Hybrid Solar and Bio-Gas System For a Chicken Farm

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ABSTRACT: The energy load profile for chicken farms indicates that between the lighting and fan loads, a good portion of the overall demand can be satisfied by solar photovoltaic (PV) systems during the daylight hours, especially the peak fan loads and sunny conditions match quite well. To be completely off the grid however, there is a need for providing power to fans and some lighting after dusk and before dawn. In this study, the conversion of the bio-waste into bio-gas and powering small micro-turbines is evaluated. Storing solar electric power in batteries is an option, but costly and not ideal. Bio-gas on the other hand is a by-product of the chicken farm, can be generated and stored on site, and used as fuel for small, reliable micro-turbines.

INTRODUCTION: The electric load pattern of typical chicken farms have been analyzed. A 4-house farm with 42' by 500' (approximately 14 meters by 150 meters) high hooped structures has a base load requirement of 15 to 25 kW depending on the season and location, and a peak load of 45 to 60 kW also depending on the need for lighting and ventilation. A solution that includes a 20 kW solar electric system and a 65 kW gas powered micro-turbine is proposed. The performance of the system in response to load variations is simulated for this application. Actual weather conditions, and historical load patterns are used. Using only solar and farm generated bio-gas, the system must be able to provide all the power required.

METHODOLOGY: The cost of solar electricity with solar photovoltaic (PV) panels has become economically feasible in recent years[3]. Lower cost of panels and availability of reliable inverters that convert direct current electricity to alternating current is making solar electricity competitive with conventional power generated with fossil fuels. The LCOE (Levelized Cost of Electricity) which is a method developed by NREL for US Department of Energy, allows a fair comparison basis of various generating methods. The LCOE of solar electricity is currently at US$ .08 for many installations. If peak load charges are considered, the LCOE is even more competitive in regions where TOU (Time of Use) rates are utilized. Chicken farms, like many other power users, have peak electric demands that coincide with peak solar generation, typically between 10 in the morning and 2 in the afternoon on sunny days. The main disadvantage of solar electricity is that it needs to be stored for night time use. Electricity storage is still quite expensive, requires batteries and maintenance, and generally not considered practical with current technology. An alternative to storage is developing hybrid systems such as the one suggested in this paper. By using locally generated fuel, in this case the biogas from the chicken farm, the night time needs, as well the requirements during cloudy or rainy conditions can be met without the need to buy power from the grid.

HYBRID DESIGN: Any combination of more than one source of energy is considered a hybrid system. Depending on the lowest cost of the available options, we may consider solar and natural gas, or solar, wind and bio-mass[1], or even solar and oil fired power plants. However, we will limit the definition of hybrid plants to environmentally acceptable solutions. In case of biogas, there can be an argument that we will still generate carbon dioxide, which is greenhouse gas, and some other emissions. Nonetheless, the impact of locally produced gas is considered as carbon neutral, or at least greenhouse gas neutral. One could also argue that the impact of locally produced bio-gas[2] is less environmentally harmful than the alternative: lead-acid battery maintenance or life-time impact. After a review of the solar electric components, including the solar panels, the inverters and the BOS (Balance of System), we discuss the net bio-waste production of the chicken farm, and the equipment required to convert this waste into electrical power. These include the bio-digester, the treatment of the raw bio-gas into treated gas that can be the fuel source for micro-turbines, and the principles of operation of micro-turbines.

MULTI-DISCIPLINARY DESIGN:

The main challenge of any hybrid-system design is the multi-disciplinary nature of these projects. In the specific case of this hybrid system, the following disciplines are required:

Electrical Engineering
Mechanical Engineering
Structural Engineering
Chemical Engineering
Solar Engineering
Civil Engineer
Knowledge of Farming
Knowledge of Chicken Farming

The paper describes the details of a 20 kW solar PV system, designed and implemented as ground-mount installation, the energy efficiency features that are also added to lower the overall peak load, and the interconnection of the micro-turbine for a seamless energy operation. The controller which is at the heart of the system provides smart programming features that allow the user to determine the hierarchy between the solar and the micro-turbine sources. The micro-turbine can be operated as a base load provider, and the solar for peak demand, or in sunny cool conditions, when the solar generation exceeds the load, the solar system can be programmed to serve as the base load, and turn the micro-turbine on for peak. Alternatively, any combination of solar to gas turbine generating ratio can be achieved depending on operating conditions, fuel prices, and other factors.

SUMMARY: Hybrid systems combining solar, wind, bio-mass, biogas or micro-hydro need to be considered in any energy project. By designing for a flexible systems and controllers, users will be given more choices on how to power their operation. This specific project shows a practical example of how to achieve this goal using both economics and a common sense approach

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