carport

### B. *Design of solar carports for three car parks on the university campus*

The designing of photovoltaic systems was done in the software PV SOL premium 2024, as 3D analysis. For taking photos of car parks and dimensions calculation application Google Earth Pro was used, dimensions of the parking building and surrounding buildings also were verified from photos taken personally in the car park locations and a tour of the site, the values are approximate.

As the first step, parking areas were selected, followed by the design of the PV system, as a roof-mounted PV system. This process was carried out in the following steps: Painting a 3D structure of the parking houses and surrounding objects, define solar array and placement of panels, shading analysis, calculation of solar output capacity. Sketches of the designed solar carports in car parks are shown in Fig.4, Fig.5, Fig.6.

Fig. 4. Sketch of the designed solar carports in car park T14

Fig. 5. Sketch of the designed solar carport in car parks T12

Fig. 6. Sketch of the designed solar carport in car parks CESA

### C. *Parameters of PV panels in carports*

As photovoltaic panel in all systems module FU 500 Silk premium is chosen, which has the following parameters:

PV power output: 500 Wp, dimensions: 2185 x 1098 x 35 mm, type: monocrystalline, half-cut cells, efficiency: 20.84%.

### D. *Parameters of carports structures:*

#### 1) *The high and shape:*

In general, the height of carports is around 2.5 m and 4.5 m [7], the height of structure here 2.7 meters (high of bottom edge) in T14 and T10, the highest floor in parking areas T12. However, in T12 the structures in middle floor have a high of 3.7 m and in the lowest floor has high of 4.7 m. The structure in all car parks mounted with a slope of 15 degrees, structures can be from aluminum with shape of single column, T structure, titled 15 degrees in one direction like in Fig.1.

*2) Solar carport width:*

The width of solar carport roof is in general about 3 to 7 m, according to size and number of car rows to cover the cars [3].

In T14: carport roof has 3 vertical modules on row width, then depth of array row is 6.34 m.

In T12 and CESA: carport roof has 5 horizontal modules on row width then the depth of array row is 5.3 m.

## *E. Solar PV capacity and sufficient parameters of systems*

In the following table the other sufficient parameters are determined for designed solar carports:

*Table 1: sufficient parameters determined for designed solar carports.*

| **Car park** | **PV output (kWp)** | **Modules number** | **Array direction** | **Number of areas** |
|---|---|---|---|---|
| T14 | 177 | 354 | South-west | 1 |
| T12 | 350 | 700 | South-west<br>South-east | 3 |
| CESA | 182.5 | 365 | South | 3 |

## *F. Shading analysis:*

The system was designed with consideration the shading of surrounding objects and the shading of solar modules, shading analysis was performed, the allowed limit was chosen as 5%, that means the shading on the solar panel did not exceed more than 5%, as seen in the following figures.

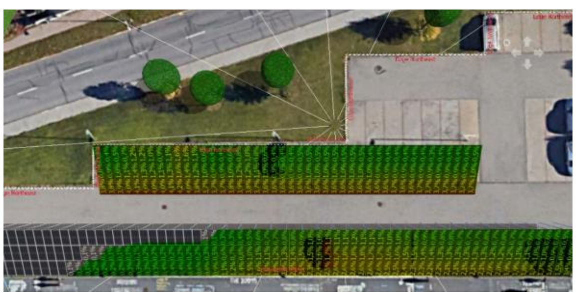

Fig. 7. View of shading analysis of designed solar carport in T14 car park, maximum 4.2%

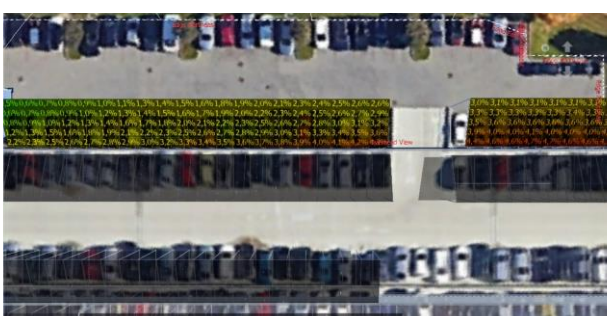

Fig. 8. View of shading analysis of designed solar carport in T12- first area car park, maximum shading 4.7%

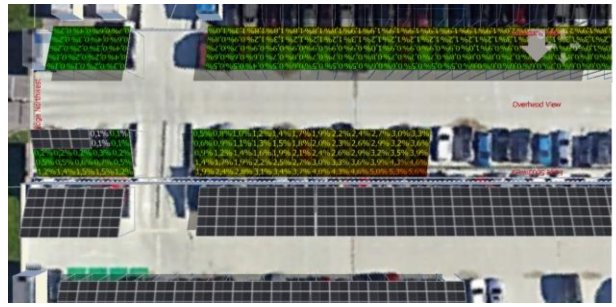

Fig. 9. View of shading analysis of designed solar carport in T12-middle area car park, maximum shading 5.6%

Fig. 10. View of shading analysis of designed solar carport in T12- middle area car park other side, maximum shading 2.4%

Fig. 11. View of shading analysis of designed solar carport -upper area car park, maximum shading 5.1%

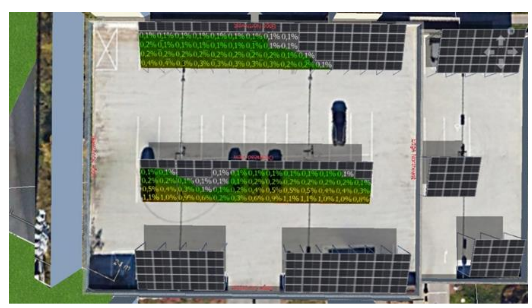

Fig. 12. View of shading analysis of designed solar carport in CESA parking house - first area (upper), maximum shading 1.1%

Fig. 13. View of shading analysis of designed solar carport in CESA parking house - second area, maximum shading 6% (one panel), 2.9%

Fig. 14. View of shading analysis of designed solar carport in CESA parking house -third area, maximum shading 3.4%

## IV. REQUIREMENTS FOR CONNECTING CATEGORY B1 PRODUCTION FACILITIES TO THE LOCAL DISTRIBUTION SYSTEM

The following rules summarize the requirements that need to be considered when connecting category B1 electricity production facilities to the MV network of the Local Distribution System Operator (PLDS):

**Category of Production Module:** B**, limit:** 1 MW**, Subcategory :** B1, **limits PLDS :** ≥ 100 kW and < 1 MW **Requirements:** According to article 14 for production modules B, article 20 for asynchronous production modules category B [7].

### *A. Relevant Legislation and Regulations*

For the establishment of a production facility and electrical storage device, it is necessary to comply with current regulations and standards in PPLDS Attachment 4: Rules for Parallel Operation of Production Facilities and Storage Devices with the Distribution System Operator's Network [7] to ensure suitability for parallel operation with the DSO network and to eliminate disruptive back feeding effects on the network or devices of other consumers.

## V. CONCLUSION

In conclusion, using solar carport carried many benefits, from point of energy production for EVs charging. Electric vehicles consume an average of 0.2 kWh/km, and photovoltaic (PV) power can provide up to 60% of the energy needed for charging electric vehicles [8]. Also, it offers economic benefit, so smart EVSPLs offer additional services that reduce charging costs for both EV owners and grid operators [1].

The article provided an essential overview of solar carports, evaluate the use of selected parking areas owned by Brno University of Technology in terms of installation of PV systems. The solar capacity of parking parks, in terms of generated power output, which the designed photovoltaic system could generate as mentioned in Tab.1: In parking area **T14: 177 kWp**, in parking area **T12: 350 kWp**, in parking area **CESA: 182.5 kWp.**

Later, the aim of the study will be to evaluate the use of selected parking areas at BUT in terms of parked electric vehicles within the vehicle-to-grid concept. In addition, will explore the possibility of EV charging, and the utilization of EVs as battery storage. The study considerations will include time-of-use analysis of the parking lots and driver behavior patterns.

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