Feasibility Analysis of Smart Renewable Hubs in EU Islands

Jose M. Estebaranz, Daniel Pereira, Alberto R. Rocha
Cobra Instalaciones y Servicios
Madrid, Spain

Revekka Gkogkou , Georgia Asimakopoulou (PHD),
A. L. Dimeas (PHD), N. D. Hatziargyriou (Prof.)
School of Electrical and Computer Engineering, National Technical University of Athens (NTUA),
Athens, Greece,

Petros Markopoulos, Maria Kourasi (PHD), Eirini Stavropoulou
Hellenic Distribution Network Operator (HEDNO)
Athens, Greece

Jorge Servert, Eduardo Cerrajero, Diego Lopez
IDIE
Madrid, Spain

***Abstract*— The Flexible Electricity Generation coming for RES technologies is the key point of the future European electricity system and the Energy Union in Europe. However, PV and wind power are non-synchronous generators, which affects grid stability; they, also, strongly depend on weather conditions. As a consequence, fossil fuel backup systems are a must for security of supply and stability. CSP (Concentrated Solar Power) technology adds firmness, security of supply, flexibility and stability, eventually, being able to eliminate dependence from fossil fuels acting as the synchronous generator providing stability to the grid. This paper presents the European H2020 research project GRIDSOL. GRIDSOL aims to provide secure, clean and efficient electricity by combining primary renewable energy sources (RES) and technologies under an advanced control system. GRIDSOL will allow increasing clean power (RES) installed in the system, reducing the dependency on fossil fuel backup, without compromising grid stability and security of supply in an efficient manner.**

Keywords—Gridsol; Concentrated Solar Power; hybrid station; non interconnected islands

I. INTRODUCTION

In a context of high Variable Renewable Energy (VRE) generation and ambitious decarbonisation targets, flexibility starts to play a key role to guarantee grid stability in the Non Interconnected Islands of the European Union (EU). The majority of the EU non interconnected islands rely heavily on oil and gas for their power production, which is a fact that contributes to expensive and polluting electricity. In this regard, GRIDSOL project presents a new concept to increase renewable energy penetration in a grid-friendly manner: Smart Renewable Hubs (SRH).

An SRH is a flexible hybrid power plant that combines power generation and storage technologies like: Concentrated Solar Power (CSP), Solar Photovoltaics (PV), Wind, Biomass, Battery Energy Storage (BES), Thermal Energy Storage (TES), and a fossil- or bio-fuelled turbine with a Heat Recovery System (HYSOL). To make this hybridization possible, GRIDSOL develops a Dynamic Output Manager of Energy (DOME). This advanced control system considers market and grid requirements, providing ancillary services and relieving pressure on the Electricity System Operator.

The aim of this study is to evaluate the socio-economic benefits of the SRHs for four non-interconnected EU islands (Crete, Fuerteventura, Madeira and Cyprus) in 2030. The choice and size of each technology included in the SRH is optimized for the desired location, aiming at a renewable content of at least 80% on a yearly basis and an investment rate of return above 7.5 % for a 25 year life.

II. METHODOLOGY

The integration of any power station in the operation of the electricity system must comply with the rules set by the Regulator. The Operator, on the other hand, during the day-ahead planning and the real time operation of the system is bound by the market rules to ensure the economical operation of the entire system, to serve the load in its totality and to respect the technical limitations of the various production units.

To this end, the commitment and dispatch of the production units on an hourly basis is planned well before the real time operation. Thus, the individual production units are provided with a production program from which minor deviations are allowed. In the case of GRIDSOL, this means that the power station is supplied with a 24-hour curve indicating the desirable set-point calculated by the System Operator. The power plant coordinates the various resources in order to achieve the given set-point and avoid deviations (and the relevant penalty), while respecting the technical limitations of the available energy sources.

In Table I, the assessed SRH configurations per location are presented.

TABLE I SRH CONFIGURATIONS PER LOCATION

	Fuerteventura	***Madeira***	***Cyprus***	***Crete***
ST Nominal Power (MW)	10	3	13	9
GT Nominal Power (MW)	7	4	9	10
PV Power (MW)	27	26	43	22
Wind Power (MW)	18	8	0	20
BESS Nominal Charge / Discharge Power (MW)	3	11	9	15
BESS Autonomy (h)	3	4	4	8
TES Time (h)	19	20	20	13

The feasibility studies for all the locations are projected in 2030, so assumptions regarding the annual load and the maximum demand load for 2030 have been taken into consideration. These values were obtained by TYNDP 2018, and the ENTSO-E database [1].

In order to calculate the economic effect the addition of a Smart Renewable Hub would have on the Electrical System of each island, a number of prices had to be determined. The cost of the production of conventional units comprises three factors: fuel cost, CO2 emissions cost and cost for Operation and Maintenance. The 2030 prices of HFO and LFO were calculated by taking into account the current prices for Crete increased by 40%, which was the percentage recommended by TYNDP for 2030. Additionally, the 2030 prices of Gas and CO2 emissions were obtained by the TYNDP for 2030 calculations [2]. These 2030 prices are shown in Table II.

TABLE II. THERMAL PRODUCTION COST PARAMETERS FOR 2030

Heavy Fuel Oil (€/tn)	***Light Fuel Oil (€/klt)***	***Gas (€/tn)***	***CO2 emissions (€/tn)***	***O&M (€/MWh)***
494	1172	430	84.3	3

The existing RES stations of each island are remunerated with different Feed-in Tariffs (FiTs) depending on the time of their installation. With the use of historical production and remuneration data regarding RES stations, the average FiTs are shown in Table III.

TABLE III. FEED-IN TARIFFS PER ENERGY SOURCE (€/MWH)

	Fuerteventura	***Madeira***	***Cyprus***	***Crete***
PV	38.4	33.34	250	400
Wind	50.4	88.8	166	99
Hydro	-	112.4	-	-
Biomass	-	-	135	-
Waste Incineration	-	89	-	-
SRH's LCOE	177	173	142	238

III. RESULTS

Figure 1 presents the effect of Gridsol on each system's thermal energy production. It is shown that the highest reduction in the thermal production appears in the system of Madeira (9.9%), in Fuerteventura the thermal production after Gridsol is added is reduced by 7.9%, in Crete Gridsol contributes to a 4.2% thermal production reduction, while in Cyprus, the energy produced by the thermal power plants is reduced by 2.6% when Gridsol has been added in its system.

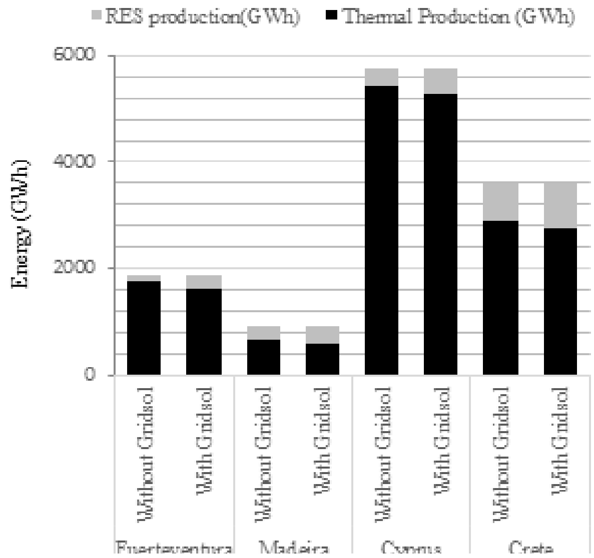

Figure 1. Thermal and RES production with and without Gridsol

The selected SRH configurations had different impact on each island system in terms of economy, environmental protection and security of supply as it is easily noticed in Table IV, although all positive.

TABLE IV. ENERGY AND COST RELATED RESULTS ON THE SELECTED LOCATIONS DUE TO GRIDSOL

	Fuerteventura	***Madeira***	***Cyprus***	***Crete***
Fuel cost reduction (%)	13.36	14.35	1.87	6.46
RES penetration increase (%)	7.4	9.0	2.5	3.4

CO2 emissions reduction (tn)	134,760	53,128	141,814	116,858
NSL with SRH (% of the overall load)	0.10	0.09	0.24	0
System cost reduction (%)	5.39	9.49	0.61	1.51

As presented in Table IV, the fuel cost of each island has been reduced when Gridsol was added. The highest reduction was in Madeira (14.35%) and the lowest in Cyprus (1.87%). Similar reductions were observed in the systems' CO_2 emissions when Gridsol has been added.

Additionally, the effect of Gridsol in terms of the security of supply of each location can be seen through the limited Non Served Load which is observed when it operates on the selected Electrical Systems.

Finally, the total energy cost of each location has been reduced with the addition of Gridsol. As shown in Table IV Fuerteventura's total energy cost has been reduced by 5.39%, when Gridsol is added, whereas Madeira's energy cost has been reduced by approximately 10%. The smallest reduction was presented in Cyprus (0.61%), while the expected reduction in Crete's energy system was found to be around 1.51 %.

IV. Conclusions

The effect of the operation of an SRH in 2030 on four different non interconnected islands, Fuerteventura, Madeira, Cyprus and Crete, has been investigated.

Each of the selected islands have different characteristics, so due to that the addition of a Gridsol plant has affected differently each island.

- Madeira is benefited both financially and environmentally. The total energy cost of Madeira is reduced by 9.49% and there is a great rise of RES penetration of 9% observed.
- Crete's total energy cost is reduced by 1.51% and the RES penetration is increased by 3.4%.
- Fuerteventura's total energy cost is reduced by 5.39% and the there is a 7.4% rise in RES penetration observed.
- Cyprus seems to be less affected by Gridsol's addition with a significant lack of installed power resulting in high non served load, a tiny financial effect and a very small rise in the RES penetration.

Based on the results presented in this paper, the possibility to have a big thermal plant substituted by Gridsol has not arisen. However, since there is an increase of the demand in 2030, the results show that there is not a need for the installation of a new thermal plant because this extra demand is covered by Gridsol. Specifically, as it can be seen in Table IV, the total load of Crete is served by the installed units (thermal and RES) and the Gridsol since there is no NSL.

From the investor's perspective, certain parameters of a Gridsol station are shown in Table V and they can be compared.

TABLE V. Financial results due to the addition of Gridsol in each different location

System	*Annual Revenue (M€)*	*LCOE (€/MWh)*	*Energy Curtailment (% of available energy)*	*Capacity factor (% of nominal energy)*
Fuerteventura	24.3	177	14.28	70.71
Cyprus	20.4	142	14.54	67.75
Crete	28.7	238	2.85	59.7
Madeira	11.9	173	13.7	58.7

Madeira seems to have the lowest Capacity Factor and Annual Revenue, however since Gridsol's LCOE is relatively low, the addition of Gridsol in Madeira's electrical system has a positive effect (great reduction) at the total energy cost of Madeira's system. On the contrary, even if the capacity factor of Gridsol in Crete is similar to the capacity factor of Gridsol in Madeira, much higher compensation is needed due to Gridsol's configuration. Fuerteventura and Cyprus have a very high capacity factor of around 70% despite the significant curtailment (around 14%) resulting in a competitive LCOE.

As a general remark, it is shown that the most of the SRH configurations tested have high energy curtailment values. It is believed that the curtailment of the produced energy by the SRHs can be reduced by increasing the capacity of the BESS or/and introducing Power-to-x (Gas or heat) and X-to-Power options. However, the cost effectiveness of both options should be taken into consideration.

There are several challenges associated with project development in these islands. The most significant challenges are the achievement of social acceptance, the limited space for Gridsol's installation and the ongoing expansion of tourism. It is believed that social acceptance can be achieved since Gridsol reduces the CO2 emissions and the fossil fuel usage, which will benefit the environment. Also Gridsol is expected to enhance the employment ratio in the local societies. Additionally, Gridsol could possibly initiate collaborations with the R&D departments of Universities and Research Centres located on those islands. Even though the islands' limited space might seem an obstacle to future Gridsol installations, the results of our simulations showed that Gridsol plants installation is possible with the prerequisite of smaller configurations tailored to the specific geomorphology of each island.

References

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