Smart Micro-Grid Electrical Energy Management: Techno-Economic Assessment

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Received: 5/11/2021 Accepted: 25/104/2022

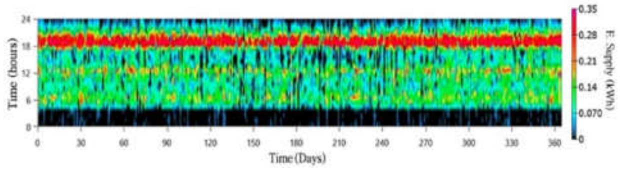
Extended Abstract

Introduction: Renewable energy sources may be unstable and unreliable in geographical areas[1]. It is not possible to provide electric power through photovoltaic systems at night, and the wind energy system may not be active during the day. Therefore, the design and integration of different sources of renewable energy, especially photovoltaic-wind, under combined systems and the use of suitable storage and backup systems can arouse the desire for using renewable systems as well as manage the problem of the nature of energy periodicity [2].

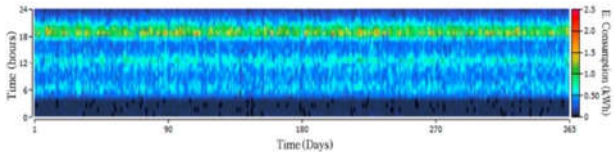
Materials and Methods: The annual average temperature of the environment in the evaluation of geographical location and meteorological variables using the measured meteorological data is equal to 21.2 Celsius. The components of the hybrid renewable energy conversion system in real time include electronic circuits, solar and wind sub-systems, charge controllers, battery banks, sensors, ready-made circuits, safety circuits, converters, voltage intervention circuits, relays, inverters, data loggers and computer switchings. The integration and construction of the hardware of the intelligent direct-current combined renewable energy conversion system for testing the system in real time has been done and installed on a green cottage.

Discussion and Conclusion: Considering the combination of solar and wind energy and the use of battery backup and generator, 13 logical scenarios have been calculated for the arrangement of the sub-systems. A combination that uses all subsystems and has a cost of electricity generation (COE) of $0.381 per kWh includes a solar subsystem of $0.205 (with an initial cost of $410) with 1 i500 model wind turbine (initial cost $1000) and TG2500DC model gasoline generator (electric motor) with a nominal capacity of 0.890 kW and 2 batteries of 100 amp hours. Figure (1) shows the electricity production and consumption of the green cottage during a one-year period. The results of the electricity consumption of the green cottage demonstrate that the pattern of household electricity consumption will reach the peak at night from sunset to 3 hours after. The maximum electricity consumption in some days of the year has reached 2.09 kilowatt hours. The minimum consumption was recorded in blackout hours and equal 0.01 kilowatt hours. At time of sunrise, the start of electricity consumption in the green cottage was 0.33 kW until sunset it was measured as an annual average of 0.47 kW. From the point of view of electrical engineering, the load factor of green cottage was calculated as 22%. In the optimization of the combined renewable energy conversion system, all the different arrangements of the electricity supply of green cottage were examined according to limitations and real data in order to achieve the most economical mode for the life cycle cost. In order to model this system, we added

information about the solar source and the wind speed of the region to the model. The one-hour step model has calculated the amount of energy of renewable sources and has performed scale analysis for all types of small energy systems, especially those that have intermittent renewable energy sources.



A: Power generation of combined renewable energy conversion system



B: Green cottage electricity consumption

Fig. 1. Power generation and consumption of green cottage during a one-year period

The annual production of the solar sub-system with 20% fraction equals 331 kilowatt hours per year and the wind sub-system with 40.8 percent fraction equals 675 kilowatt hours per year and the gasoline generator with 39.2 percent fraction equals 647 kilowatt hours per year. The performance of the gasoline generator shows that the total energy produced by this unit is 675 kilowatt hours per year, and the electrical output of this system has been recorded as 0.502 kilowatts (minimum 0.223 and maximum 0.798).

The use of the battery energy storage source has shown that the nominal voltage of 12 volts is suitable and the average energy production cost of this source will be 0.0977 dollars per kilowatt hour. The energy input into the battery storage source has been 577 and the energy output from this source has been 446 kWh per year. The power loss has been 111 kilowatt hours per year and the total transient energy from the batteries has been recorded as 499 kilowatt hours per year. Also, the independence of the battery energy storage source in supplying the electricity demand of green cottage has been 7.03 hours and the production cost has been 0.112 dollars per kilowatt hour. The intelligent combined renewable energy conversion system manages the largest share of the electric power demand of the green cottage. Figure (2) shows the possibility of the fraction of renewable energies with dynamic decision-making component and the net investment value. As the average wind speed increases and the fuel price decreases, the net investment value decreases.

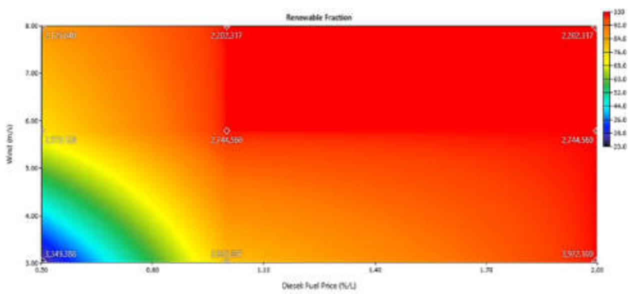


Fig. 2. Fraction of renewable energies with dynamic decision-making component and net investment value

Increasing the investment from $3300 upwards is irrational and increases the cost of energy production linearly, taking into account the average wind speed of 3 meters per second and removing the gasoline generator from the mix, using 3 batteries and increasing the capacity. Under the solar and wind system, the cost of renewable electricity production can be reduced to 0.402 dollars per kilowatt hour. The first method is to provide electricity for the green hut with an "economic" purpose. In this method, the fraction rate of renewable energy is 23.8%, and non-renewable energy with the consumption of 407 liters of fuel.

Therefore, the first scenario with renewable energy fraction of 23.8% is the most economic. Scenario 2 has an economic justification with renewable energy fraction of 54%; implementing scenario 3 with the renewable energy fraction of 100% is not economical in Iran. However, with respect to social and biological

effects, environmentally, the implementation of this method does not pollute the environment due to the absence of generators and the consumption of fossil fuels.

Keywords: Energy, hybrid systems, reliability, energy management, renewable energy, fossil fuel

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