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A Methodology of Using Fuzzy Logics and Data Analytics to Estimate the Life Cycle Indicators of Solar Photovoltaics

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Abstract : This study outlines the method of how to develop a surrogate life cycle model based on fuzzy logic using three fuzzy inference methods: (1) the conventional Fuzzy Inference System (FIS), (2) the hybrid system of Data Analytics and Fuzzy Inference (DAFIS), which uses data clustering for defining the membership functions, and (3) the Adaptive-Neuro Fuzzy Inference System (ANFIS), a combination of fuzzy inference and artificial neural network. These methods were demonstrated with a case study where the Global Warming Potential (GWP) and the Levelized Cost of Energy (LCOE) of solar photovoltaic (PV) were estimated using Solar Irradiation, Module Efficiency, and Performance Ratio as inputs. The effects of using different fuzzy inference types, either Sugeno- or Mamdani-type, and of changing the number of input membership functions to the error between the calibration data and the model-generated outputs were also illustrated. The solution spaces of the three methods were consequently examined with a sensitivity analysis. ANFIS exhibited the lowest error while DAFIS gave slightly lower errors compared to FIS. Increasing the number of input membership functions helped with error reduction in some cases but, at times, resulted in the opposite. Sugeno-type models gave errors that are slightly lower than those of the Mamdani-type. While ANFIS is superior in terms of error minimization, it could generate solutions that are questionable, i.e. the negative GWP values of the Solar PV system when the inputs were all at the upper end of their range. This shows that the applicability of the ANFIS models highly depends on the range of cases at which it was calibrated. FIS and DAFIS generated more intuitive trends in the sensitivity runs. DAFIS demonstrated an optimal design point wherein increasing the input values does not improve the GWP and LCOE anymore. In the absence of data that could be used for calibration, conventional FIS presents a knowledge-based model that could be used for prediction. In the PV case study, conventional FIS generated errors that are just slightly higher than those of DAFIS. The inherent complexity of a Life Cycle study often hinders its widespread use in the industry and policy-making sectors. While the methodology does not guarantee a more accurate result compared to those generated by the Life Cycle Methodology, it does provide a relatively simpler way of generating knowledge- and data-based estimates that could be used during the initial design of a system.

Keywords : solar photovoltaic, fuzzy logic, inference system, artificial neural networks
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