Enhancement of the Photovoltaic Systems Performance

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ABSTRACT

Photovoltaic solar energy (PV) is considered as one of the most promising environmentally friendly renewable energy sources. Performance of PV systems is affected by many environmental factors such as solar irradiation, humidity, ambient temperature, wind speed, and dust accumulation. Dust accumulation is one of the natural phenomena that leads to a significant decrease in the efficiency of the photovoltaic solar system, in the sense that it reduces the transmittance of the solar cell glazing. Rate of dust accumulation depends upon the dust properties (chemical properties, size, shape,…etc.) as well as on the site climatic conditions such as humidity and wind speed. Moreover, the surface finish, and the tilt angle also affect the rate of dust accumulation.

In this thesis, the work presents the results of a study carried out at Fayoum University with a detail experimental procedure that divided into three aspects: (1) designing a systematic experiment to accurately characterize the influence of dust pollutant type on the performance of monocrystalline and polycrystalline PV cells (indoor experiment), reviewing and comparing improved models for particle accumulation effect on transmittance of these cells; (2) monitoring the behavior of PV modules under Fayoum climate (outdoor experiment) and developing theoretical models to predict the output power of these PV modules; (3) carrying out characterization analysis of natural dust collected from Fayoum environment and finding out the effect of settled dust on glass and testing its transmittance.

Firstly, the particle shape and morphology of the natural collected dust were analyzed using a Scanning Electron Microscope (SEM). From the particle size distribution of the dust, we found that there are large number of

particles with diameters in range of 5–10 μm. The EDX analysis of the natural dust collected was done and the analysis obtained that the dust sample contains a large amount of O, C and very little amount of Na.

In the frame of the indoor experiment, artificial dust pollutants such as cement, sand, calcium carbonate, and silica fume were deposited uniformly over the surface of the monocrystalline and polycrystalline PV cells. It was found that, the smallest reduction in the short circuit current and maximum power was observed in the case of sand followed by calcium carbonate, cement and natural collected dust, while the greatest reduction was observed for silica fume for the same deposition density. Moreover, sand with different particle sizes were used and it was observed that finer particles have a significant effect on the maximum output power and short circuit current of PV cells than larger particles. However, these finer particles have a negligible effect on the open circuit voltage and the larger particles have slight effect on the open circuit voltage. It was also found that, the difference in performance due to the type of PV cell was not obvious in case of calcium carbonate, cement, silica fume and sand with particle diameter less than 180 μm. For sand particles whose diameter larger than 180 μm, the reduction in the output efficiency of monocrystalline was higher than that of polycrystalline PV cell. Besides, three kinds of physical optical models were proposed and compared with the aim to study the effect of the artificial dust accumulation on the performance of the monocrystalline PV cell. It was obtained that the overlapping model is the most suitable model to be applied on medium and large particles of dust.

In the context of the outdoor experiment, a glass sample was prepared and placed in the outdoor environment to calculate the degradation in

transmittance caused by natural dust deposition using Ultraviolet-visible spectroscopy (UV-Vis). Results showed that light transmission through the glass is significantly reduced for longer periods of outdoor exposure without rains and cleaning. Moreover, the performance of the four different types of PV solar modules (three polycrystalline modules and one mono-crystalline module) which belong to different manufacturers was monitored, under Fayoum climate for two months in winter without cleaning. Different performance parameters were measured on weekly basis and the results showed that panel 3 (German origin) had the lowest reduction in efficiency while, panel 2 (Chinese origin) had the highest reduction in efficiency. Over the period of this study, the power output of modules decreased due to the dust accumulation in rainless period and then increased due to rains as in the third and fifth weeks. In the last four weeks there were no rains, however the temperature decreased, so the efficiency remains nearly the same. On the other hand, two linear prediction regression models were developed to predict the output power of the polycrystalline PV modules exposed to natural accumulation of dust as function of exposure days and dust deposition density under Fayoum governorate climatic conditions. The presented two regression models, after validation with the experiments, can be used to predict the output power of any exposed module in winter.