Iran rural microgrids

With renewable energy resources progressively becoming popular universally, environmental crisis and global warming are still considerable challenges [1]. The main prevalent environmental crises include pollution, resource evacuation, global warming, and environmental degradation. Environmental crises are detrimental effects by man-made activity on the biophysical environment. Environmental devastation imposed by human beings is a universal, continuous difficulty. The human effects on land can be viewed in different ways. The significant one is the temperature elevation and global warming which have been present for 50 years, mostly due to human activities (https://en.wikipedia /wiki/List_of_power_stations_in_Iran).

Based upon previous studies, there was a gap to be resolved by this study. Although different economic research has carried out for remote stand-alone hybrid electrification systems with DG, wind, and PV, their authors did not simultaneously and comprehensively perform economic and environmental feasibility study for one single province for stand-alone rural regions especially for northwest of Iran. The principal purpose of the current research is to study 6 stand-alone villages in East Azerbaijan province, Iran to explore the best composition of existing renewable energy systems. The research was performed through HOMER software. Furthermore, net present cost (NPC), cost of energy COE ($/kWh), and initial capital were regarded as the optimization metrics.

Table 1 demonstrates most relevant literature review which performed in the last few years by researchers.

To the best knowledge of the authors, there is no comprehensive novel work on economic and environmental evaluation of PV/Wind/Diesel hybrid system in one single province. On the other hand, this novel research focused on economic and environmental investigation of one single province in order to find the best possible optimization for selected locations. Although various economical investigations have been performed for remote off-grid hybrid electrification systems with PV, Wind, and diesel generators, their authors did not simultaneously and comprehensively evaluate economic and environmental feasibility for one single province for off-grid rural areas especially for northwest of Iran. As some instances, the following studies have been performed over the past few years.

Farivar Fazelpour et al. [20] focused on economic analysis of HE systems in Tehran, Iran, where PV - wind turbine - DG hybrid systems were examined in this research. Hydrogen was applied through DG to warrant a pure fuel is applied, contributing to a minimal environmental impact. Further, battery was employed in the system dependability evaluation. HOMER software was applied for the economic evaluation. The aim was to improve the energy utilization and reduce the dependency on fossil fuels in domestic utilization by demonstrating the technical and economic possibilities correctly. The obtained results showed that amongst five hybrid systems, the most cost effective was the hydrogen-battery system which had a total NPC of US$68,189 and COE of US$0.873/kWh.

Luis Santiago Azuara Grande et al. [21] performed economic and environmental feasibility study of stand-alone PV-BESS for electric vehicles in Spain. For ascertaining the effectuality of the considered scheme, its performance was compared against grid electricity charging, in terms of environmental aspects. The primary objective was to achieve an economic goal for EVs, which assured the system performance, while being viable economically and technically. The results showed that off-grid PV-BESS were economically reliable. In addition, they would allow a remarkable decline in air pollution.

M. Kashif Shahzad et al. [23] concentrated on techno-economic analysis of a stand-alone solar-biomass system for rural regions in Pakistan applying HOMER software. The fundamental objective of this research was to offer optimized configuration for electricity production applying hybrid Photovoltaic-Biomass for an agricultural plantation and a residentiary district placed in a small suburb in Pakistan. In order to handle the load conditions, HOMER was applied to design and carry out economic and technical evaluation applying Biomass-Photovoltaic hybrid system. The results showed that the system is economically feasible based upon the NPC and cost of energy.

Monotosh Das et al. [24] focused on techno-economic analysis of a stand-alone hybrid system applying metaheuristic methods in India. A sensibility investigation based upon loss of load possibility was performed to explore the possibility of the recommended model. The purpose of that research is to gain an economic and technical design of stand-alone hybrid battery-biogas G-PV system with the aid of metaheuristic methods for a radio site in India. The result indicated that both considered metaheuristics were useful in gaining the best design, though water cycle algorithm outperformed the others in design.

A. Can Duman et al. [25] studied the techno-economic feasibility of stand-alone PV-wind-fuel cell system compositions as compared to regular households. In that research, electrical energy usage of stand-alone vacation houses through FC-PV-wind turbine hybrid systems was examined from economic and technical viewpoints. Twenty-four various simulations were presented via HOMER software under different climatic statuses of Izmir, which has nearly high wind and solar energy for Turkey where vacation houses are placed. The results showed that the COE of stand-alone systems was above that of grid electricity but less than previous years.

The number of households with available electricity grid in the East Azerbaijan province has been growing since 2011. In the East Azerbaijan province, there are 513,845 households with accessibility to the electricity grid. Although the remaining (12,846 individuals) does not have access to the electricity grid, over 75% have accessibility to renewable energy resources. Even though many remote rural regions in the East Azerbaijan province do not have access to the electricity, village electrification has developed over the past few years. Hence, applying wind turbines, diesel generators, and PV panels can be a rational solution for satisfying peak electrical demands as an alternative renewable clean energy for remote rural areas of East Azerbaijan province.

The main objective of the present study is to investigate six off-grid villages in East Azerbaijan province, Iran with different locations and diverse climate conditions in order to choose the best compound of existing

renewable energy systems for finally providing electricity demands in a reliable and sustainable way for each locality. In addition, the cost of energy (COE) ($/kWh), initial capital, and net present cost (NPC) have been considered as the main optimization metrics.

Geographical position of proposed study areas

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