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Profitable small-scale renewable energy systems in agrifood industry and rural areas: demonstration in the wine sector

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Abstract. The project "Profitable small-scale renewable energy systems in agrifood industry and rural areas: demonstration in the wine sector (LIFE REWIND)" is partly funded by a €676,265 grant from the European Union's LIFE+ program. This project addresses climate change in regard to the rural environment with objectives in both mitigation and adaptation. In terms of mitigation, it seeks to decrease the CO_2 emissions resulting from energy consumption in rural areas. In terms of adaptation, the project facilitates the acclimation of agriculture to climate change by allowing the production of clean energy for irrigation in locations without an electric grid. The project provides other positive outcomes by omitting noise, waste and other undesirable environmental effects. It also reduces visual impacts by avoiding the construction of electrical grids.
The demonstration takes place in the wine sector, where two different environments are considered: field and winery. In each one a prototype is installed that produces on-site renewable energy through photovoltaic generation.

Key words

Renewable energy, agrifood industry, wine sector.

1. Introduction

The LIFE REWIND [1] project may be relevant for the improvement of the environmental policies for sustainable development in the areas of agriculture and energy. In addition, several of the aspects treated in this project are covered by the priority objectives of the 7th European Programme of Environmental Action [2] in a productive sector not included in the ETS (Emissions Trading System) because it is in agriculture. It contributes to the achievement of the objectives on renewable energy and increases energy security while reducing dependence on imported fuels. The project shows and disseminates the technical feasibility of using renewable energies on-site in agricultural activities. It also shows that it is possible to use hydrogen in mobility and agricultural machinery, including the production of hydrogen from renewable energy on the farm. Long-term replication of the solutions proposed by the project will result in the multiplication of the environmental, economic and social benefits.

There are four beneficiaries of the project: Universidad de Zaragoza (UNIZAR), Consejo Superior de Investigaciones Científicas (LIFTEC-CSIC), Intergia energía sostenible S.L. (INTERGIA) and Viñas del Vero S.A. (VIÑAS del VERO).

2. Prototypes

Two prototypes (field and winery) that produce on-site renewable energy through photovoltaic generation have been designed and installed. Both prototypes are on land owned by the company Viñas del Vero (Barbastro, Spain). Figures 1 and 2 show the location of the prototypes (42°03'36.2"N 0°05'40.2"E).

Fig. 1. Location of Viñas del Vero.

Fig. 2. Location of the prototypes (42°03'N 0°05'E).

A study of the renewable resources where the prototypes were located found that the wind resources were not adequate. Wind measurements were available where the prototypes were placed, with average annual wind values of 1.6 m/s (at 10 m height). The use of wind turbines was ruled out because of these average values of wind speed.

However, with the measures available, the solar resources where the prototypes were placed amounted to between 4800 and 4900 Wh/m^2·day, so it was deemed more adequate to place photovoltaic panels.

Multi-crystalline silicon photovoltaic (PV) panels with an anti-reflective surface treatment were used in the two prototypes.

A. Field prototype

In the field prototype, the system is grid-isolated and feeds an irrigation system. The excess energy is used to produce hydrogen by the electrolysis of water in an off-road vehicle equipped with a fuel cell.

Figure 3 shows the floating PV system [3], which has an installed power of 21600 Wp and is located over the aeration raft (Figure 2), and Figure 4 shows the off-road vehicle equipped with a fuel cell. Figure 5 shows the inverters and batteries used in the installation. A three-phase inverter has been used to convert the DC electricity generated by the PV panels into AC three-phase 400 V, 50 Hz. Three single-phase inverters that are connected in a three-phase configuration manage the charging and discharging of the batteries (2680 Ah C10, 48 V).

The main of objective of the prototype field is to feed the pumps necessary to irrigate a nearby vineyard. The first one (7.5 kW) carries water from the aeration raft (where the wastewater from the winery is purified) to an area where it is filtered with sand (filtration raft), and the second (2.2 kW) takes the filtered water to the irrigation raft, which is located at a greater height than the filtration and aeration rafts. In addition, another pump is fed (11 kW) whose function is to take the water from the irrigation raft and pressurize it for drip irrigation.

The two pumps with higher power (7.5 and 11 kW) are fed using frequency converters, thus avoiding peak current at start-up, achieving a smooth stop and allowing the motor-pump assembly to work efficiently.


Fig. 3. View of the floating PV installation

The irrigation season can vary from year to year and usually occurs between 16 May and 15 September. Therefore, in order not to lose all the surplus energy generated by the PV panels, hydrogen is generated to supply an electric vehicle (Figure 4).

Fig. 4. View of the off-road vehicle equipped with a fuel cell.


Fig. 5. View of the inverters and batteries.

B. Winery prototype

In the winery prototype, the generation is connected to the electric grid on self-consumption, supplying part of the electric demand of the winery.

Figures 6 and 7 show the rooftop PV plant and solar tracker one, with a total installed power of 21600 Wp.

Fig. 6. View of the rooftop PV plant.

Fig. 7. View of the PV installation with solar tracker (two axes).

The rooftop PV system has an inclination that can be adjusted to two positions (37º and 5º). The first corresponds to the maximum annual production, while the second is suitable for the summer and is used for demonstrative purposes and technical comparison (in relation to the field prototype).

The system uses two three-phase solar inverters. The 40 panels of the floor support are connected to one of them in two strings (with independent MPP followers) of 20 panels each. The 40 solar tracker panels are connected to the other in two strings (with independent MPP trackers) of 20 panels each. These inverters transform the DC electricity generated by the photovoltaic panels into three-phase AC of 400 V at 50 Hz.

C. Communication and control systems

The pieces of electronic equipment (photovoltaic inverters, insulated inverters, sensor box, web box, H_2 production control subsystem, energy control subsystem and inverters of pump motors) are connected to each other via Ethernet. An 8-port switch and a 5 GHz link to the warehouse facilities allow the connection to the Internet, through which the portal of the inverter manufacturer can be accessed and the main parameters of the system can be monitored. In addition to the hardware and software incorporated in the electronic elements (inverters, etc.), there are two general subsystems of control in the field prototype. One of them is responsible for managing the production of hydrogen and all related elements. The other control subsystem is responsible for energy management. This function is relevant in an isolated system, which depends on the variations of solar irradiation for renewable generation and has a very limited capacity of accumulation. The energy that is produced at any moment must be used or stored at that moment, otherwise it is lost. This subsystem controls the starting of different loads, some of them by user commands (mainly irrigation orders) and others automatically (mainly lifting pumps). A touchscreen (Figures 8 and 9) facilitates the introduction of commands and the reading of the operating parameters. The energy control subsystem not only displays the energy status of the system but is also able to estimate future production and offer the user a prediction of how the production-accumulation-consumption set will evolve over time during the fulfillment of the orders.

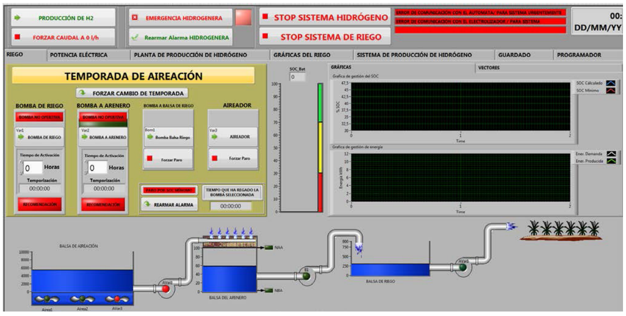

Fig. 8. Picture of the touchscreen (monitor) of the system. Detail of the pumping system.

Fig. 9. Picture of the touchscreen (monitor) of the system. Detail of the two prototypes.

Given the experimental nature of the prototype, in addition to the sensors necessary for the operation and management of the system, other sensors have also been incorporated to obtain more exhaustive data that allow a detailed analysis of the system's operation in the medium and long term. The data capture is done every second and the 10-minute and hourly averages (and in some cases also the maximum and minimum) are recorded.

Among other parameters, the following are measured:

- Battery charging status (SOC).
- Operating states (0/1) of each and every one of the loads.

- Hydrogen reservoir status.
- Temperature in the zone of production of hydrogen.
- Energy produced by the photovoltaic generator at its three-phase output.
- Energy consumed in each of the loads.
- Amount of hydrogen produced.
- Battery charging current.
- Solar irradiation on horizontal plane.
- Solar irradiation on the panels of the PV field.
- Ambient temperature in the vicinity of the PV panels.
- Temperature of the PV panels.
- Wind speed.

This will allow for determining the difference in temperature and performance of the floating panels compared to conventional solutions on the ground, among other measurements. The control parameters can also be monitored to adjust in order to minimize the surplus energy.

The prototypes incorporate two IP cameras, one of which is motorized, connected to the Internet with the double aim of increasing the security against vandalism or theft and allowing remote visits to the installation.

4. Environmental benefits

The implementation of the project will provide several direct environmental benefits in reducing emissions, saving energy, and avoiding environmental and landscape impacts. All of these are due to the replacement of fossil fuels by electricity obtained from renewable sources, which reduces the electricity consumption of the electric grid and avoids the construction of new power lines.

In order to study the environmental benefits of the project, it is possible to evaluate the reduction of CO_2, SO_2 and NO_x due to the installation and operation of the prototypes.

In the case of Spain, the emissions of the whole generating park for December 2015 were approximately [4]:

0.269 kg of CO_2/kWh
0.623 g of SO_2/kWh
0.424 g of NO_x/kWh

For the winery prototype, it is possible to carry out a study of the environmental benefits that it entails. Thus, the following consumption and emissions data for the warehouse were determined before installation of the prototype:

- Annual power consumption of the electricity grid: 2,031,000 Wh
- Annual associated emissions of CO_2: 489,471 kg
- Associated annual emissions of NO_x: 737 kg
- Associated annual emissions of SO_2: 1,044 kg

The following results are expected after installation of the prototype:

- Reduction of the annual power consumption of the electricity network: 23,000 kWh
- Reduction of associated annual CO_2 emissions: 5,543 kg
- Reduction of associated annual NO_x emissions: 8.35 kg
- Reduction of associated annual SO_2 emissions: 11.82 kg

The emission reductions indicated above are initial estimates. The real values will be obtained from the final measurements of the prototypes.

On the other hand, the use of an electric vehicle fueled by hydrogen in the field prototype will also give rise to important environmental benefits. The conventional multipurpose vehicle that is currently used on the farm has an average daily consumption of 4.56 liters of fuel and a working cycle of 200 days per year. Thus, the annual consumption is 912 l of diesel, and annual emissions amount to 2,544 kg of CO_2.

With the field prototype, the following results are expected:

- Elimination of the annual consumption of diesel of the vehicle
- Elimination of associated annual CO_2 emissions: 2,544 kg

5. Conclusion

The expected results from the LIFE REWIND project are both environmentally beneficial (reducing the emissions of CO_2, SO_2, NO_x, etc.) and socioeconomically beneficial (creating qualified employment and improving the rural environment, etc.).

In addition, other results are expected, including the following:

- Generalized implementation at the level of the wine company and an effect on the indicators of the product (cost per bottle of wine, CO_2 emissions per bottle of wine).
- Widespread implementation in the wine sector.
- Implementation in agricultural irrigation, agricultural machinery and the agrifood industry.

Acknowledgement

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