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Modelling and Assessment of an Off-Grid Biogas Powered Mini-Scale Trigeneration Plant with Prioritized Loads Supported by Photovoltaic and Thermal Panels

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Abstract : This paper is intended to give insight into the potential use of small-scale off-grid trigeneration systems powered by biogas generated in a dairy farm. The off-grid plant object of analysis comprises a dual-fuel Genset as well as electrical and thermal storage equipment and an adsorption machine. The loads are the different apparatus used in the dairy farm, a household where the workers live and a small electric vehicle whose batteries can also be used as a power source in case of emergency. The insertion in the plant of an adsorption machine is mainly justified by the abundance of thermal energy and the simultaneous high cooling demand associated with the milk-chilling process. In the evaluated operational scenario, our research highlights the importance of prioritizing specific small loads which cannot sustain an interrupted supply of power over time. As a consequence, a photovoltaic and thermal panel is included in the plant and is tasked with providing energy independently of potentially disruptive events such as engine malfunctioning or scarce and unstable supplies of fuels. To efficiently manage the plant an energy dispatch strategy is created in order to control the flow of energy between the power sources and the thermal and electric storages. In this article we elaborate on models of the equipment and from these models, we extract parameters useful to build load-dependent profiles of the prime movers and storage efficiencies. We show that under reasonable assumptions the analysis provides a sensible estimate of the generated energy. The simulations indicate that a Diesel Generator sized to a value 25% higher than the total electrical peak demand operates 65% of the time below the minimum acceptable load threshold. To circumvent such a critical operating mode, dump loads are added through the activation and deactivation of small resistors. In this way, the excess of electric energy generated can be transformed into useful heat. The combination of PVT and electrical storage to support the prioritized load in an emergency scenario is evaluated in two different days of the year having the lowest and highest irradiation values, respectively. The results show that the renewable energy component of the plant can successfully sustain the prioritized loads and only during a day with very low irradiation levels it also needs the support of the EVs' battery. Finally, we show that the adsorption machine can reduce the ice builder and the air conditioning energy consumption by 40%.

Keywords : hybrid power plants, mathematical modeling, off-grid plants, renewable energy, trigeneration
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