Environmental Modelling Tools for Simulating of the Photovoltaic Power Plants Operation

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Abstract

This paper describes the creation of a 3D model of the PV system environment directly in the PVSOL software tool and compares it with a second 3D model created in the PIX4D photogrammetric software. The main advantage of both 3D models is the accuracy of the shading simulation. Any shadow on the PV module reduces the output power, so it is important to have an accurate model of any object that could shade the PV modules. This paper also describes the PV system design in the PVSOL design software.

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GENERAL INFORMATION

When designing a photovoltaic system, it is important to evaluate several aspects. These aspects include the geographical location, specific system location and orientation, system size, and shading effects. Because the shading greatly affects the output power of the photovoltaic modules, great care should be taken to avoid this effect. For this reason, it is advisable to precisely determine the degree of shading of the photovoltaic modules and adjust the system to ensure the highest efficiency and yield of the system. The PVSOL design software allows you to create 3D models of buildings on which photovoltaic modules can be installed. Creating larger and more complex 3D models in PVSOL is very laborious and time consuming. That is why the photometric software PIX4D was used in this work, which enables to create a real 3D model of larger building complexes and their surroundings and thus increase the accuracy of the screening and also to determine the influence of larger surroundings on the screening of photovoltaic modules.

CREATING 3D MODELS¨

PVSOL

PVSOL software allows you to create 3D building models by pulling an object from the map. Use this tool to eject a 3D object from an aerial photo of a building. The tool is sufficient to determine the degree of shading of panels and is often used for most buildings. It is very suitable for determining the degree of shielding of objects placed on the roof (chimney, satellite, sunroof). With this tool it is also possible to create distant large objects eg factory chimney. A problem may arise if a building with a photovoltaic system is surrounded by a large number of buildings that cast shadow on the photovoltaic modules. These objects can be created, but implementation would be very time consuming.

Fig. 1: 3D model created in PVSOL (part of town)

Fig. 2: Detail 3D model created in PVSOL (building)

PIX4D

Photometric software PIX4D is used for digitizing photographs taken from drones. However, any 3D model can be created using this software. Unlike PVSOL, where one photo and knowledge of all building dimensions is used to create 3D models, PIX4D needs a large number of photos to create a real 3D model. 103 photos from different angles were used for the 3D model (Fig. 3). However, the advantage is that to determine the exact scale of the model, it is necessary to know only one exact dimension of the building, eg the length of the wall. For this work, photos taken in Google Earth were used. By combining the photographs, a 3D model of the part of the city of Brno, in which the building with the proposed photovoltaic system is located, was created.

Fig. 3: 3D model created in PIX4D (part of town)

Fig. 4: Detail of3D model created in PIX4D (building)

PHOTOVOLTAIC SYSTEM DESIGN

After creating a 3D model, the design of the photovoltaic system is very individual. In the PVSOL software it is possible to select the type of the modules, their placement and fixing to the roof. Regarding the selection of the inverter for the designed system, PVSOL allows for automatic configuration and selection of the inverter based on the selected panels, their distribution into strings and performance. The cable connection is generated automatically and can be modified. The big advantage of PVSOL is that every photovoltaic component (inverters, modules, batteries) available on the market is cataloged and has a model with exact parameters in PVSOL. [3]

SHADING SIMULATION

The PVSOL software allows simulation of average annual shading. An important input parameter for the simulation is the geographical location of the object with a photovoltaic system. Shading simulation calculates the average annual shading of each module in the system. The result of the simulation is shown as a percentage and using a color scale. Comparing the shading simulations of the two 3D models, we can see that the models are very similar (Fig. 5, 6). Both 3D models also have very similar specific annual yields. Yield differs by 4.52 kWh / kWp, or 0.44%. Another important output value of the simulation is to reduce the yield by shading. At this value, the models differ by about 0.5% / year or 9.8% of the total yield of the photovoltaic system.

Fig. 5: Shading simulation of PVSOL model

Fig. 6: Shading simulation of PIX4D model

ECONOMIC SIMULATION RESULTS

The total energy produced by the PV generator is 28 282 kWh/year. Almost all of the energy produced is consumed directly in the building (99.5%). Only 137 kWh/year will flow into the distribution network. Although almost all energy produced is consumed directly, the degree of self-sufficiency is only 15.2%.

The investment costs for the PV plant were estimated at CZK 2 064 271.62. Half of this is the cost of system components. The other half is the cost of installation and all design. The aid amounts to 65% of the investment costs. The amount of support was estimated between the amount of support for medium and large enterprises according to the subsidy program that the proposed PV system could use. Furthermore, the annual cost was estimated at CZK 25 791. This amount is used to cover the maintenance of the PV plant.

After the installation of the PV plant, the amount of energy savings is approximately CZK 133 000. If we deduct maintenance costs, we get annual savings of about 110 000 CZK. With the same savings each year, the payback is just 6.6 years. This means that in nearly 7 years the PV system will save the same amount as the initial investment with a subsidy.

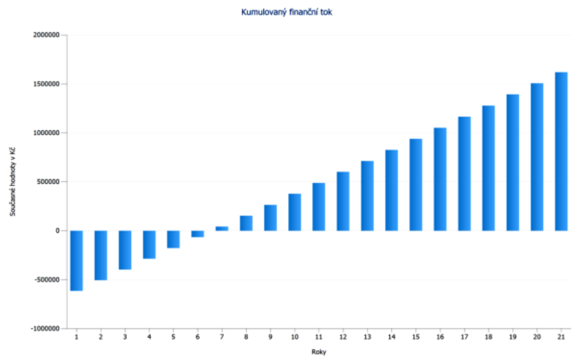

Fig. 7: Economic simulation of designed PV system

Table I: Financial analysis

Total investment costs	CZK 2 064 271.62
Total return on capital	15.38%
Amortization period	6.6 Years
Own production costs of electricity	2.27 CZK / kWh

CONCLUSION

Shading is an important influence on the output of the photovoltaic system. By determining the exact screening rate, the system yield can be determined sufficiently accurately. The main aim of this work is to describe the creation of 3D models in PVSOL and PIX4D, accuracy of shielding simulations and their comparison. Comparing the results of the shielding simulation it was found that both models are very similar. The model created in PIX4D has a greater degree of shading. This was probably due to inequalities in the 3D model. Due to small variations in simulation results, this model can be described as sufficiently accurate. In terms of the time required to create 3D models, it depends on the complexity of the objects that can obscure the photovoltaic modules. If it is an environment with minimal shading of surrounding objects (arrays, separate objects) it is preferable to use the 3D editor PVSOL. On the other hand, for built-up environments (cities, company premises) it is better to use the photogrammetric software PIX4D.

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