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ANALYSIS OF A PILOT MEXICAN HYBRID GENERATION PLANT

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ABSTRACT
This contribution details the operation of a pilot hybrid (wind-photovoltaic) plant of generation, installed to supply of electrical energy to a local community located in San Juanico, Baja California Sur, Mexico. The characteristics of the installed hybrid system are described. The voltage profile provided by the hybrid plant of generation is analyzed.

KEY WORDS
Pilot hybrid plant, wind, photovoltaic, voltage profile.

1. Introduction

During the design of the renewable hybrid systems it is necessary to keep in mind diverse social, cultural, economic aspects and mainly the care of the environment. Undoubtedly, mankind fears the extinction of conventional fossil sources of energy, *e.g.* petroleum, natural gas and coal. With the present rate of consumption, it is very likely to expect that the fossil fuel reserves will last for only a few more years [1,2]. Renewable sources of energy have emerged as an attractive alternative to conventional sources since are limitless, environment friendly and do not contribute with gasses emission to the world warming-up effect [3,4]. They a natural resource found in different forms in nature, *e.g.* wind, sun light, organic matter, water, geothermic energy, among others, which can be potentially used by the human being to produce electrical energy [4]. The San Juanico generation plant described in the paper mainly operates with wind-photovoltaic sources of renewable energy, abundant in the region. Details on the construction and operation analysis of the San Juanico hybrid plant are given in the following sections.

2. Description of the pilot hybrid plant of generation

The 167 KW San Juanico Hybrid Power plant is located in the Comundú region of Baja California Sur, México, to supply electrical energy to a small fishermen village of about 400 people. Figure 1 illustrates the location of the San Juanico hybrid plant, built-up with financial contribution given by power supply enterprises such as the Arizona Public Service, Niagara Mohawk and the Comisión Federal de Electricidad (CFE), respectively, as well as independent institutions of the United States of America and of the Baja California Sur government, in México.

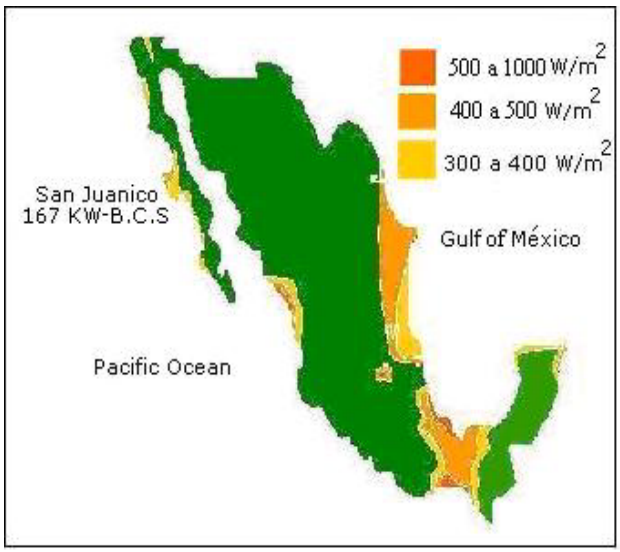

Fig 1. Location the hybrid wind-photovoltaic pilot plant[5].

For the simulation of the hybrid system data, provided by CFE Center-West Division were used [5].This refers to time series of wind speed, sun insolation, temperature and loads. The data available from CFE are basically,

- Time series of wind speed
- Time series of sun radiation
- Time series of weather temperature
- Loads

Data provided by CFE are from may to december 1999, when the hybrid plant started operation. Some technical data of equipment installed in the hybrid plant are

confidential and were not available. The system was analyzed with the HYBRID2 digital simulation package [6].

San Juanico has an estimated 50 KW power demand, including public lighting. Figure 2 illustrates the plant schematic diagram and Figure 3 the single-phase diagram. Details of the main equipment for the hybrid plant are given in Appendix A.

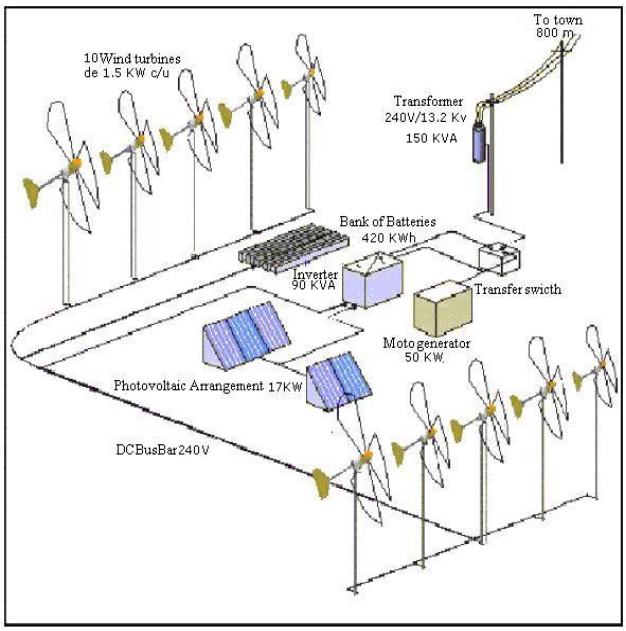

Fig 2. Schematic diagram of the San Juanico Hybrid Plant [5].

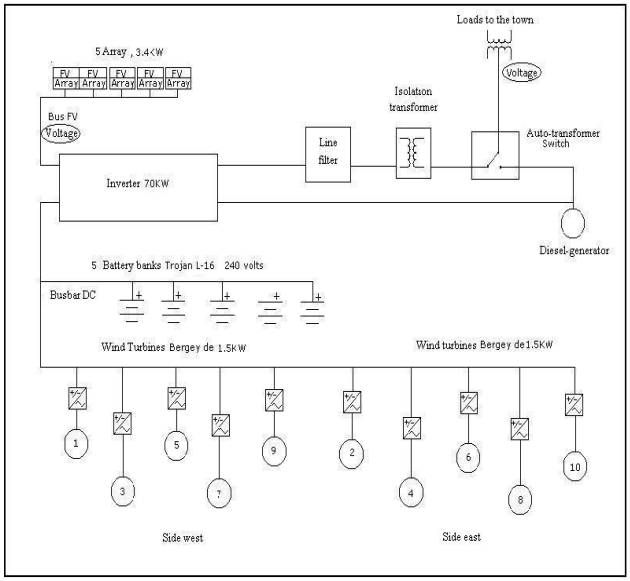

Fig 3. Single-phase diagram of the San Juanico Hybrid Plant [5].

3. Representation with Hybrid2

The San Juanico hybrid plant was represented with the HYBRID2 digital simulator [6,7]. This simulator allows the user to analyze different configurations, an economic assessment when the location and load conditions are known, besides of analyzing strategies for the appropriate system operation. It requires input data of wind and sun resources, practical details of wind turbines, photovoltaic shells, bank of batteries, connected loads ant weather temperature. In the Figure 4 the configuration of a conventional hybrid system is illustrated.

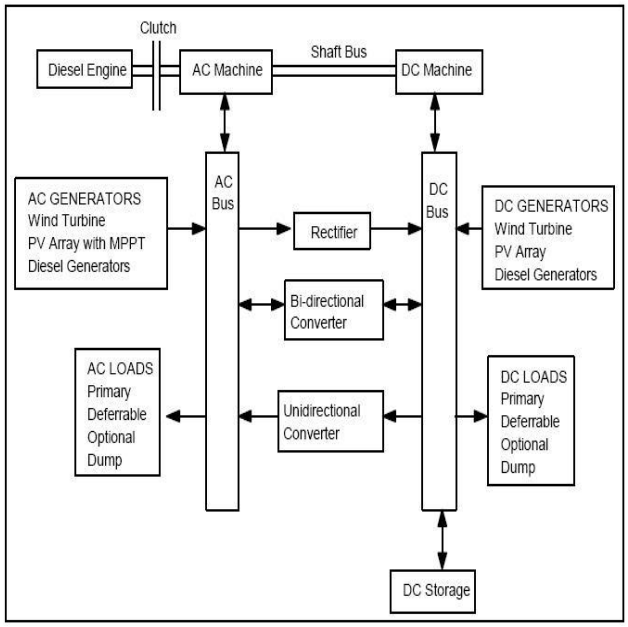

Fig 4. Configuration of a hybrid power system [6].

The main output variable of the wind turbine model during the simulation is the average turbine power and the standard deviation of the wind turbine power. The output variable is on the base of the busbar.

The photovoltaic shell requires four basic parameters to define the simulation unified conditions: 1) a light current, 2) a diode inverse saturation current, 3) a series resistance and 4) a parameter fitting curve. The generation power, current and voltage are obtained from the photovoltaic model at each integration step. The Figure 5 illustrates the photovoltaic panel equivalent circuit [8].

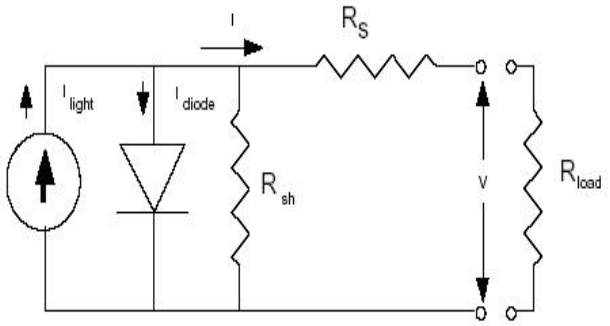

Fig 5. Equivalent circuit of the photovoltaic panel.

4. Results

Figure 6 illustrates the average *voltage profile* for May 1999. The maximum registered voltage was *225.984 volts* on May 30 and the minimum was *206.185 volts* on May 1st. It is important to note that for plotting the data obtained from the simulation in HYBRID2 a daily average voltage was used. This is because the output file shows the results for the twenty four hours per day. During this period of time the incoming sun radiation on the photovoltaic shells tends to be significant. In general for an specific day the sun radiation is not the same for each hour. The photovoltaicshells contributed with *1350 KWh,* whereas the wind source with *5209 KWh* for the analyzed period of time.

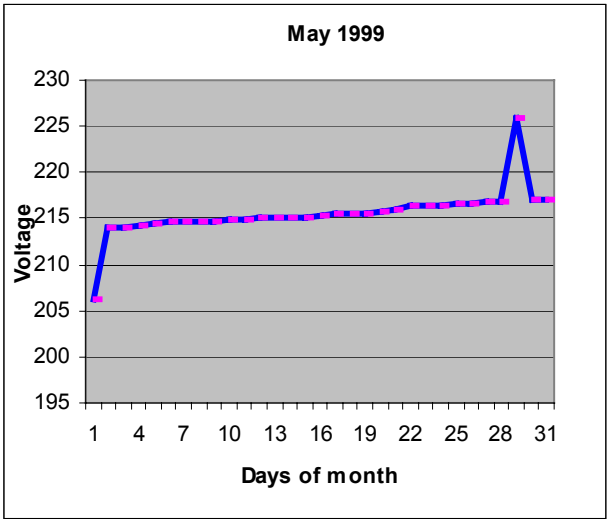

Fig 6. Voltage profile, May 1999.

Figure 7 illustrates the *voltage profile* for July 1999. During this period of time the, voltage profile reached a maximum value of *219.224 volts* and a minimum of *219.204 volts*. Starting from the second week of the month, the voltage was oscillating until it reached a steady state of *219.224 volts*. These small voltage variations took place for approximately one week; during the fourth week the voltage remained practically constant. It is important to mention that the voltage depends mainly on several factors such as sun radiation, wind speed, the temperature and the load connected. Therefore voltage fluctuations existed during the different days of the month. For this case the wind was the more significant contributing resource for the energy generation, with *2601.4 KWh*; the photovoltaic resource contributed with *1663.2 KWh.*

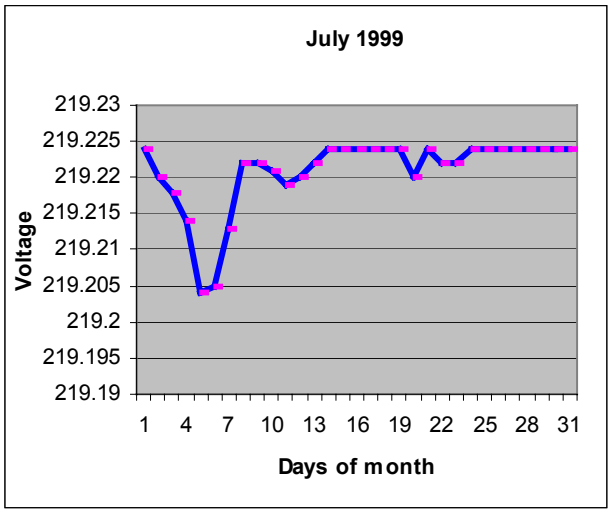

Fig 7. Voltage profile, July 1999.

Figure 8 illustrates the *voltage profile* for December 1999. During this period of time slight variations during the first three weeks took place in the *voltage profile*, with a maximum of *219.224 volts* and a minimum of *219.208 volts*. For the fourth week a more stable behavior was observed. The voltage profile was mainly affected by the weather temperature, around $4.57\,^{\circ}C$ during this month. The wind turbine contribution was *1771.7 KWh* and the photovoltaic shells contributed with *1612.8 KWh*.

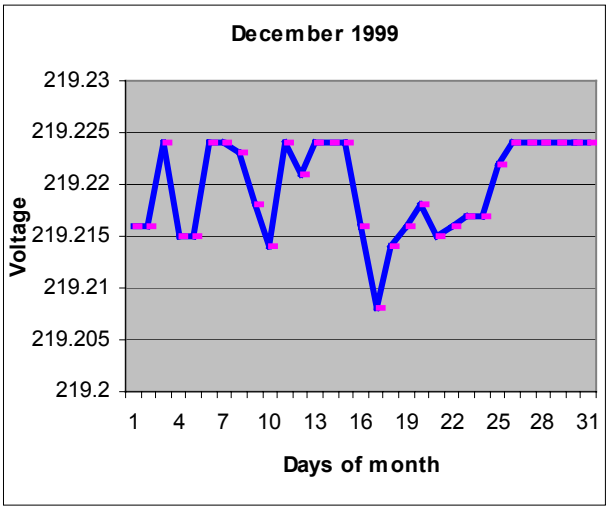

Fig 8. Voltage profile, December 1999.

5. Conclusion

This contribution has analyzed the steady state operation of the San Juanico hybrid wind-photovoltaic plant, using the HYBRID2 digital simulator.

The observed behaviour of the obtained voltages at the San Juanico hybrid plant showed slight variations, mainly due to the variation of the sun radiation in the photovoltaic shells, the wind speed and the connected loads during the months under study.

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Appendix Data of the main hybrid plant equipment

Wind Generators

Ten 1.5 KW, 240 V wind generators with three-blade rotor (7m diameter), mounted on a 30m tower.

Photovoltaic Modules

Sixty 285Wp modules, 50.5 V, 5.9 A DC peak and 60 V, 6.5 A DC in open circuit, type ASE-300-DGF/50.

Diesel Generator

One 50 KW, 100 KVA, 240 V, 3-phases, 60 HZ Cummins Onan diesel generator.

Inverter

One 70 KW,90 KVA, 135 KVA in five seconds. Trace inverter 240V+2 %, 3-phase, 3 wires, 60 Hz, 450V DC bus voltage bi-directional three-phase bridge. Includes a 112.5 KVA, 240/240 V isolating transformer.

Batteries

Five battery banks of deep cycle, 60 V, Trojan type L16PF, 350 Ah capacity, with an eight hours discharge period.

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