The role of RES and desalination plants. A case study

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***Abstract*—The world climate situation shows remarkable changes from the past. Many regions are affected by rising average temperatures and reduced rainfall. Scientific research is studying when process very carefully. From the analysis of meteorological data, it can be said that the process has begun, and some solution must be found as soon as possible. Renewable energy sources can find their role in producing energy that can power desalination plants. The article analyzes a feasibility of realizing a desalination plant installed in southern Italy powered by wind power. In this way, desalinated water can be produced to feed reservoirs that are being drained and meanwhile allocate some of the renewable energy in case the power grid is saturated.**

Keywords— RES, desalination plant, water scarcity, climate change

I. Introduction

Climate change is putting a strain on water supplies in many countries [1]. Southern Italy is experiencing a negative trend in annual rainfall amounts that is now very dangerous [2], [3]. Data from regional weather stations installed in Sicily, southern Italy, show that there has been a sharp decrease in rainfall over the years. Using 108 weather stations scattered throughout the region, this trend just described could be seen. Figure 1 shows the site and distribution of weather stations across the region [4].

Fig. 1. SIAS weather stations in Sicily

By extrapolating data provided by the stations of the "Sicilian agrometeorological information service" (SIAS, in Italian) it was possible to verify data for the last 20 years of rainfall falling in Sicily, see Figure 2 [4].

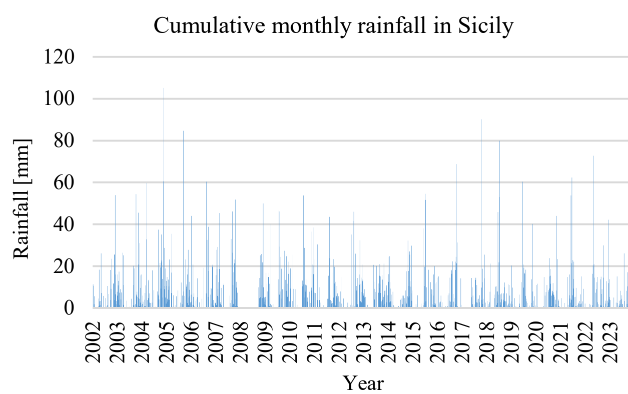

Fig. 2. Cumulative monthly rainfall in Sicily in the last two decades

This climatic situation led the engineering department of the University of Palermo to carry out studies on desalination plants powered by renewable energy [5], [6]. Seawater treatment plants are identical to traditional seawater treatment plants [7], the only difference being that they use a renewable energy source such as wind, solar, or wave power plants [8], [9]. Energy saving and the use of renewable energy are now indispensable [10], [11].

All sectors must make the most of the possibility of reducing primary energy consumption and producing waste [12] that will not be recycled [13]. European and world governments reward countries that aim to develop sustainable activities [14]. The research of the University of Palermo fits into this by trying to study possible solutions in all sectors [15], [16]. Desalination systems are essentially composed by four steps [17]:

- Water withdrawal section from the sea by pumps.
- Pre-treatment section required to eliminate aspirated substances and components not needed for treatment.

- Water desalination section.
- Post treatment section necessary to make the water usable, e.g. adjust conductivity, PH etc.

In literature several desalination technologies are listed, the following Figure 3 shows the main classification.

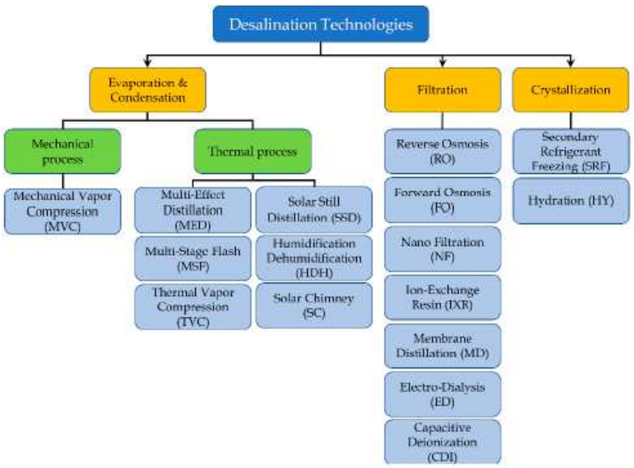

Fig. 3. Working principal classification for desalination plants

This paper will address the issue of water poverty in low rainfall areas by studying the possibility of electrically powering a desalination plant from renewable sources [18]. A case study will be studied by estimating the production of electricity from one of the renewable sources such as solar, wind, or wave in order to produce freshwater [19], [20].

A system consisting of renewable energy plant feeding a desalination plant can provide several services [21], [22]. The primary one is to produce freshwater and reduce water scarcity in sensitive areas of the world. A secondary service is that it could serve as energy storage to balance power grid regulation in small islands, instead the use of chemical batteries [23]. When grid inertia goes down one could split the production of renewables to feed the desalination plant [24].

The case study will focus commercially desalination plant and renewable sources with the aim to quantify the freshwater production and the electrical energy saving related to RES exploitation [25], [26]. The electrical energy production could be carried out by a Wind turbine installed in Mazara del Vallo, in the western part of Sicily (see Figure 4).

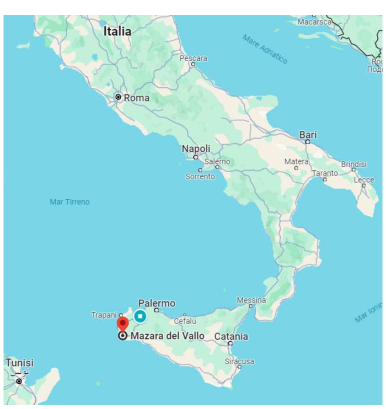

Fig. 4. Wind Power site, Mazara del Vallo

II. The Case Study

A wind turbine is designed to capture the kinetic energy possessed by the wind and transform it into electrical energy by passing through the stage of conversion to mechanical energy of blade rotation. Its structure is as follows:

- A support tower made of metal material.
- Nacelle content speed increaser, electric generator, transformer, braking system and control system.
- Rotor, consisting of the hub and the blades.

Each type of wind turbine has an operation characterized by precise speed values [27], [28]; the blades start moving when the wind reaches the minimum starting speed, the so-called cut-in speed. Cut-in thresholds vary according to size; in fact, wind speeds of 2-4 m/s are sufficient for small wind turbines. As the wind speed increases, there corresponds a gradual increase in the power output of the machine, until the rated speed (10-14 m/s) is reached, at which the generator reaches its rated power. Above a certain speed, called the cut-off speed (about 20-25 m/s), which is the maximum threshold tolerated by the machine, the generator stops producing power and becomes safe, resorting to protection systems in order to avoid damage to mechanical parts [29].

The power that can be extracted from a wind turbine depends on several factors, including wind speed, the area swept by the turbine blades, and the power factor, and can be calculated using the following equation 1

$$P = \frac{1}{2}\rho A v^3 C_p \qquad (1)$$

Where:

- P is the net power collected by blades [W]
- ρ is the air density [kg/m^3]
- A is the area swept by the blades [m^2]
- v is the wind speed [m/s]
- C_p is the power coefficient, which represents the aerodynamic efficiency of the turbine. The theoretical maximum value of C_p is 16/27≈0.5926, known as the Betz limit.

This case study involves the producibility study of a 15 MW wind turbine in one year. Then it is assumed that a desalination plant will be installed to be fed. The technical parameters of the turbine and desalination plant are given in Table I and II.

TABLE I. Wind Turbine Technical Data

Parameter	*Value*
Rated power	15 MW
Rotor diameter	236 m
Number of blades	3
Supply voltage	66 kV

TABLE II. DESALINATION PLANT TECHNICAL DATA

Hourly production	*Daily production*	*Required power*
10,000 lt/h	240,000 lt/day	55 kW

Using the power curve of a turbine of this size, the producibility of the site was initially estimated. Wind data for the area were collected using the Sicilian Agrometeorological Information Service network. After obtaining wind speed data from the stations for a sufficiently long period of time (at least one year to capture seasonal variations), the probability density function (PDF) can be created, and the annual energy production calculated. Before proceeding, however, a consideration must be made regarding the anemometer data that are available for an altitude of 2 m or 10 m. The wind generator is installed at higher elevations, it is necessary to correct the database used through one between the Logarithmic Law and the Power Law. From the anemometer data, wind speeds are divided into classes (bins) with regular intervals, each bin expressing the number of times a certain speed was observed. For each velocity class, one counts the number of events that fall into that class, then normalizes the event counts by dividing each count by the total number of measurements. At this point, then, we obtain the Probability Density Function (PDF), which is the relative frequency for each speed class [30]. The following Figure 5 show the PDF analysis.

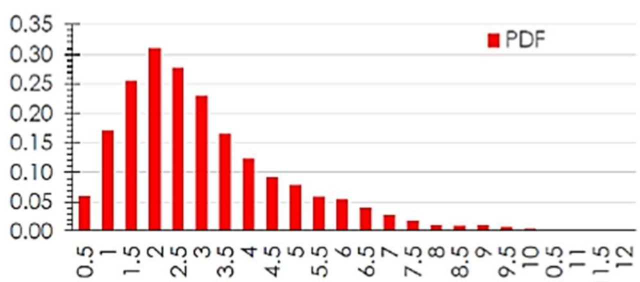

Fig. 5. PDF analysis

Cumulating the latter the Cumulative Probability Density Function (CDF) can be calculated, see Figure 6.

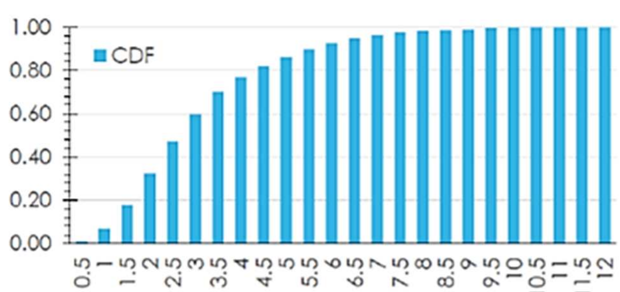

Fig. 6. CDF analysis

In studies of probability distributions, there are several distribution functions, and the one that is best suited in the anemometer study is the Weibull probability distribution function, which is used to model the variability of wind speed at a given site, allowing an estimate of energy producibility to be made.

The PDF formula of the Weibull distribution is given in equation 2:

$$f_{wb}(v) = \frac{k}{\gamma}\left(\frac{v}{\gamma}\right)^{k-1} e^{-\left(\frac{v}{\gamma}\right)^{k}} \quad (2)$$

The CDF formula of the Weibull distribution is given in equation 3.

$$f_{wb}(v) = 1 - e^{-\left(\frac{v}{\gamma}\right)^{k}} \quad (3)$$

Where:

- v is wind speed.
- k is the shape factor, a dimensionless parameter that takes on a value between 1 and 3 in the anemometer range.
- λ is the scale factor, which has the same measure as the velocity.

The next step is to calculate the average annual power by integrating the product of the PDF and the turbine power curve. The estimated annual producibility expected from a 15 MW wind turbine is shown in Figure 7.

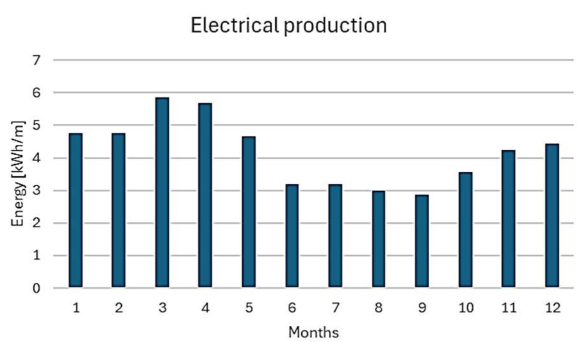

Fig. 7. Annual electrical producibility

Having completed the study phase on wind power generation, the boundary conditions can be analysed.

In Sicily during the year, wind production can be interrupted because the grid is saturated and cannot accept any more input. This means that the distributor will have to pay an economic penalty to the producer who cannot sell energy.

To solve this problem, it is possible to store this surplus energy in accumulations of various kinds. Storage is understood to be either classical electrochemical cells, electrolyser power, or desalination plant power. This article considered powering desalinators because, as described in the introduction, water scarcity in southern Italy is a great problem. Considering a large production of electricity from renewables, it would be more convenient to be able to power a desalinator like the one shown in Table II [31]. A reverse osmosis plant works by powering a pump that acts on water extracted from the sea and sends it to a semipermeable membrane. At the outlet, desalinated water and brine will be obtained [32]. The desalination plant is composed by the following components:

- Control box.
- Flowmeters.
- Reverse osmosis membrane.
- High pressure pump.
- Filters

The figure 8 shows diagram flow of this devices [5].

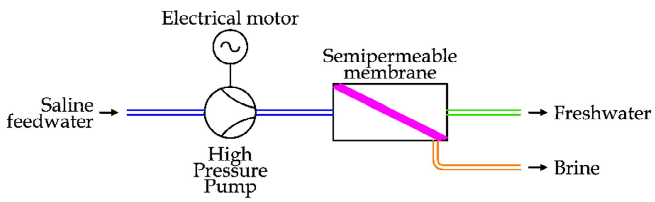

Fig. 8. Reverse osmosis desalination plant flow diagram

Considering the size chosen and if it works for 7,000 hours/year, 70,000 cubic meters of water could be stored per year.

III. Conclusion

The paper showed initial experimental research on the possibility of producing wind energy and storing part of it in ancillary services. The electricity grid can suffer in certain cases of the year due to excessive electricity production and low temporary demand. Energy storage by powering a desalination plant can help the electricity grid and above all try to address water scarcity. In this study, the energy consumption linked to pumping stations that would raise the water produced in the suffering basins was not analyzed. This energy contribution would further help electricity consumption at times when the grid requires it. Future developments could affect the conditions of the basins in Sicily and understand how much water they would need. After the estimate you could think about feeding them with desalinated water. The contribution of the lack of production will be analyzed and the energy flows from the electricity grid will be balanced.

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