Simulation of ARMAX model for Forecast of Power Output of a Photo-Voltaic Grid

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***Abstract*—This work is devoted to the simulation of an ARMAX model proposed in the literature for better forecasting of power output of a Photo-Voltaic (PV) grid; the model includes information of environmental inputs (average temperature, precipitation amount, insolation duration, humidity) that classical time series approaches did not include. The simulation is performed using three different noise distributions in order to establish a comparison of the time series.**

***Index Terms*—ARMAX, Photo-Voltaic grid, simulation, random noise, outliers, environmental inputs, time series.**

I. Introduction

Photo-Voltaic (PV) systems, nowadays, are growing relevant due to the increasing obligation to global warming and production of renewable energies. It is often desired to forecast the amount energy that can be obtained through these systems, in order plan its distribution and usage.

II. Problem Formulation

As previously mentioned, the output of the PV system is an stochastic process. The standard approach to forecasting the behavior of this system has been modelled using ARIMA models, using only information of the past of the same system, but it does not take into consideration the external environmental factors that may affect the power output [1]; as for the problem of this particular work, the main objective is to simulate the ARMAX model proposed in [1] with different noise distributions, particularly with outlier behavior and show that it is not always adequate to assume normality of some random processes.

III. Theoretical Approach

A. General ARMAX model

This work uses an ARMAX model presented in the literature; hereby, let the general ARMAX model be presented:

$$z_{t+1} = \sum_{i=0}^{h_1} a_i z_{t-i} + \sum_{i=1}^{m} \sum_{j=0}^{h_2} b_{ij} u_{i,t-j} + \sum_{i=0}^{h_3} c_i \xi_{t-i} \tag{1}$$

for $t = 0, 1, 2, \ldots$; $u_{l,k}$ are external inputs (type l and lag k), and ξ_k are random noises of lag k.

B. Rössler System

The Rössler system is a set of ordinary differential equations:

$$\begin{cases} \dot{x} = -y - z \\ \dot{y} = x + ay \\ \dot{z} = b + z(x - c). \end{cases} \tag{2}$$

These equations originally proposed by O. Rössler in [2]; it is well-known that, under certain parameters, the output of the state variable z presents peaks in a aperiodic (stochastic) manner [3]. This model is used to emulate the behavior of one of the inputs for the ARMAX model, since it presents quite an unusual behavior and this method gives a decent representation.

C. Normal Distribution

Let ξ be a random variable. We say $\xi \sim N(\mu, \sigma)$ if the probability density function (PDF) is given by

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} \tag{3}$$

with mean μ and standard deviation σ.

D. Cauchy Distribution

Let ξ be a random variable. We say that ξ has a Cauchy distribution if the PDF is given by

$$f(x) = \frac{1}{\pi\gamma} \left[\frac{\gamma^2}{\left(x - x_0\right)^2 + \gamma^2} \right] \tag{4}$$

with location parameter x_0 and scale γ.

E. Student's t-Distribution

Let ξ be a random variable. We say $\xi \sim t_\nu$ if the PDF is given by

$$f(x) = \frac{\Gamma\left(\frac{\nu+1}{2}\right)}{\sqrt{\nu\pi}\,\Gamma\left(\frac{\nu}{2}\right)} \left(1 + \frac{x^2}{\nu}\right)^{-\frac{\nu+1}{2}} \tag{5}$$

with ν degrees of freedom.

IV. Numerical Aspects

A. ARMAX Model

In this particular case, the model obtained in [1] is:

$$z_t = 237.565 + 0.426 z_{t-1} + \xi_t - 0.153\xi_{t-1} + 8.9087 u_{1,t} - 1.557 u_{7,t} + 31.919 u_{8,t} - 2.045 u_{9,t} \tag{6}$$

where z_t is the power output of the PV grid in Watts (W); $u_{1,t}$ is the daily average temperature, $u_{7,t}$ is the precipitation amount, $u_{8,t}$ is the insolation duration and $u_{9,t}$ is the humidity.

B. Input values

For the inputs, it was used several historical data to simulate their values. In this manner, $u_{1,t}$, $u_{8,t}$ and $u_{9,t}$ was simulated using normal distributions with values for (μ, σ) of $(28.81, 1.10)$, $(8.95, 3.40)$ and $(73.14, 6.99)$ respectively. On the other hand, $u_{7,t}$ was simulated using three times the z value for a simulation of a Rössler circuit. It was simulated using the Runge-Kutta's method with a step of 0.01 to a time of 182 with parameters $(a, b, c) = (0.29, 0.14, 4.52)$ and initial conditions of $(x_0, y_0, z_0) = (0.72, 1.28, 0.21)$, the output was sampled every $1s$.

C. Noise values

The noise was simulated using different distributions:

1) A Normal distribution, with $\mu = 0$ and $\sigma = 1$
2) A Student t-distribution, with $\nu = 0.7$
3) A Cauchy distribution, with $x_0 = 0$ and $\gamma = 2$

This distributions were used to contrast the normal distribution, as they generate outliers.

V. Numerical Results

In the following figures, the simulations of the model for different distributions can be found.

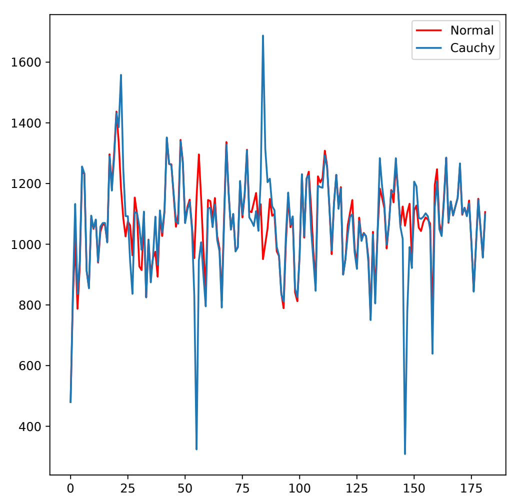

Figure 1: Results using Normal and Cauchy distribution.

It is important to notice, that for Figs 1, 2 the time series has unusual behavior as it has some random spikes. This is due to the nature of the distributions used, as they generate outliers.

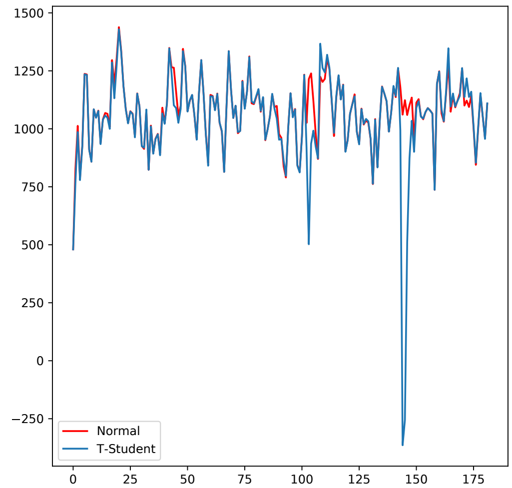

Figure 2: Results using Normal and T-Student distribution.

On the other hand, it is seen that for every simulation the normal distribution and the other one have a similar pattern for most of the time simulated. In this manner, these distributions do not change drastically the behavior of the time series.

Furthermore, the simulations in this work gave a higher value that the one presented in [1]. This is an unexpected behavior and raises the question of which simulation is correct. This could be explained for this work, as it was not know the noise values that the original paper used.

VI. Conclusions

In this article, an ARMAX model was successfully simulated. Furthermore, it was seen the impact that different distributions for the stochastic noise can have in the behavior of a time series. At the same time, it is important to remark the importance of historical data to make comparisons as the model in this paper did not have similar values to the one in [1]. This probably occurred because the values for the noise that the original paper used are not specified.

References

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