FROM FUEL BASED GENERATION TO SMART RENEWABLE GENERATION: PRELIMINARY DESIGN FOR AN ISLANDED SYSTEM. PART II: SELECTION OF FUTURE SCENARIO AND ECONOMICAL ISSUES

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ABSTRACT

The subject addressed in this paper is the analytical study of the transition of the energy generation system for a real MV/LV distribution system from a 'fuel based' one to a distributed and smart 'renewables based' one. The paper outlines the economical issues related to such transition from one type of system to the other and it is the prosecution of a companion work addressing the technical topics concerning this subject. The study is carried out for a real islanded MV/LV distribution network.

INTRODUCTION

As it was underlined during the 2009 Major Economies Forum on Energy and Climate, "*moving to a low-carbon economy provides an opportunity to promote continued economic growth and sustainable development as part of a vigorous response to the danger posed by climate change*" [1]. Thus an urgent need is identified for the development and deployment of clean energy technologies. In this framework, the generation, delivery and usage of electricity represents a key issue and the development of the so-called smart grids has the potential to greatly improve the efficiency of the electricity network, providing for economic and technical values as well as for significant environmental benefits. However, the electricity generation still strongly depends on fossil fuels and the infrastructure used to transmit and deliver electricity to consumers is also relatively inefficient. As a result, electricity accounts for a significant share of the carbon emissions generated by energy consumption.

In this context, the subject addressed in this paper is the analytical study of the transition of the energy generation system from a 'fuel based' one to a distributed and smart 'renewables–based' one. The paper is the prosecution of a companion paper [2], which focuses the technical issues related to such transition for a real distribution system. The chosen test power system is the MV/LV distribution network of the Island of Pantelleria (a little island of the Mediterranean Sea). The study was carried out in different phases. Firstly the test system was studied in details, considering all the electrical and topological features as well as the existing technologies for metering and automation. The second phase was aimed at identifying the local natural energy sources. Finally, the relevant energy transformation systems were suitably sized in order to meet the energy demand. The minimum and maximum sizes of the plants were hypothesized, taking into account the particular features of the system, the geographic location, the environmental constraints, the availability of space and the potential social acceptance. Starting from this, different scenarios were defined for the transition from the fuel based generation to the smart distributed renewable based one. The control system was also designed and the main control functions as well as the telecommunication system were hypothesized considering the relevant features of the installations. For each scenario different simulations in normal working conditions and during outages were carried out. The obtained results were analyzed, putting in evidence the technical and environmental benefits of using smart technologies and renewable energy sources.

In this paper, the economical issues are outlined, which are related to the transition from one type of system to the other. Benefits include environmental issues, incentives and other benefits deriving from the idea that the energy system can be truly integrated over the territory. The costs-benefits analysis is carried out for a specific scenario chosen among the ones proposed in [2]. In the paper, firstly the main features of the test system are recalled and the selected scenario is described for the transition from fuel based generation to smart renewable generation. Secondly the approach for the costs-benefits analysis [3] is described and the obtained results are presented and discussed.

FUTURE SCENARIO TO SMART RENEWABLE GENERATION. THE CASE STUDY.

As detailed in [2], the MV/LV distribution network of the Island of Pantelleria is currently supplied by a diesel power plant, with both electric generators and turbines, whose total installed power is of about 20 MW. The energy demand is of about 44 GWh/year, the 56% of which is during the summer months (because of the tourists influx). The peak of the power demand varies from a minimum value of about 3 MW on January (at about 3:00 am) to a maximum of 7-10 MW on August (at about 9:00 pm).

The renewable sources which can be introduced in the Island of Pantelleria were identified to be the photovoltaic, wind, geothermal, waste and thermal solar plants [2].

Among the possible scenarios, the selected one, which is analyzed in this paper, provides for a covering of the 50% of the energy demand of the Island by means of the following renewables:

– photovoltaic plants, with a total installed power of 0,33 MWp and a potential energy production of 0,51 GWh/year;
– a 2,5 MW geothermal plant, with a potential energy production of 20 GWh/year;
– a 0,365 MW waste plant, with a potential energy production of 1,6 GWh/year;
– thermal solar plants, with a total installed power of 0,53 MWp and a potential energy production of 1,065 GWh/year.

COSTS-BENEFITS ANALYSIS FOR THE SELECTED SCENARIO

For the considered scenario, an economic costs-benefits analysis (CBA) [3] was carried out in order to evaluate the economic impact connected to the transition from the current energy generation system to the aforesaid scenario. The costs and benefits related to the transition from the fuel based generation to smart renewable generation, according to the selected scenario, were identified and evaluated. The analysis was developed as a "project analysis", i.e. taking into account all costs and benefits at large, without considering the subjects (even various) who should face the costs or profit by benefits. This is a simplifying assumption but it is well suited for the aim of the present study, which is to evaluate the overall impact of the smart energy generation, including not only the typical financial elements but also socio-economic aspects such as the environmental and health benefits.

Costs and benefits evaluation

The costs can be synthesized as follows.

C.1 investments for the installation of the power plants;
C.2 investments for the infrastructures needed for the plants connection to the existing electric distribution network;
C.3 investments for the control system;
C.4 extra costs;
C.5 yearly costs for energy production, management and maintenance of the power plants.

The monetary values of the aforesaid costs are synthesised in Table I and II. They were deduced from some market analyses and the technical characteristics of the considered power plants, infrastructures and control system [4-6]. The extra costs C.4 were estimated to be equal to a value of 20% of the investment costs for the geothermal and waste plants and the control system. For the photovoltaic and solar plants, the costs C.2 and C.4 were included in the investments C.1. The yearly costs C.5 for the control system and the solar plants were estimated to be equal to 1,5% and 2,5% of the investment cost C.3, respectively.

Table I Investments Costs (C.1 – C.4)

Costs (thousands of €)	Photo-voltaic	Geo-thermal	Waste	Solar	Control system
C.1	1.320	8.750	1.825	2.625	--
C.2	--	345	105	--	--
C.3	--	--	--	--	350
C.4	--	1.819	386	--	70

Table II Energy production, management and maintenance Costs (C.5)

	Photo-voltaic	Geo-thermal	Waste	Solar	Control system
Energy production (MWh/year)	510	20.000	1.600	--	--
Unitary cost (€/MWh)	80,00	80,00	100,00	--	--
Costs C.5 (thousands of €/year)	40,8	1.600	160	65,6	5,25

As regards the benefits, they can synthesized as follows:

B.1 savings on the reduction of the electricity produced by the existing diesel plant;
B.2 incentives for the energy production by means of renewable sources;
B.3 environmental benefits related to the savings of CO2 and other greenhouses gas emissions and local environmental costs reduction;
B.4 benefits related to different waste management.

The benefits B.1 (see Table III) were evaluated by multiplying the energy production of each renewable source by the price of the fuel needed to produce the electricity with the existing diesel plant. The benefits B.2 (see Table IV) were evaluated by considering the monetary incentives currently offered in Italy [7] for the energy production by means of renewable sources. As regards the benefits B.3, in [8] it was shown how it is possible to find an equivalent CO_2 coefficient to quantify the emissions of each type of power plant. This coefficient considers the emissions related to the energy life-cycle from the construction of the plant, to the mining and processing of the fuel, routine operation of the plant, the disposal of used fuel and other waste and finally the disposal of the plant. As a consequence, it is possible evaluate the CO_2 reduction which derives from the energy production by means of renewable sources instead of fuel-based ones. From an economic point of view, this reduction can be considered as both an externality (environmental benefit) [9] and a financial benefit (emission trading) [10]. The monetary evaluation of environmental benefits was carried out by following the approach of the "ExternE, Externalities of Energy" Research Project of the European Commission [9]. In brief, the ExternE Project is aimed at the quantification of the so called "external costs" of energy, providing a methodology for transforming the impacts of the energy production into monetary values. In accordance with this study, the environmental benefits can be divided into two contributions: benefits on global warming, which are related to the savings on CO_2 emissions; benefits on environmental impacts, caused by releasing either polluting substances (e.g. fine particles, SO_2, NO_X, CO, etc) or energy (noise, radiation, heat) into the air, soil and water. For the first contribution, the ExternE Project proposes to use an avoidance costs approach, which leads to a the central value of 19 €/ton CO_2; this value can be suitably incremented in order to take into account also the second contribution (environmental impacts) [8]. As regards the financial benefits related to the saving on CO_2 emissions, the price of the tradeable CO_2 permits was taken into account, whose value oscillates between 10-20 €/ton of CO_2, depending on various factors, such as climatic conditions, politic decisions, fuels cost etc [10]. By considering both externalities and financial issues, a monetary value of 25 €/ton of CO_2 was considered in this study. The benefits B.3 are outlined in table V. Finally, the benefits B.4 are related to the use of waste for the energy production. They were evaluated by considering the avoided cost for the waste transfer to dump and disposal, which was estimated to be equal to 150 €/ton. This avoided cost was multiplied by the amount of waste to be used for the energy production (about 1.500 tons/year), thus obtaining an economic benefit of 225.000 €/year. Other benefits can be identified concerning the reduction of energy losses and voltage drops at grid level and the advantages related to the implementation of smart control functions (reduction of interruption times, improvement of service quality etc.). These benefits essentially have a technical nature and thus they have not been monetized in this project analysis; this is a pejorative hypothesis for the final results.

Table III Benefits on reduction of electricity produced by the existing diesel plant (B.1)

	Photo-voltaic	Geo-thermal	Waste	Solar
Energy production (MWh/year)	510	20.000	1.600	1.065
Fuel cost (€/MWh)	40,00			
Benefit B.1 (thousands of €/year)	20,4	800	64	42,6

Table IV Incentives for the energy production by means of renewable sources (B.2)

	Photo-voltaic	Geo-thermal	Waste	Solar (*)
Energy production (MWh/year)	510	20.000	1.600	--
Incentives (€/MWh)	422,00	151,00	220,00	--
Benefit B.2 (thousands of €/year)	215	3.020	352	289
Duration of incentives (year)	20	15	15	5

(*) the incentives for the solar plant consist on recovering the 55% of the costs C.1 in 5 years (11% for each year)

Table V Environmental benefits (B.3)

	Photo-voltaic	Geo-thermal	Waste	Solar (*)
Energy production (MWh/year)	510	20.000	1.600	1.065
Coefficient of reduction of CO_2 emissions (kg/MWh)	882	911	885	882
Savings on CO_2 emissions (tons/year)	450	18.200	1.400	940
Monetary value of CO_2 emissions (€/ton)	25,00			
Benefit B.3 (thousands of €/year)	11,25	455	35	23,5

CBA parameters and results

In order to carry out the CBA two basic parameters have to be chosen: the time horizon and the discount rate [3].

The time horizon is the maximum number of years for which forecasts are provided. It takes into account the economically useful life of the project and its likely mid/long term impact. In the case of long-life investments, like those of the case study, the forecasts should take into account also the various phases of construction, usage and disposal of plants. Moreover, in the case study also the incentives fruition periods have to be taken into account, which are different for the various renewable sources. Thus, the time horizon for the CBA was fixed in 20 years, which is the longest incentives fruition period (the one for the photovoltaic plants). With respect to the time horizon the CBA should take into account also the residual value of the investments with a longer life time; this value should be considered among the benefits. For sake of simplicity the residual value of the investments was not considered in the CBA, leading to pejorative final results. Moreover, the CBA was carried out assuming that all the investments are done at the beginning of the first year and considering that all the investment and extra costs (C.1-C.4) totally incur at year zero. This is a simplifying assumption but it is well suited for the case study, as the CBA is mainly aimed to evaluate the maximum potential economic impact deriving from the forecasted scenario. The choice of the discount rate (i.e. the rate at which future values are discounted to the present) was made by taking into account both economic and financial aspects related to the project analysis. As regards the economic issues, a social discount rate should be considered, as the project has an impact on the environment and, as a consequence, on the social welfare [3]. On the other hand, the financial issues should be addressed by taking into account a financial discount rate (opportunity cost of capital), that can be different from the social discount rate [3]. For the present CBA a discount rate of 5,5% was chosen, as it was supposed to be a suitable trade-off between the financial and the social discount rates.The economic tables are defined by the cash flows, which synthesize inflows, outflows and balances for each year (from the initial time 0, i.e. the beginning of the first year of the time horizon to the final time of 20 years). The performance indicator chosen for the CBA analysis are the Net Present Value (NPV), the Internal Rate of Return (IRR) and the Pay Back Period (PBP). The NPV of a project is defined as:

$$NPV(S) = \sum_{t=0}^{n} a_t S_t = \frac{S_0}{(1+i)^0} + \frac{S_0}{(1+i)^1} + \cdots + \frac{S_0}{(1+i)^n}$$

where S_n is the balance of the cash flow at time n, a_t is the financial discount factor chosen for discounting and i is the discount rate (a_t is the coefficient for discounting a future financial value in order to have the actual value). The IRR is the value of i that zeroes out the NPV of the investment. The PBP is the length of time required to recover the costs of the project. The NPV trend over the whole time horizon of the project is represented in figure 1, where also the Pay-Back Period is put in evidence (see the dot line in the figure); the values obtained for performance indicators are reported in Table VI. It can be observed that the NPV is positive and the IRR is high if compared with the chosen discount rate. Moreover, the PBP is very short, thus the costs of the project can be recovered in few years.

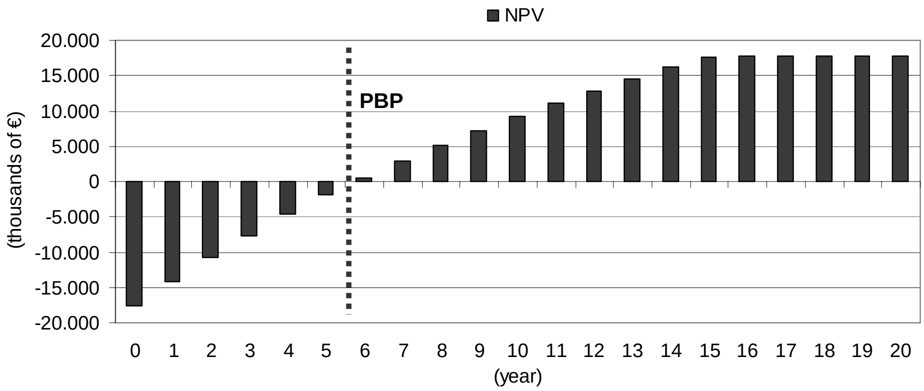

Figure 1 – Net present value trend and Pay-Back Period for the transformation of the energy supply system

Table VI. Performance indicators

Net Present Value NPV (thousands of €)	17.727
Internal Rate of Return, IRR (%)	18,77
Pay-Back Period, PBP (years)	5,5

CONCLUSIONS

In this paper an analytical study has been presented, concerning the transition of the energy generation system for a real MV/LV distribution system from a 'fuel based' one to a distributed and smart 'renewables based' one. The attention was focused on the economical issues related to such transition. An economic costs-benefits analysis was carried out for a specific scenario of transition, which was studied in a companion paper from a technical point of view. The analysis included not only the traditional financial aspects but also environmental issues, incentives and other benefits deriving from the idea that the energy system can be truly integrated over the territory. The results of the analysis are positive, demonstrating that the deployment of smart and clean energy technologies represent not only a big opportunity for the sustainable development but also a cost-effective investment.

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