SIMENERG: THE DESIGN OF AUTONOMOUS SYSTEMS

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ABSTRACT

This work describes a methodology and a software tool-kit (SimEnerg) for the design of autonomous electricity systems. A criterion for comparing autonomous against grid connected systems is given, based on the annual energy deficit of the system with a given confidence. As an example, a map for choose the best technology with given power demand and the geographical position in Uruguay is shown. The modeling of the wind velocity and the solar radiation as a stochastic sources are described.

INTRODUCTION.

This work is a result of a study made by the Renewable Energy Group of the Engineering Faculty of Uruguay for the Uruguayan utility UTE.
The main target of the study was the analysis of the available technologies that can be an alternative solution for the electrification of potential consumers placed far away from the national electrical grid. Thus, for different levels of demands the cost of the system based on solar and wind energies must be computed and compared with the cost of powering up the consumer with a connection (using low cost rural line) from the electrical network.

THE SIMENERG SOFTWARE TOOL

Simenerg (R. Chaer et al., 1993) is a set of software tools specially designed to be a help for the evaluation and the design of autonomous electricity systems.
Having a system to study, Simenerg allows easy building of an efficient simulator for it. The service quality and others' aspects of the system can be evaluated by simulating many years of its life. Also, by leaving free some of the design parameters and choosing a cost function one can carry out an optimization on the unconstrained parameters, to minimize the cost function guaranteeing a giving energy availability of the system with a given confidence.
Simenerg is an open set of tools, so once the user has understood its general philosophy, he can modify and add more refined tools without limit.
Basically, the simulators that can been created using Simenerg are energy dispatchers that use a criterion based on offer and demand of energy packets with prices. The energy packets transactions are decided over a time step base.

A SERVICE QUALITY INDEX.

Bearing in mind the purpose of comparing the different technologies as candidates for energy supply a given demand, it is necessary to define a Service Quality Index (SQI). Thus the cost of the different implementations, having the same SQI, can be properly compared.

The supply's security of any electric system is measured evaluating the magnitude and the frequency of energy cuts in a period of time, usually one year.

This is not an easy task in a renewable energy based system due to high aleatory component in its instantaneous values. This situation makes it necessary to use statistic techniques.

One of the alternative technologies is the connection to the electrical network using a Earth Return System (ERS). These kind of lines are currently in use and then its SQI can be measured. The utility statistics data about fault and restoring rates for these rural lines shows that with a confidence of 90% the energy not supplied is less than the equivalent of 7 days of black-out.

An equivalent day of black-out is defined as the mean value of the daily demand.

The SQI is then defined as the numbers of equivalent black-out days that can be expected for the system with a confidence equal to 90%.

Using this criterion the design of the systems was forced to have a SQI of 7 days in order to make possible the comparison with the ERS.

The SQI is measured for a given design by simulating many years (i.e. 200) of the system behavior, computing for each year the amount of not supplied energy expressed in days of black-out and making a histogram with these values. The resulting SQI is the value with 90% confidence in the histogram.

MAP OF THE BEST TECHNOLOGY FOR URUGUAY.

Using the defined SQI, different designs was proposed for different levels of the consumer demand.
The evaluation of the systems was made over a twenty years period, using a five percent discount rate and a SQI of 7 equivalent blackout days.

Demand model

The used demand model was a constant profile one expressed in Wh/day. This model is very draft, but works for the purpose of a first broad evaluation of the different technologies.

Photovoltaic systems

The number of PV panels and battery capacity for each demand level was computed by simulations carrying out an optimization in order to minimize the cost of the system and constrained to have the established value for the SQI.

Table 1 shows the results of the optimized designs. As you can observe the cost is quasi linear dependent with the demand level.

Table 1. Optimal designs of PV-panels based systems.

Demand Wh/day	batteries AH	panels 48Wp modules	cost U$S
100	100	1	1160
200	150	2	2090
300	200	3	3020
400	250	3	3250
500	350	4	4410
600	400	5	5340
700	450	6	6270
800	550	7	7430

Hybrid systems

These kind of systems were assembled with PV panels, a wind generator and the corresponding battery bank.
Due to the discrete values of the rated power of the available wind generators, the number of PV panels and the battery capacity for each demand level were computed, using the same kind of optimization that the previously described, for each of the available wind generator models.
These computations was made for winds with a annual mean value of 5.6m/s (South of the country) and a annual mean value of 3.3m/s (North of the country). At any place in Uruguay, the undistorted wind speed has an annual mean value between these two values. For a given geographical point the local topography affect the undistorted wind speed. For example placing the wind generator on the top of a hill, an increase in the wind speed will be obtained. For the purpose of a first evaluation it was considered that the annual mean value of the undistorted wind speed is a good first-indication.

Earth return systems (ERS)

The connection to the electrical network at the level of 15kV was considered using a economic ERS design. The use of an economic line is possible due to the low levels of the considered demands.
This kind of lines are build of galvanized wire (steel-iron,17/15), with wood posts separately 200m, resulting in an cost of 1100 U$S/km.
The cost of the ERS was computed from the consumer view point. That is the line energy losses and the cost of it maintenance were excluded because in Uruguay they are assumed by the utility. The cost of the consumed enegy, in the evaluation period, was also included.

Figure 1 shows the economic evaluation results. There are two kind of curves, the two labeled “se.3.3” and “se.5.6” are the result for the most economic renewable systems at a place with annual mean wind speed of 3.3m/s an 5.6m/s respectively. The other curves,the parallel ones, are the cost of the ERS line for different values of “kilometers by user” (that is the number of line kilometer that each user must pay).

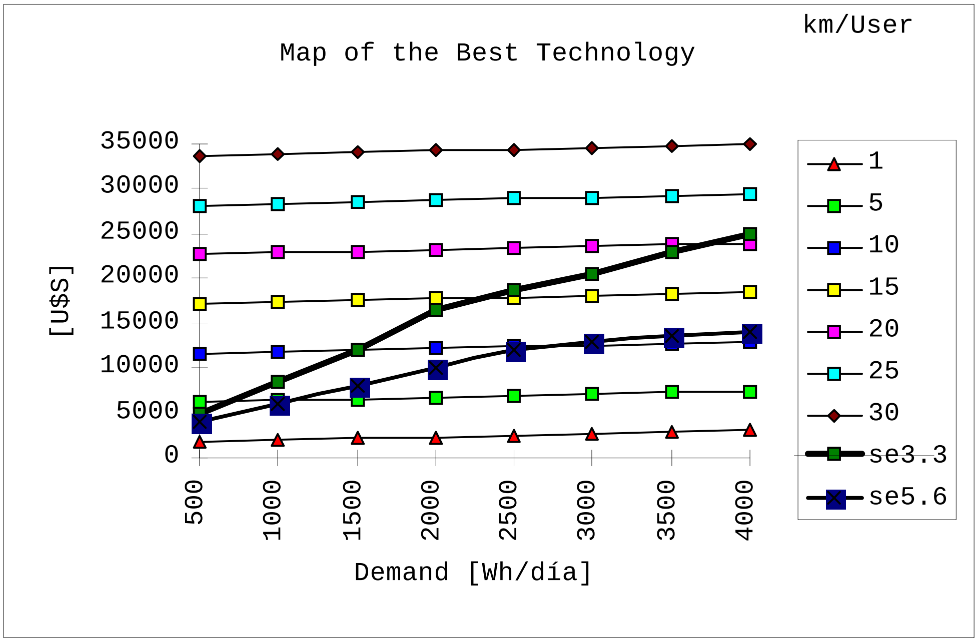

Fig. 1. Map of the best technology

For example, for a place with low wind speed (3.3 m/s) and a network distance of 15km for only one user, the renewable system are the more economics for a demand level less than 2200Wh/day. On the other hand, for a place with a wind speed greater than 5.6m/s the renewable solution is the best one in the range of the studied demand levels.

MODELING THE RENEWABLE RESOURCES.

The SQI (and any measure of a design) is a random variable due to the intrinsic random behavior of solar radiation, wind speed and the power demand. To get significant results, histograms of the variables must be built. In order to get rich statistic measurements, synthetics series of the wind speed and solar radiation was used. A method to build these series having the same statistic behavior that the historical data is described in the following . The descriptions are brief (due to the lack of room) but precise.

Wind speed.

Using the available Historical Data (HD) for a given place, an identification process is used building a model with which synthetics series can be generated. First,a bar diagram of the spectral density of the HD is computed. The bars which are very high compared with the average of the values of the nearest ones are separated because they show a periodic deterministic behavior. Then the original signal is splitted into the Deterministic Signal (DS) an the Noise Signal (NS). To model the NS, a distortion function (DF)that transform the NS in a Gaussian Noise (GN)is first computed. This GN is modeled catching the past dependence in a linear Digital Filter (DF). The input of the DF is a Gaussian White Noise (GWN) random source. An output of a linear system is Gaussian when the input is also Gaussian. These model (GNW+DF) synthesizes new series of GN that, using the inverse transform of DF, are mapped on series of synthetics NS with the same histogram function that the original NS. The complete identification process is shown in figure 2 while the synthesizing process is shown in fig. 3.

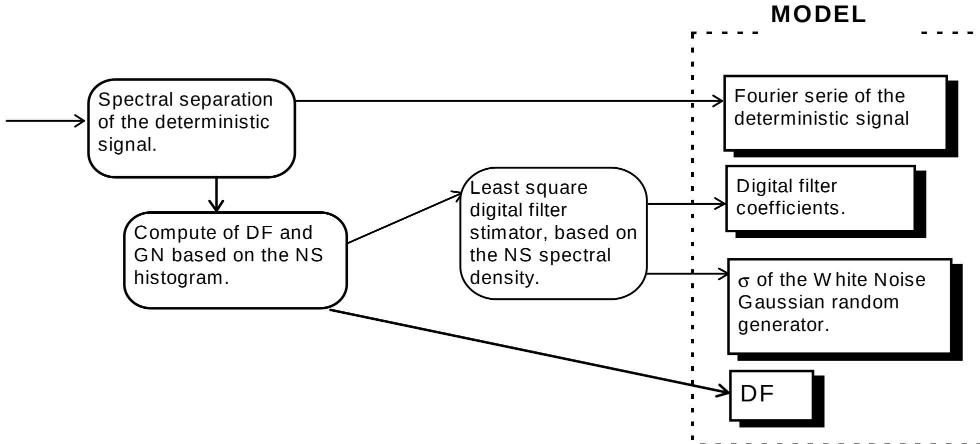

Fig. 2 identification process.

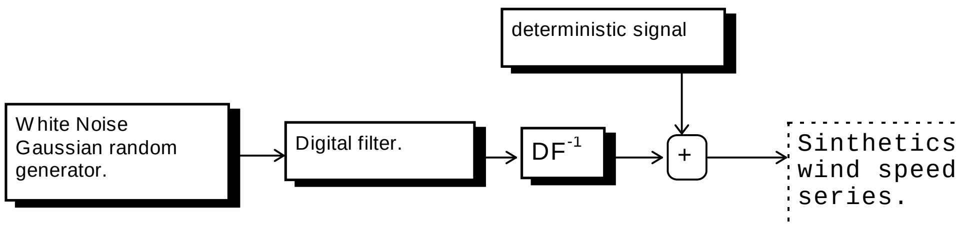

Fig. 3 The synthesizer operation.

Solar Radiation.

The data available of solar radiation in Uruguay is a series (8 years) of daily global radiation at a geographical point called "La Estanzuela" and the mean value of the same parameter for each month at 18 meteorological stations distributed over the country. First, a series synthesizer for daily radiation at "La Estanzuela" was built. Then, using a mapping function constructed with the monthly mean value information, multipliers are used to place the synthesized signal at the desired geographical position. With the daily global radiation at the true place, a separation by hour and in direct and diffuse components is made using optionally the criterion of Lui-Jordan, HDKR or Perez. The model used for the synthesizer consists of the solar radiation (out of the atmosphere) multiplied by a noise. A series of noise is computed from the original data (8 years). This series is connected as a ring from which the synthesizer choose values using the following criterion: take three consecutive values and jump to a new random position on the ring.

CONCLUSIONS

SimEnerg has proven to be an useful tool when studying renewable energy autonomous systems. Once the "best technology map" is computed, a technical solution for the actual energy suppy problem can be chosen. If an autonomous system is the recommended choice, SimEnerg can be employed to carry out a more detailed design.

Looking the map for Uruguay, we can conclude that an autonomous system became a more expensive solution than grid connecting throw ERS for most of the potential electricity consumers with a Km/user value less than 15, because they are placed at low wind speed areas.

REFERENCES.

Chaer, R., Zeballos, R., Uturbey, W., and Casaravilla, G. (1993)., "SIMENERG: A novel tool for designing autonomous electricity systems", 1Proceedings of the ECWEC 93, pp. 330-333.