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Journal of Systematic Innovation

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Support the international scientific community in its written production Science, Technology and Innovation in the Field of Engineering and Technology, in Subdisciplines of electromagnetism, electrical distribution, sources innovation in electrical, engineering signal, amplification electrical, motor design science, materials in electrical power, plants management and distribution of electrical energies.

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The works must be unpublished and refer to topics of electromagnetism, electrical distribution, sources innovation in electrical, engineering signal, amplification electrical, motor design science, materials in electrical power, plants management and distribution of electrical energies and other topics related to Engineering and Technology.

Presentation of the content

In the first article we present, *Validation of solar irradiation forecasting from a numerical weather predictor model and weather stations observational data on three regions of Sonora-Mexico* by NIEVES-MONARREZ, Gustavo Alejandro, SOSA-TINOCO, Ian Mateo, RUIZ-IBARRA, Erica Cecilia and ROBLES-MURUA, Agustín, with adscription in the Instituto Tecnológico de Sonora, in the next article we present, *Comparison of detectors and distance metrics for pose estimation* by MARTÍNEZ-DÍAZ, Saúl, with adscription in the Instituto Tecnológico de La Paz, in the next article we present, *Dehydration: An efficient process for ensuring food conservation in vulnerable regions* by GONZÁLEZ-ROSAS, Angelina, ORTEGA-MARIN, Blanca Andrea, GONZÁLEZ-ISLAS, Juan Carlos and GODÍNEZ-GARRIDO, Gildardo, with adscription in the Universidad Tecnológica de Tulancingo, in the last article we present, *Experimental analysis to identify colored noises in electrical systems* by HERNÁNDEZ-SANTIAGO, Joaquín, ALEJANDRO-CRISANTOS, Carlos, ESCOBEDO-TRUJILLO, Beatris Adriana, GARRIDO-MELÉNDEZ, Javier, with adscription in the Universidad Veracruzana.

Content

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Validation of solar irradiation forecasting from a numerical weather predictor model and weather stations observational data on three regions of Sonora-Mexico

Validación de la predicción de la irradiación solar a partir de un modelo numérico de predicción meteorológica y datos observacionales de estaciones meteorológicas en tres regiones de Sonora-México

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Abstract

Lately continuous usage of fossil fuels has become a significant problem due to environmental pollution coming from the usage of these energy sources. Therefore, this has caught attention around the world, looking to stop getting a worse environmental situation. One energy source that has become popular in the last few years is solar energy which can effectively be utilized as renewable and clean energy. However, reliable is a big problem for this kind of energy due to high intermittency by solar radiation. On this paper, we aim to analyze three regions from Sonora in Mexico to evaluate how good is our numerical weather predictor (WRF-Solar) to forecast solar radiation for a year on semi-arid regions and valley-like region. We used WRF-Solar and weather stations observational data to contrast and evaluate accuracy from our model. This looks to help to get a better focus on solar radiation forecasting on northwestern region in Mexico due to high capability to produce solar photovoltaic energy.

Solar energy, Energy forecasting, Energy resource, Renewable energies

Resumen

Últimamente, el uso continuo de combustibles fósiles se ha convertido en un problema importante debido a la contaminación ambiental proveniente del uso de estas fuentes de energía. Por ello, esto ha llamado la atención en todo el mundo, buscando que deje de empeorar la situación ambiental. Una fuente de energía que se ha vuelto popular en los últimos años es la energía solar, que puede utilizarse efectivamente como energía limpia y renovable. Sin embargo, la confiabilidad es un gran problema para este tipo de energía debido a la alta intermitencia de la radiación solar. En este artículo, nuestro objetivo es analizar tres regiones de Sonora en México para evaluar qué tan bueno es nuestro predictor meteorológico numérico (WRF-Solar) para pronosticar la radiación solar durante un año en regiones semiáridas y regiones tipo valle. Utilizamos datos de observación de estaciones meteorológicas y WRF-Solar para contrastar y evaluar la precisión de nuestro modelo. Esto busca ayudar a enfocar mejor el pronóstico de radiación solar en la región noroeste de México debido a la alta capacidad para producir energía solar fotovoltaica.

Energía solar, Predicción de energía, Fuente de energía, Energías renovables

Citation: NIEVES-MONARREZ, Gustavo Alejandro, SOSA-TINOCO, Ian Mateo, RUIZ-IBARRA, Erica Cecilia and ROBLES-MURUA, Agustín. Validation of solar irradiation forecasting from a numerical weather predictor model and weather stations observational data on three regions of Sonora-Mexico. Journal of Systematic Innovation. 2022. 6-19: 1-10

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I. Introduction

On the last few years, renewable energy integration on power systems has gained a lot of interest due to climate changes effects and the necessity to reduce CO2 emissions from usage of fossil fuels. However, most of the renewable energies that have been developed has some major problems considering how uncertain and intermittent they are. For example, solar energy depends on many parameters as cloudiness, dust, location, etc. (Alrashidi, Alrashidi, & Rahman, 2021; Agbulut, 2021).

In this case, solar energy continues to be one of the most resourceful ways to produce energy, but as mentioned before intermittency can be unreliable for continuous production. Given the high demand on this kind of technology to integrate to the traditional power grid, prediction or forecast has become one of the most important keys to a transition from traditional to a smart grid environment, where uncertainty is as low as possible and let electricity suppliers to adapt and distribute energy with quality and assurance (Cannizzaro, *et al.*, 2021).

As a remainder, several countries (Patsalides, Makrides, Stavrou, & Georghiou, 2016) around the world are finding challenging to allow residential customers to install photovoltaic systems due to impacts on the network capacity, this derived for possible effects on the network as noise, unbalanced lines, electrical values changes, etc.

As claimed by (Ochoa, 2021), several barriers must be removed to allow new energy sources penetration on the traditional network, as well distribution companies should increase photovoltaic hosting capacity for low and medium voltage networks for a better understand on how intermittent energies can behave on a robust network. On Mexico, solar photovoltaic systems have become a trend along the whole country, which has helped to reduce costs on these systems and help to increase the diversification of our electrical network. According to the last United Nations Framework Convention on Climate Change (COP27), Mexico has compromised to reduce on a 35% pollution gas emissions and double renewable energies production by 2030, which at 2021 was around 26.8 GW installed capacity.

That being the case, renewable energies as photovoltaic and wind will have a huge increase on capacity (CULLELL, 2022). Hence, the northwestern region of Mexico, according to IRENA (International Renewable Energy Agency for its acronym in English), has values of irradiation that can go up to 7 to 8 kWh/m2d, which becomes a very attractive region for energy production coming from solar technologies (Agency, 2018; J. A. Rosas-Flores, 2019). On this paper we will show the progress on a doctoral project focused on solar radiation prediction on the northwestern region of Mexico by the name of "Simulation of the availability, generation and distribution of electricity with photovoltaic systems in northwestern Mexico".

As main purpose of this research is to corroborate how our model ensemble for forecasting works using observational data from weather stations and how accurate it is.

This paper is divided in five chapters, starting by chapter one were introduction and objectives are shown.

Chapter two where literature review and antecedents according to our theme have been worked.

Chapter three where materials and methodology that emphasize on our numerical model for radiation forecasting and resource maps.

Chapter four where our results show a one year analysis for Sonora region for solar radiation through a three zones (North, Center and South) and a comparative to database from several weather stations.

Chapter five consists on our conclusion on how our system work and how we evaluate it considering a forecast prediction skill score considering data obtained

II. Literature review

Solar radiation forecasting has taken interest on diverse places around the world especially in countries which have transitioned into a more diversified energy network. A few authors have tried to increase accuracy on forecast methods using multiple procedures as data-based forecast, artificial intelligent, machine learning, etc. Some of this authors are our base to apply some of these methods to get a better forecast.

According to (Lara-Fanego, Ruiz-Arias, Pozo-Vazquez, Santos-Alamillos, & Tovar-Pescador, 2012) an evaluation was done for a three days ahead forecast focusing on variables as global horizontal irradiance (GHI) and direct normal irradiance (DNI) for Andalusia, Spain. On this evaluation, values as MBE (median bias error) and RMSE (root median square error) were used to compare how accurate WRF can be in opposition to a trivial persistence model.

It showed that both errors have high dependence on sky conditions (presumably on cloudy conditions and overcast) and season of the year. Values for MBE on GHI and DNI show that from a clear sky to an overcast situation can go from 10% up to 75% and RMSE from 10% to 50% respectively.

On (Sosa-Tinoco, *et al.*, 2016) a methodology to generate a high resolution global solar irradiance assessment was done on south Sonora, using WRF downscaling as a validation on the output and observation taken from different weather stations on this region. It is shown that WRF it's less accurate when an annual simulation is run, this can be concluded from values taken for RMSE in consideration of observable data which responds as values around 6.4% up to 9.91%.

Considering that each time a forecast is made up, there are several factors that has to be considered to make it valid, (Blaga, *et al.*, 2019) demonstrated that in literature there was a tendency to avoid reporting model performance assessment in places or on time horizons, where was known that each model might be suspicious of low performance.

Therefore, a complete research on each method of modeling as persistence, classical statistic, machine learning, cloud motion tracking, numerical weather prediction and hybrid models. For that, the usage of normalized values for MBE and RMSE were taken in consideration as a standard value for performance on forecast models, additionally, this study, mentioned that hybrid models tend to have the best performance among all others in any climate and place.

Values on accuracy and capacity of each forecast ensemble might be ambiguous depending on how each author manages parameters and comparison with observable data, however, (Yang, et al., 2020) managed to standardize a new concept for accuracy on solar forecast considering quality, value and consistency called Skill Score, which is based on uncertainty and variability considering factors as RMSE on clear sky persistence index. On contrast with any other actual development on enhancing accuracy and updates which WRF have taken, (Yang, *et al.*, 2021) examined an extension on WRF specialized on solar radiation forecast by name of WRF-Solar, this was done by using a tangent linear model (TLM) to analyze individual input variables and initial conditions and achieve knowledge on uncertainty values in outputs values. Therefore, this study indicated that 14 input variables can be highly sensitive to uncertainty and this method by TLM usage can identify physical modules on WRF-Solar that can be stochastically perturbed and modify ensemble based on probabilistic.

Most recently, a study considering input variables as sunlight hours and a model study using Angstromm-Prescott and polynomial regression to quantify solar radiation in a semi-desert region as Ciudad Juarez, Mexico was done, according to (Mejia, *et al.*, 2022) they obtained values for RMSE up to 91.36 W/m2, as stated by them this kind of model for solar radiation quantification can be applied to almost any semi-arid region with extreme weather changes.

III. Materials and methods

3.1 Geographical selection

As stated on previous chapters, our objective is to focus on the northwestern region of Mexico, which is known as a geographic place with high irradiation values along the whole year; this region consists on the following states Sinaloa, Sonora, Baja California and Baja California Sur. Therefore, on this paper we chose to start with Sonora as our first geographical location to work with, which can be compared to (Sosa Tinoco, 2015) as which is stated as an analysis on the southern part of Sonora for solar resource. For this study, Sonora was selected due to weather and agro-weather station density, alongside typical climatological characteristics.

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This state considers 72 municipalities, for this was decided to divide by three major zones (Southern, Northern and Centre) where most of the population it's concentrated.

3.2 Observational data

Sonora has at least two weather station network, Automated Weather Station Network of Sonora (REMAS for its acronym in Spanish) (SIAFESON, 2021) and National Institute for Forest and Agricultural Research (INIFAP for its acronym in Spanish) (Remotos, 2022). These networks offers several weather stations historical data as well as real time data including solar radiation, temperature, wind speed, precipitation, humidity, etc. on a time set given of 10 min. Therefore 34 weather stations were selected from 116 allocated all over Sonora state, this is due to highly concentrated on agricultural places and help to verify each region taken in consideration on our simulation, these were divided by 6 for the northern, 11 for the center and 17 for the southern part of Sonora, all of them taken from Automated Weather Station Network of Sonora.

3.3 Typical meteorogical year

According to (Sosa Tinoco, 2015), there are several methods to reduce stress on computational cost when using WRF-model, though a typical meteorological year consisting of at the minimum six days per month for 2021 got selected for this case of study considering mean global horizontal irradiation for each month and season, as well this allows us to analyze a complete region instead of a certain location by one-by-one weather station. However, other authors may consider a typical meteorological year for more days and more years of data, this study only considered one year to reproduce values and correct our numerical weather prediction model.

3.4 Model and set up

In this study, Weather Research Forecast (WRF) model v4.3.3 was used along with WRF Pre-Processing System v4.3.1. Our model run on a local server provided by Instituto Tecnologico de Sonora considering that we didn't take in consideration the very first six hours of each day, due to WRF needs time to prepare and stabilize. Domain and physics set up are described as below.

3.5 Domain set up

As stated before, we chose three different zones on the most populated places of Sonora. For each of these zones three domains were selected being 9 x 9 km, 3 x 3 km and 1 x 1 km of resolution by a grid of 100 x 100 points for these three places which are shown on figure 3 to 5.

Figure 1 Weather station selected on North Sonora

Figure 2 Weather station selected on Center and South Sonora

3.6 Physics schemes

Our physics schemes were taken from (Sosa-Tinoco, Prosper, & Miguez-Macho, 2022), which allowed us to activate WRF-Solar scheme for a better solar energy applications forecast, this specific configuration improves solar tracking algorithm for deviation associated with Earth's orbit, moreover, it represent direct normal irradiance and diffuse irradiance components on account for radiation parametrization.

As it reduces errors in simulation of clear sky irradiances and surface irradiance biases in all sky conditions (Jimenez, *et al*., 2016). On table 1, physics schemes to activate WRF-Solar, as well as simulation parameters, are shown.

Simulation parameters	
Simulation period	Three days per month (36 days total)
Model version	WRF-Solar 4.3.3
Domains	3
Horizontal resolution	9, 3 and 1 km
Time step	30 s
Physics scheme	
Cumulus Parameterization	Kain-Fritsch scheme (Kain, 2004)
Longwave radiation physics	RRTMG Longwave (Iacono, *et al*., 2008)
Shortwave radiation physics	RRTMG Shortwave (Iacono, *et al*., 2008)
Planetary boundary layer	MYNN 2.5 level TKE (Nakanishi & Niino, 2006)
Surface layer option	MYNN Monin-Obukhov (Nakanish, 2001)
Land-surface physics	Noah-MP land-surface model (Tewari., *et al*., 2004)
Microphysics	Thompson aerosol-aware (Morrison., Thompson, & Tatarskii, 2009)
Fast All-sky Radiation Model (FARMS)	Activated (Xie, Sengupta, & Dudhia, 2016)

Table 1 Set up parameters

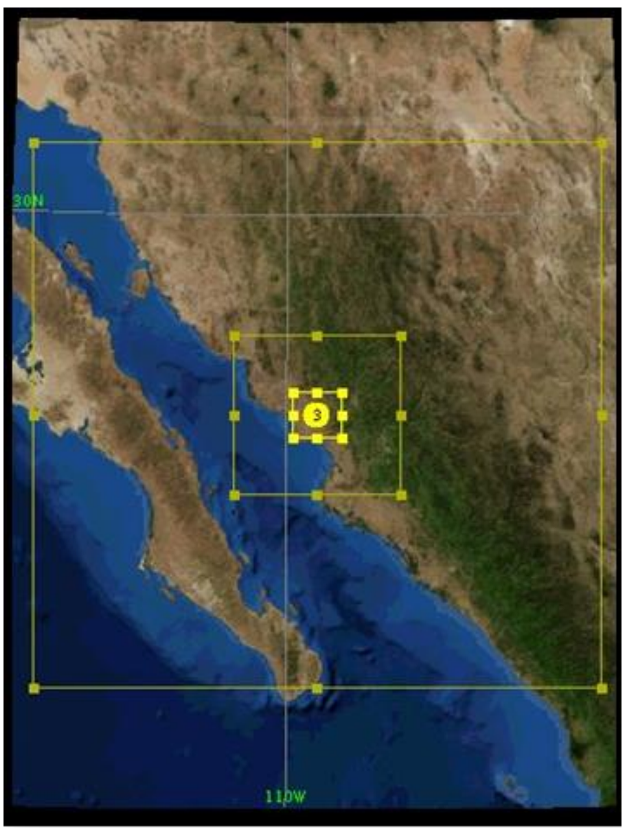

Figure 3 South zone domains

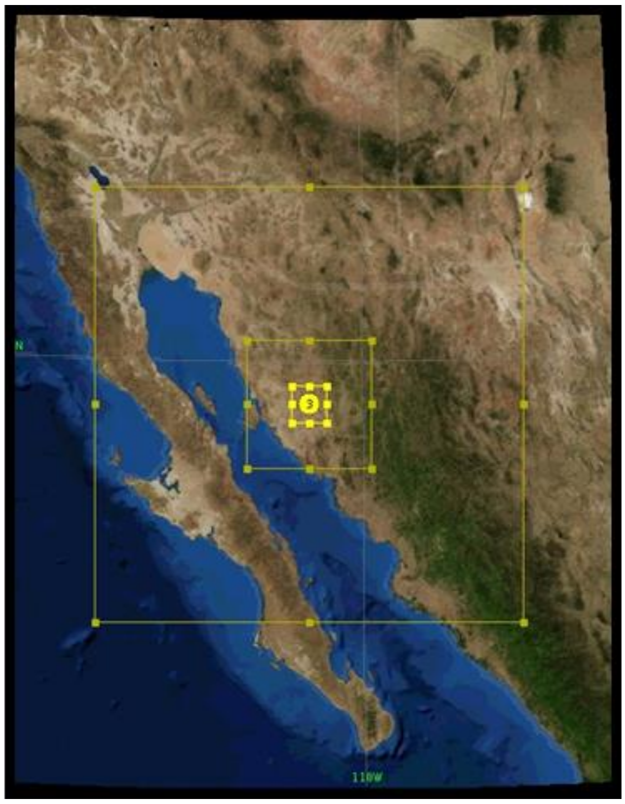

Figure 4 Center zone domains

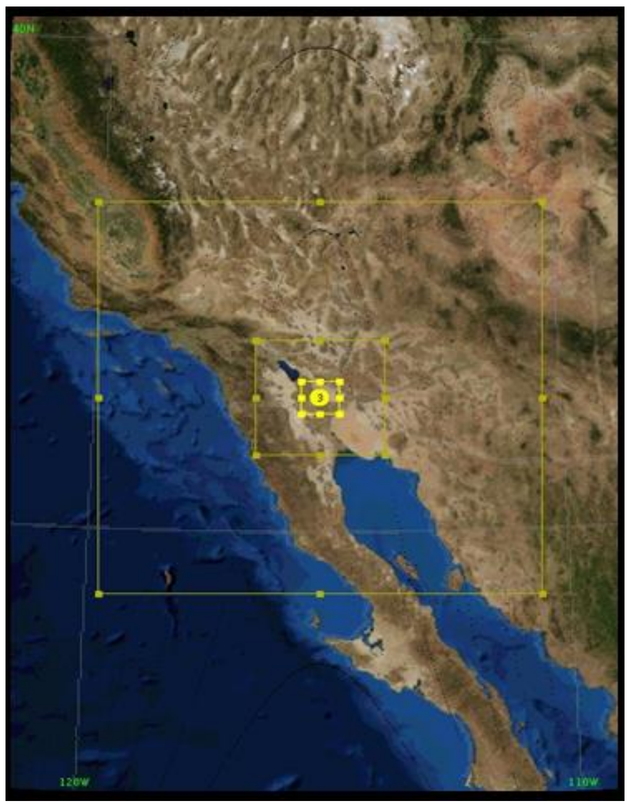

Figure 5 North zone domains

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IV. Results and discussions

4.1 Validation metrics

As said on previous chapter, we evaluated for a representative year model by using a standard of three representative days per month to compare data coming from our forecasting tool and weather stations. These days were selected with weather conditions as cloudy, overcast, sunny days, etc. These are shown on table 2.

Days selected for analysis (YYYY-MM-DD)	
2021-1-3	2021-7-2
2021-1-16	2021-7-12
2021-1-19	2021-7-25
2021-2-10	2021-8-18
2021-2-20	2021-8-23
2021-2-24	2021-8-27
2021-3-8	2021-9-7
2021-3-15	2021-9-18
2021-3-28	2021-9-27
2021-4-1	2021-10-1
2021-4-14	2021-10-11
2021-4-23	2021-10-27
2021-5-1	2021-11-3
2021-5-5	2021-11-7
2021-5-28	2021-11-25
2021-6-16	2021-12-1
2021-6-21	2021-12-9
2021-6-23	2021-12-19

Table 1 Days used for analysis

Therefore, observational data taken from REMAS weather stations were used with exact same days on 10-minute data frame.

4.2 Model results

4.2.1. North region

For our north region (San Luis Rio Colorado), results show that this region is less likely to have changes or weather conditions that can affect along the year. As this region shows high values for solar irradiation especially on spring and summer seasons (from April to September). However, root mean square error (RMSE) shows a lower value on Autumn and Winter seasons, around RMSE=100 and 104 W/m^2 respectively, despite these seasons can have lots of cloudy days, on contrast for Spring and Summer, around 162 and 152 W/m^2 respectively. This can be explained by weather effects on this region on certain seasons as Monsoon.

Therefore, our model shows a highly reduce on accuracy considering certain days can be difficult to simulate due to cloud, dust and other factors that can affect radiation. Results are shown on seasonal values every three months on figures 6 to 9.

As saw on figure 6 to 9, days that have several cloud weather can be pretty hard to analyze for WRF-Solar using only the scheme configuration we used, as well, some values might not look like our observational data can relate directly to values from WRF-Solar, however, if we analyze each under the curve value for each day, they can relate with a low error between them, as shown our RMSE for every season are not more than 150 W/m^2.

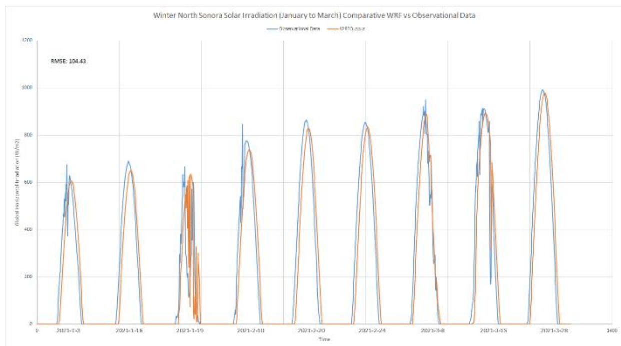

Figure 1 Winter North Sonora Comparative WRF vs Observation

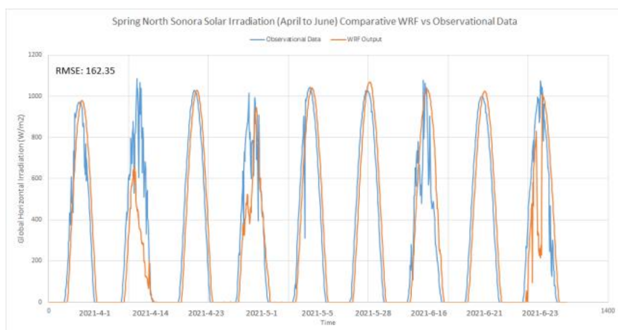

Figure 2 Spring North Sonora Comparative WRF vs Observation

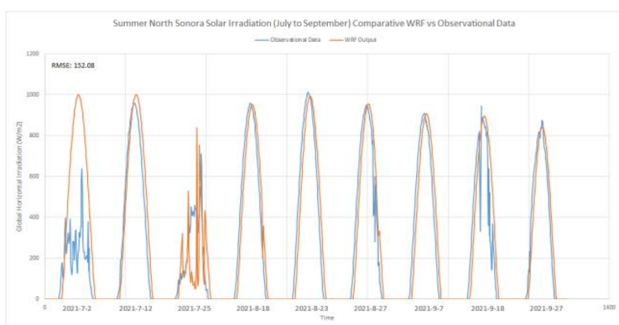

Figure 3 Summer North Sonora Comparative WRF vs Observation

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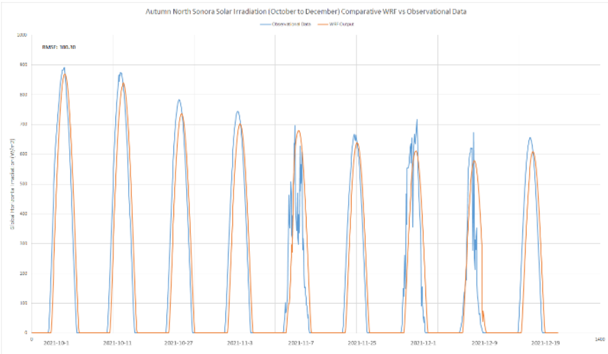

Figure 4 Autumn North Sonora Comparative WRF vs Observation

The dispersion plot in figure 10, show the comparison between forecast and observation values for the whole year on the northern region. The R^2 is high for this case, with a greater density of data close to the trendline, between 70% and 100%, meaning that the model is performing well on most days with clear sky conditions.

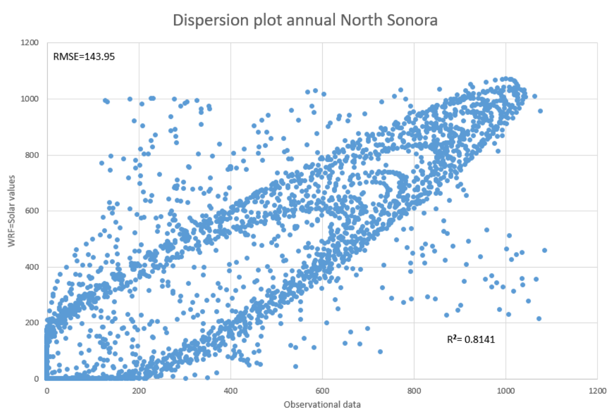

Figure 5 Dispersion plot North Sonora

4.2.2 Center region

Center region or Hermosillo it's known by being a high heat place and lots of sunny days on these region, however lots of variability is shown on seasons that are supposed to be the highest irradiation. Results are shown on figures from 11 to 14, where are possible to observe several days affected by cloudiness specially on summer, although, autumn which is supposed to be a season with high quantities of rain and/or cloudy days show the lowest variability from WRF-Solar values and observational data from weather stations, only with an RMSE value of 107.65 W/m^2.

As well, our dispersion plot, on figure 15, for this region shows a high correlation between observational data and WRF-Solar values as R^2 it's around value of 80%, which means a high efficiency on our model working for this region.

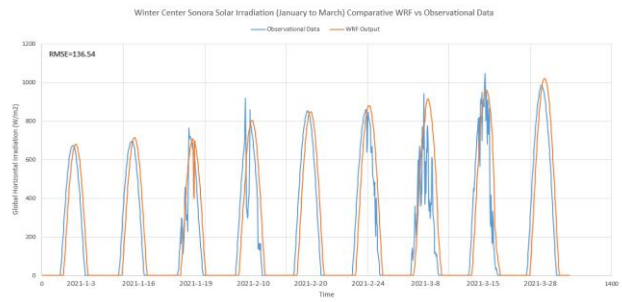

Figure 6 Winter Center Sonora Comparative WRF vs Observation

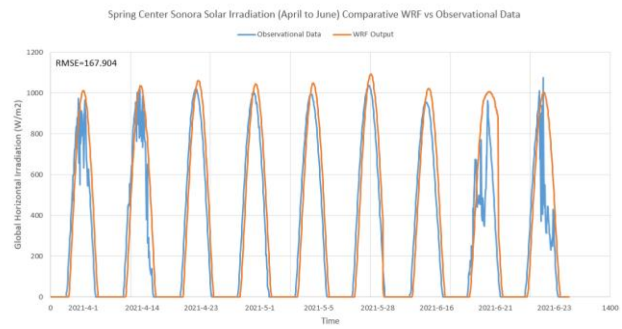

Figure 7 Spring Center Sonora Comparative WRF vs Observation

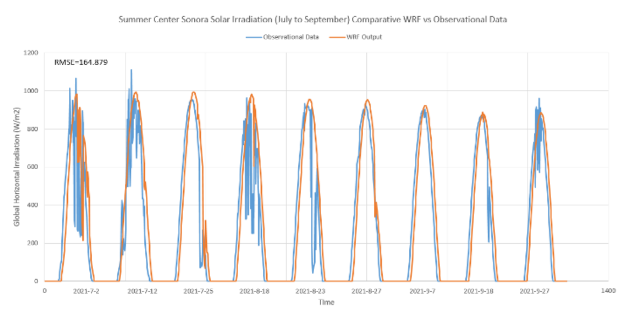

Figure 8 Summer Center Sonora Comparative WRF vs Observation

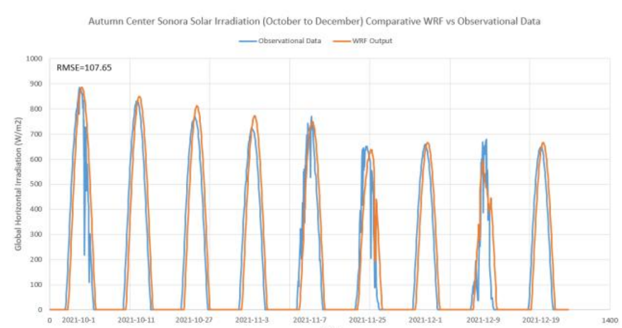

Figure 9 Autumn Center Sonora Comparative WRF vs Observation

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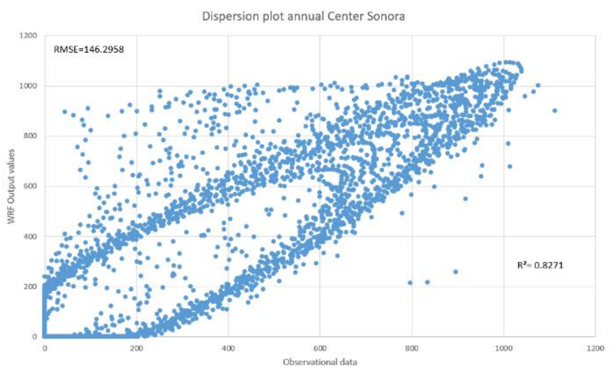

Figure 10 Dispersion plot Center Sonora

4.2.3 South region

Finally, our southern region in Sonora it's one of the most affected by weather conditions along the whole year due to its valley surface. Results are shown on figures from 16 to 19. We can see that our worst season would be summer due to high variability along the whole season, again, this is capable to be due to weather phenomena as Monsoon effect on this region, it reports values of RMSE as high as 160.874 W/m^2 and then again our best season for our forecast would be autumn with the lowest RMSE value of 99.01 W/m^2.

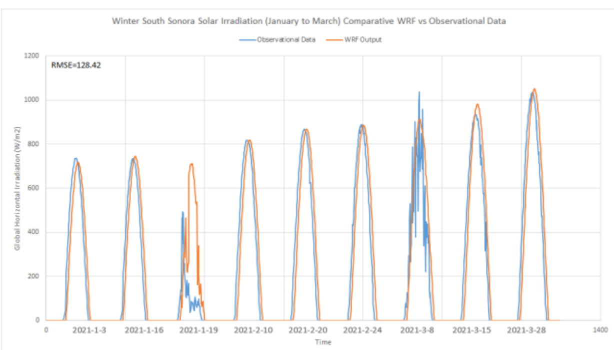

Figure 11 Winter South Sonora Comparative WRF vs Observation

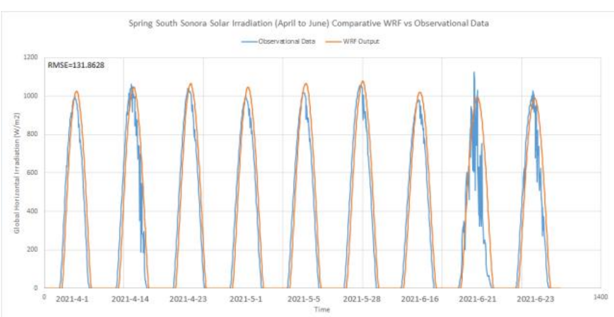

Figure 12 Spring South Sonora Comparative WRF vs Observation

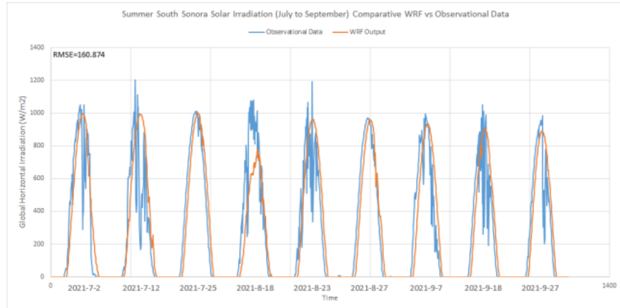

Figure 13 Summer South Sonora Comparative WRF vs Observation

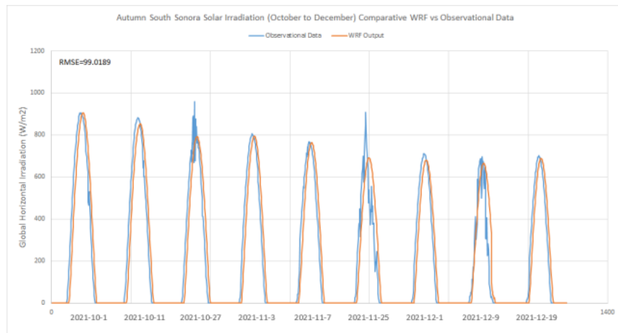

Figure 14 Autumn South Sonora Comparative WRF vs Observation

As our dispersion plot for this region shows a high tendency between values where R^2 can be seen as high as 85%, therefore our model can be performed effectively on this region as well.

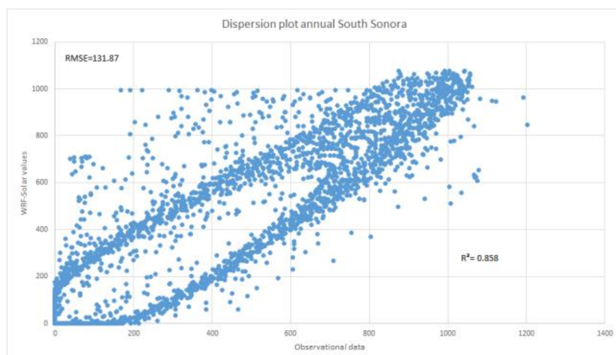

Figure 15 Dispersion plot South Sonora

V. Conclusions

In the present work an analysis for solar energy forecasting based on WRF-Solar and weather stations data in Sonora State was done to inspect how several regions with different weather conditions along the year can affect our model accuracy to forecast solar radiation.

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At first, we evaluated our results directly from WRF-Solar output against weather station observational data for a year by using representative days per month. Subsequently, we look into our data correlation by applying statistics so we can evaluate by RMSE how disperse are our values for the observed values. A low RMSE values indicates that our model has high accuracy to predict real data occurring on the place where weather stations are working.

As we can appreciate on dispersion plots, values from RMSE for northern and center region are almost identical, this can be merely by the semi-arid regions and the tendency on this places to have similar days along the year.

However, southern region analyzed show a low RMSE compared with the others, even though this region is considered as climate changing place due to its valley surface form.

We consider that regions that are semi-arid as northern and center Sonora places, can have effects as high dust concentration that affect somehow solar radiation.

Even though, we obtained RMSE values as high as 160 W/m^2 for some regions, a few adjustments on physics and model schemes as Aerosol Optical Depth add-in might correct these high values on RMSE for semi-arid regions and forced satellite images for cloud modeling for valley-like regions are solutions to get a better accuracy.

Overall, this forecast model has proven to be capable for forecast on semi-arid regions. It presents good accuracy with a high temporal resolution and a good performance for different regions along on one of the biggest Mexico state.

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Comparison of detectors and distance metrics for pose estimation

Comparación de detectores y métricas de distancia para la estimación de pose

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Abstract

In many artificial vision applications, it is necessary to know the pose (rotation and translation) of the camera with respect to some object in the real world. To know this pose, many algorithms are based on the detection and matching of common points of interest in two or more images. For that reason, it is necessary to have adequate algorithms for point detection and a robust metric for pose estimation. This paper presents a comparative analysis of three of the most popular algorithms for point detection and two popular metrics. In the detectors, the robustness to geometric distortions, robustness to noise and processing speed were compared. In the metrics robustness to noise and processing speed were compared.

Point detectors, Pose estimation, Artificial vision

Resumen

En muchas aplicaciones de visión artificial es necesario conocer la pose (rotación y traslación) de la cámara con respecto a algún objeto del mundo real. Para conocer dicha pose, muchos algoritmos se basan en la detección y emparejamiento de puntos de interés, comunes en dos o más imágenes. Por esa razón, es necesario contar con algoritmos adecuados para la detección de puntos y una métrica robusta para la estimación de la pose. En este artículo se presenta un análisis comparativo de tres de los algoritmos más populares para la detección de puntos y dos métricas populares. En los detectores se compararon la robustez a distorsiones geométricas, robustez a ruido y velocidad de procesamiento. Para las métricas se compararon la robustez al ruido y la velocidad de procesamiento.

Detectores de puntos, Estimación de pose, Visión artificial

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Introduction

In many applications, such as autonomous robot navigation (Wang, Liu, & Li, 2015) (Knudson & Tumer, 2011), simultaneous localization and mapping (SLAM) (Mur Artal & Tardos, 2017) (Mur Artal & Tardos, Visual-inertial monocular slam with map reuse, 2017) and augmented reality (AR) (Chatzopoulos, Bermejo, Huang, & Hui, 2017), pose estimation is an important topic.

In this context, pose represents the position and orientation of a three-dimensional object with respect to a reference system, in real world. Usually, orientation is represented by a 3x3 rotation matrix and position is represented by a 3x1 translation vector.

Most techniques of pose estimation rely on detection of key points. The basic steps for pose estimation, based on key points, using two images from a video sequence are:

– Detect key points in the images

– Match corresponding points in both images performing a nearest neighbor search

– Apply a robust estimator, such as Random Sample Consensus (RANSAC) algorithm (Torr & Zisserman, 2000), to reduce mismatches

– Compute pose using information of matched points, camera parameters and geometric techniques.

Key points must be visually significant points that can be easily identified in each image. An ideal key point detector should find salient image regions, despite change of viewpoint. Each detected point is represented by a vector of features, called descriptor, which is extracted from such point and its neighbors.

A good descriptor should make it possible to uniquely distinguish each point. Corners can be used for this porpoise; however, other better algorithms have been introduced, being some of the most important:

Scale-Invariant Feature Transform (SIFT) (Lowe, 1999), Features from Accelerated Segment Test (FAST) (Rosten & Drummond, 2005), Speeded-Up Robust Features (SURF) (Bay, Ess, Tuytelaars, & Van Gool, 2008), Binary Robust Invariant Scalable Keypoints (BRISK) (Leutenegger, Chli, & Siegwart, 2011), Binary Robust Independent Elementary Features (BRIEF) (Calonder, Lepetit, Strecha, & Fua, 2010) and Oriented FAST and rotated BRIEF (ORB) (Rublee, Rabaud, Konolige, & Bradski, 2011). Some detectors include its own descriptors.

The desirable characteristics of detectors and descriptors are speed, robustness to geometrical distortions and robustness to noise.

Note that selection of a good detector and descriptor are very important tasks for pose estimation. This paper presents a comparison between the main detectors and descriptors used for estimation of pose. Besides, a comparison between two distance metrics, namely Sum of Squared Difference (SSD) and Sum of Absolute Difference (SAD), is included.

Basic Concepts

In this section we present a brief review of the algorithms to be compared, including detectors FAST, SURF and BRSK, and the two metrics, SSD and SAD.

1. Features from Accelerated Segment Test (FAST)

FAST use a circle with a perimeter of 16 pixels, around the corner candidate pixel p. Pixels are numbered clockwise, starting from top center pixel. The algorithm classifies p as a corner if there is a set of n contiguous pixels in the circle, all within a range $p \pm t$, where t is a threshold value (normally, $n = 12$ is chosen). To speed up execution, four pixels are examined at the positions 1, 5, 9 and 13. For p to be a corner, at least three of these values must be in the indicated range, Otherwise, p is discarded. The number of features detected, and the speed of detection is determined by the threshold t. In addition, the 16-pixel circle can be used as a feature vector.

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2. Speeded-Up Robust Features (SURF)

SURF searches for points of interest by applying a Gaussian filter to image and calculating the determinant of its Hessian matrix H. To achieve scale invariance, Gaussian filters of different sizes are applied, divided into octaves. The maximum values obtained from the determinant of H are the indicators of the location of the points of interest. Once the points of interest have been obtained, to achieve rotation invariance, the direction of the gradient at each point is calculated using Haar wavelets.

The SURF descriptor computes orientation using the Haar wavelets in the *x* and *y* directions, in a circular region of radius 6*s*, where *s* is the scale of the point of interest.

Individual responses are weighted with a Gaussian function centered on the point of interest. The dominant orientation is obtained as the sum of all responses within a radius of $\pi/3$, using a sliding window. The vertical and horizontal responses are added and the vector with the greater value is kept. Descriptor is constructed by forming a square region of size 20*s* around the point of interest, using the dominant orientation and a Gaussian weighting. Then, the region is divided into 4x4 subregions and, within each subregion, the Haar response of points spaced 5x5 in both directions is calculated. Next, in each subregion, the vertical and horizontal responses and their absolute values are added. Finally, the vector is formed by these four components (sums) of the 4x4 regions, giving a total of 64 elements.

3. Binary Robust Invariant Scalable Keypoints (BRISK)

BRISK is method for key point detection, description, and matching. To reduce computational cost, like SURF, points of interest are identified at different scales divided into octaves, using a saliency criterion. The location and the scale of each key point are obtained using a quadratic function fitting. For description, a sampling pattern is applied at the neighborhood of each key point. The pattern consists of points lying on appropriately scaled concentric circles. Orientation is determined processing local intensity gradients. Finally, the oriented BRISK pattern is used to assemble the binary BRISK descriptor.

4. Sum of Squared Difference and Sum of Absolute Difference

Matching process requires to compare each point in the first image with all points of the second image. To determine which point matches other, a nearest neighborhood search is performed. If the distance of the closest point is less than a certain threshold, the points are matched. Besides, an algorithm to reduce outliers is necessary to reduce mismatches.

To compute distance between two points, the most used metrics are Sum of Squared Difference (SSD) and Sum of Absolute Difference (SAD). Let (x,y,z) and (x',y',z') two points to be compared, SSD and SAD are defined respectively as

$$\text{SSD} = (x - x')^2 + (y - y')^2 + (z - z')^2 \quad (1)$$

$$\text{SSD} = |x - x'| + |y - y'| + |z - z'| \quad (2)$$

Methodology

1. Selection of detector

Robustness of keyframe-based method greatly depends on techniques used for detection and matching. To choose the best detector, we tested three popular algorithms: Features from Accelerated Segment Test (FAST), Speeded-Up Robust Features (SURF) and Binary Robust Invariant Scalable Keypoints (BRISK).

We tested speed and robustness of algorithms with three different images: cameraman, Lena, and highway. First, to verify robustness to geometric distortions, we change 10% the scale of a reference image and rotate it from -15 to 15 in steps of 5 degrees; next, to probe robustness to noise, we add zero-mean Gaussian additive noise with variance of 0.01 and impulsive noise with prob-ability of 0.05 to the rotated and scaled image; then, with the three proposed detectors, we searched and matched interest points in both, the reference and modified images; finally, we computed error due to mismatches and we measured execution time. To obtain statistically correct results, 30 trials of each experiment for different realizations of random noise were performed and results were averaged. All experiments were performed in a CORE i7 processor at 2.6 GHz.

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2. Selection of matching algorithm

With the extracted features it is necessary to match points in at least two images. For this, the matching algorithm performs a nearest neighbor search by computing the pairwise distance between feature vectors. Then, it selects the strongest matches respect to a stablished threshold and returns its indices. If the number of outliers is low, the number of iterations and time consumption of RANSAC estimation method can be reduced. For this reason, we first compare robustness of two popular distance metrics, namely Sum of Squared Difference (SSD) and Sum of Absolute Difference (SAD). To test images with real rotations and noise, we match SURF features obtained from 600 stereo pairs images of sequence 00, 01, 02 and 03 from KITTI dataset (Geiger, Lenz, Stiller, & Urtasun, 2013).

We applied Random Sample Consensus (RANSAC) algorithm between each pair of images with both metrics. RANSAC is a general and very successful robust estimator used for this purpose. Since the algorithm uses a random process, to obtain statistically correct results, we perform 30 statistical trials with each pair of images and average results.

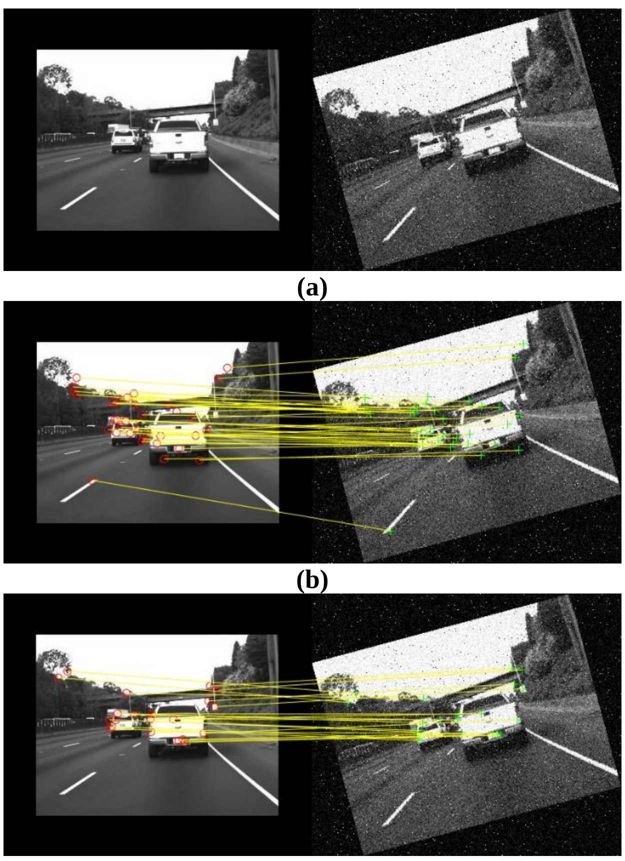
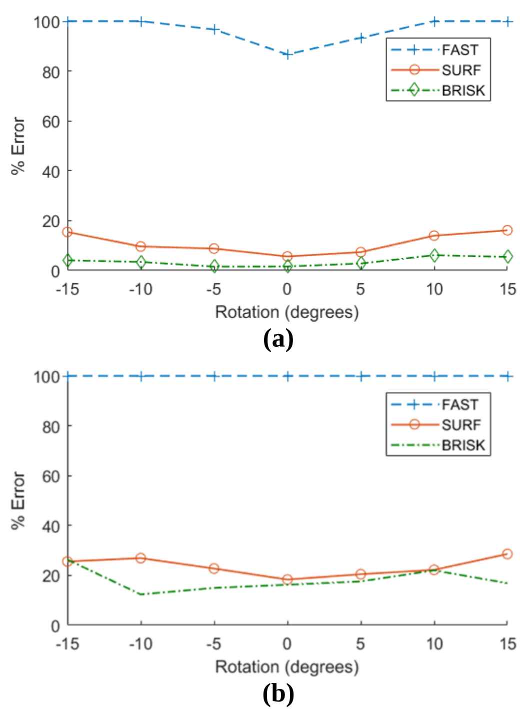


Figure 1 Example of matched points with a) FAST, b) SURF and c) BRISK detectors for highway image

Results

In this section, we show results of tested algorithms. For detectors comparison, figure 1 is an example of matched images. As can be seen in figure 1(a), due to noise and geometric distortions, FAST detector was unable to correctly match any point in these images. On the other hand, as can be appreciated in figures 1(b) and 1(c), SURF and BRISK correctly detect many points.

Figure 2 shows percentage of matching error of the three detectors with respect to rotation angle for the three tested images: a) cameraman, b) Lena and c) highway. Size of images were 256x256, 512x 512 and 240x320 pixels, respectively. Table 1 contains results of total execution time (in seconds) with each detector. Because of noise, FAST detector is unable to correctly match most points. BRISK detector reaches the best results in terms of error for al-most all tests; however, time consumption is very high compared with the other detectors (almost ten times, in some cases). On the other hand, SURF detector offers a good tradeoff between performance and time; therefore, we selected this detector for the distance metric comparison.



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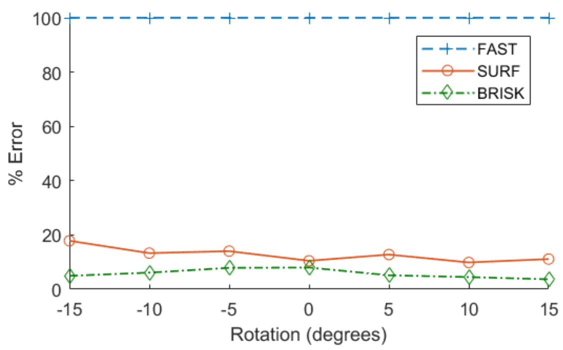

(c)

Figure 2 Percentage of mismatches of FAST, SURF and BRISK detectors with a) Cameraman, b) Lena and c) highway images

	Cameraman	Lena	Highway
FAST	7.82	11.59	8.1
SURF	5.47	17.69	6.12
BRISK	57.7	82.47	59.16

Table 1 Comparation of time (in seconds) of FAST, SURF and BRISK detectors

Method	SSD	SAD
Iterations seq. 00	48.24	34.96
Iterations seq. 01	32.32	22.25
Iterations seq. 02	39.81	28.82
Iterations seq. 03	39.36	31.44
Average iterations	39.9325	29.3675
Total time (sec)	1065.37	848.49

Table 2 Comparation of iterations and processing time of SSD and SAD

For matching algorithm comparison, table 2 shows the results of number of iterations in each sequence, average number of iterations and total time consumption for the two matching algorithms. As can be seen, SAD required fewer average iterations and less time consumption, therefore is a good candidate for matching metric in the keyframe-based pose estimation.

Conclusions

In this paper, we show a comparison of three popular detectors and two matching metrics. Selection of a good detector is crucial to get a reliable pose estimation. The detectors compared were FAST, BRISK and SURF. Although BRISK has a lower error rate, SURF offers a good tradeoff between performance and processing time. The matching metrics compared were SSD and SAD. In our experiments, since SAD is a more robust metric, it required fewer average iterations and, therefore, less time consumption than SSD.

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Dehydration: An efficient process for ensuring food conservation in vulnerable regions

Deshidratación: Un proceso eficiente para asegurar la conservación de alimentos en zonas vulnerables

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Abstract

Approximately 860 million people throughout the world currently live in extreme hunger and poverty due to income reductions, unemployment, and layoffs from the COVID-19 pandemic, all of which disproportionately affect disadvantaged homes (Unated Nations, 2022). One of the objectives of the World Bank (2022) for 2030 is to end extreme poverty and promote shared prosperity. In Mexico, there are 55.7 million people in poverty, extreme poverty, high or very high marginalization, and vulnerable situations on account of lack of food, healthcare, housing, and employment (CONEVAL, 2020). However, there is no immediate solution to rid the world of poverty and food shortage. In this project, we propose to combat the issue of poverty and food inequality with a system for conserving food that takes advantage of the solar energy available in the most disadvantaged and marginalized regions. The solar dehydration used to naturally dry fruits, vegetables, and animal proteins after the harvest will contribute to the food supply, do no harm to the environment, and create an alternative job source.

Dehydration, Food conservation, Marginalized regions, Environment, Alternative jobs

Resumen

Actualmente en el mundo existen aproximadamente 860 millones de personas en situación de pobreza extrema y hambre debido a la disminución de los ingresos, la pérdida de puestos de trabajo y los ceses laborales durante la pandemia del COVID19, que han afectado principalmente a los hogares más desfavorecidos (Naciones Unidas, 2022). Uno de los objetivos del Banco Mundial (2022) para 2030 es poner fin a la pobreza extrema y promover la prosperidad compartida. En México hay 55.7 millones de personas en pobreza, pobreza extrema, alta y muy alta marginación y en situación de vulnerabilidad por carencias en alimentación, salud, vivienda y empleo (CONEVAL, 2020). Sin embargo no existe una solución inmediata para acabar con la pobreza y el rezago alimentario. En el presente proyecto se propone utilizar como estrategia para combatir la pobreza y la desigualdad alimentaria, un sistema para la conservación de alimentos que aprovechen la energía solar disponible de las zonas marginadas del país menos favorecida a través de la deshidratación solar para el secado natural de vegetales, frutos y proteínas de animales, después de la cosecha que contribuyan a mejorar la alimentación de las personas, el cuidado del medio ambiente y una fuente de trabajo alternativo.

Deshidratación, Conservación alimentos, Zonas marginadas

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Introduction

The sun is the source of various forms of energy that human beings have used since the beginning of their history to satisfy their needs, solar energy being one of them. Every day the sun radiates, or emits, an enormous amount of energy in one second (VIU, 2021). It continuously emits a power of 62 thousand 600 kilowatts per square meter of its surface (Arancibia Bulnes and Best and Brown, 2010) (Romero Crespo, Flores Peralta, 2019). This is equivalent to about 60 times the annual consumption of human society, noting the potential of the Sun's energy to meet the world's energy demands.

Solar radiation reaching the Earth can be harnessed through the heat it produces, as well as through the absorption of radiation. In the upper part of the earth's atmosphere, on a surface perpendicular to the radiation, there is an average power of 1367 W/m2, an amount called Solar Constant (IDEAM, 2022), more than enough for its use. The sunlight that reaches the earth is composed of millions of high-energy particles called photons, where each unit of solar radiation, or photon, carries a fixed amount of energy, showing the potential of the sun's energy to meet the world's energy demands. The use of solar energy has been little disseminated in the history of mankind despite the fact that it is unlimited and without cost, making it competitive with respect to the use of fossil fuels (Bravo, 2012).

The growing energy demand is mainly due to population growth and is causing fossil fuel reserves to be depleted faster than expected, which is why energy does not reach all human beings in the same way or in the required amount, a situation that is accentuated when the marginalization and poverty level of the population is more evident (González *et al.*, 2021). In the great oil crisis of the seventies of the last century is when the massive diffusion of solar thermal systems began, in particular, with the use and dissemination of water heating for domestic use (Bravo, 2012), so that the real development of solar thermal energy occurs from this time, when all those nations involved in the embargo motivated many Western countries dependent on oil to decide to promote other energy sources such as renewables, and within these to the use of solar thermal panels (Carbonell, 2022).

Renewable energies

Solar energy has always been used by human beings in daily life and domestic tasks. The first records indicating that the sun's energy was used as a source of heat and light for constructions are in ancient Greece around 400 B.C. (Romero Crespo, Flores Peralta, 2019).

The first drying method developed by man consisted of direct exposure of the product to the sun (Hernández, 2017). This technique is still used today in rural areas of developing countries, however a large amount of product is lost due to contamination or deterioration by natural phenomena and insect attack.

Drying or desiccation is one of the oldest food preservation processes dating back to the Paleolithic era, approximately 400,000 years ago, where antecedents indicate that foods such as fruits, grains, vegetables, meats and fish were dried in the sun, learning through trial and error, to achieve a possibility of subsistence in times of scarcity of nutritious food (Bravo, 2012).

According to (Cortés, 2017) there are two alternatives for food dehydration: naturally in the sun, or mechanically, however it can also be done in a combined way, some stages in the sun and others mechanically.

Dehydration is one of the oldest forms of food processing. It consists of extracting a good part of the moisture from them, so that they do not decompose (CEUPE Magazine. (n/d). Dehydration or drying is one of the most used techniques for food preservation throughout history (De Michelis Antonio, Ohaco Elizabeth, n/d) through a simultaneous process of heat and mass transfer, accompanied by a phase change (Espinoza, 2016).

It is a food preservation procedure that, by removing all the free water from the food, prevents microbial activity and reduces enzymatic activity (CEUPE Magazine, n/d). All foods are susceptible to being altered in a greater or lesser space of time, due to the action of microorganisms that contaminate them or to enzymatic reactions of the food itself (Pinzón, 2016). Water is the main component of food, helping to maintain its freshness, flavor, texture and color (Marín *et al.*, 2006).

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Its importance lies in the fact that it serves as a transport for substances, in addition to being key in the development of microorganisms, the main agents of food spoilage. The reduction of water present in a food has been a strategy used since ancient times to preserve quality during storage periods (AgriNova, 2009). The reduction of weight and volume results in a reduction of transportation and storage costs, generally of high cost, due to the energy required during the process (Espinoza, 2016).

In addition to the water or moisture of a food, it is necessary to know its availability for certain biochemical, enzymatic and microbial reactions, the solutes present in the food, such as proteins, carbohydrates, lipids and vitamins (Marín *et al*., 2006). The moisture in the food is absorbed by the air that is in contact with the food. For this to occur, the air must be warm, dry and moving (Cutnei, 2007). This procedure allows extending the life of the food, preserving its properties as well as facilitating storage, transport and handling. Another way is the method of food processing through the application of heat, hot air (Espinoza, 2016). As can be seen, it constitutes an energy saving alternative, since the use of solar energy in food dehydration reduces the consumption of fossil fuels, is efficient, low cost and eliminates the emission of greenhouse gases (Cortés, 2017).

Likewise, the solar dehydrator is a device that allows using solar energy to dehydrate food, in less time than drying in the sun and with greater hygiene. Transforming useful heat through the greenhouse effect (Kajekui, 2017).

Another alternative is solar food drying. It is carried out by exposing the products to the open air to receive direct energy from the sun and air, drying naturally. The ideal conditions to achieve dehydration are a mass of air surrounding the product with a high temperature and low relative humidity (Cutnei *et al*., 2007). The drying process can be applied to all types of foods, from vegetables and greens to meat and fish, fruits, spices, aromatic herbs, among others (Pinzón, 2016). A current of air that accelerates and renews the environment around the product to be dehydrated, replacing the already humidified one with a dry and warm one that continues the drying process (Cortés, 2017).

Artisanal production is based on dehydration in direct sunlight resulting in poor product quality due to high solar radiation (Espinoza, 2016), sanitary errors, which involve the presence of dust, stones and organic remains, among others. Currently, a great variety of agricultural products require drying for their adequate preservation or commercialization until they reach consumers. Drying offers an alternative to the farmer when there are transportation problems or when the market demands a dry and not fresh product. Solar drying technologies offer a viable alternative to process agricultural products in a clean and hygienic way, complying with existing regulations for food handling, contributing to reduce the consumption of traditional fuels, improve product quality, reduce post-harvest losses and care for the environment (Hernández *et al*., 2017).

Food preservation is considered of utmost importance to extend the shelf life of fruits and to have access to more distant markets. Food can take from 1/2 to 3 days to reach its proper point. This will depend on the original humidity of the product and the climatic conditions of the environment (temperature, ambient humidity and level of sun radiation) (Cutnei *et al*., 2007).

The various solar energy systems are rapidly becoming a common method for fluid heating, dehydration processes of fruits, grains, flowers or electricity generation. Foods that are dehydrated with the sun's energy maintain a large proportion of their original nutritional value if the process is carried out properly. As in all preservation processes, some percentage of vitamins is lost during preparation, drying or storage (Cutnei *et al*., 2011). Healthy eating is a trend that is growing strongly, markedly so in industrialized economies but also in emerging ones (Buitrago, 2014).

Impact of dehydration

It allows preserving all foods for months or years as less water they retain; it maintains the nutritional properties of foods with the best preservation the lower the dehydration temperature (Villén, 2012), (Kajekui, 2017); flavors are intensified by concentrating their properties; in addition, storage, handling and transportation space is reduced, especially the preservation of surplus crops.

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When these properties become a problem, they imply a restriction of access to green international markets (Espinoza, 2016). In the dehydrated market, priority is given to large producers, who obtain better prices and availability for their production (Espinoza, 2016), which is why it is necessary to work on the dehydration of products that provide socioeconomic support for low-income people.

There are drying techniques where firewood can be used as fuel, however the use of these types of techniques cause damage to the environment via deforestation and air pollution (Hernández *et al*., 2017), the use of industrial dryers offers drying quality but their high initial and operating costs limit their use.

Mexico's situation

Mexico is located between latitude 23.634501 N and longitude -102.552784 W, considered a region favored in solar resources, where it receives daily, on average, 5.5 kWh/m2, being one of the best in the world (Global Solar Atlas, 2021). Its privileged location allows it to use solar radiation to obtain environmentally friendly alternative energy.

Mexico has more than 55.7 million people living in poverty, of which 10.8 million are in extreme poverty (CONEVAL, 2020) (El Economista, 2021) (El Economista, 2021), high and very high marginalization and in a situation of vulnerability due to lack of food, health, housing and employment, the project is aimed at contributing to environmental care and socioeconomic support for the most vulnerable people in the country. According to the International Renewable Energy Agency (IRENA) (Lavagne *et al*., 2015).

This also has an impact at the energy level, since the lack of communication routes to reach these rural communities, or the distance to which they are located, is an important factor that makes it more difficult to access natural gas and electricity (González *et al*., 2021). Forecasts show that the world is not on track to achieve the goal of zero hunger by 2030.

Food safety

The food security and nutritional status of the most vulnerable population groups for the case of Latin America (with a population of 644 million inhabitants, according to the World Bank (WB), 2020) and, particularly for Mexico, deteriorate further due to the socioeconomic and health repercussions of the coronavirus disease pandemic (COVID-19) (UN, 2021). Anticipating the increase of the undernourished population (FAO-UN-PAHO-UNICEF. (2021).

The consequences of the pandemic are diverse and have been directly manifested in the reduction of family income, loss of employment as a result of home confinement during the first year and a half of the health emergency and its temporary extension (WHO, 2020). The impact on the health of the population has been devastating (ECLAC-PAHO, 2020), directly affecting the physiology of those who have contracted the virus. The situation that has prevailed since the beginning of the pandemic has also been reflected in the decrease in food supply and as a result has further affected the quality of nutrition (FAO, 2020).

Given the uncertainty about the duration of the pandemic, it is expected that the population living in poverty and vulnerability will increase to 220 million people (UN, 2020). At the same time, in economic terms, the impact on the global loss of GDP amounts to 14.1% (Bank of Mexico 2020 and 2020.1), directly affecting -among others- those who depend on their own trade and/or services activities, which have been halted since the end of March 2020 (ECLAC, 2020) and with 13.5% of the population that will lose their jobs, particularly in the agricultural sector, which -by 2019- amounted to 120 million people (ECLAC, 2019, UN, 2020.1).

Both poverty and vulnerability have to be addressed jointly, since the former detonates the latter if it deepens. For this reason, they must be addressed through an integrated policy (ECLAC, 2020.1; FAO, 2020; SB, 2021).

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Specifically, the National Institute of Public Health (INSP), the Intersecretarial Group of Health, Food, Environment and Competitiveness (GISAMAC), the Food and Agriculture Organization of the United Nations (FAO), the Pan American Health Organization (PAHO-WHO) and UNICEF, the United Nations Children's Fund (2020), expressed their concern about the great inequalities that have prevailed in Mexico for decades and the current crisis has revealed that 55.5% of households present some degree of food insecurity; it is not possible for them to satisfy their minimum food needs for a prolonged period of time.

On the other hand, the decline in economic activities will make it difficult to stimulate the generation of wealth in a rapid manner, and to buy food, as in the past. Particularly in rural areas and areas of great natural wealth, according to the United Nations report (2020.1), the drop in economic activity was 5.3%, comparable to the Great Depression of 1930 (ECLAC, 2020.2).

Mexico's natural resources are of great importance - nationally and internationally - as they represent more than 40 percent of the biodiversity on planet Earth (CONABIO, 2022, SEMARNAT, 2012; 2016 and 2018, UNDP, UNEP, ECLAC & UNCTAD 2010, UNEP, 2019 and United Nations, 2020) and at the same time they are the country's natural heritage and only source of life.

However, as a result of COVID19, production in the countryside has decreased or ceased and, at the same time, the price of the basic food basket has risen, as well as fruits, vegetables and grains, according to CONEVAL (2021) and the Ministry of Economic Development (SEDECO, 2021). As a result, their supply has decreased.

All of the above has a direct impact on food security, making it a national priority that demands to know its requirements; in order to add to the availability of food products, orienting their care and management towards sustainability and, as a whole, contribute to maintaining a healthy environment and access to food (Political Constitution of the United Mexican States, 2021).

In particular to add to the actions that reduce the effects of climate change (SEMARNAT, 2022), such as climate variability and extreme conditions, droughts, extreme rains, increasing weather events that, at the same time, affect the economy and are the main factors affecting food security and nutrition (FAO, IFAD, WHO, WFP and UNICEF, 2021). Hunger is most significant in countries where agri-food systems are affected by extreme rainfall and temperature conditions, and the livelihoods of a large part of the population depend on agriculture (FAO, IFAD, WHO, WFP and UNICEF, 2021), noting that poverty and inequality are more evident in socially excluded and marginalized groups.

Renewable energies

The solar radiation received by the earth is of the order of 1.5 kilowatts (kW) per hour, which is the amount of energy capable of supporting world consumption (Pareja, 2010), however, when using this energy source, disadvantages arise such as: the way it is captured and stored; in addition to presenting variations due to meteorological, environmental and geographical conditions. However, the solar radiation emitted by the sun reaches the Earth's atmosphere considerably weakened with approximately 1360 Watts per square meter (W/m^2), due to the distance between the Sun and the Earth; subsequently it suffers an attenuation due to the atmospheric layer, so that the radiation on the Earth's surface is approximately 1000 W/m^2. The estimated share of renewables in global electricity production in 2018 was 73.8% non-renewable electricity; 26.2% renewable electricity; 15.8% hydropower; 5.5% wind power; 2.4% solar PV; 2.2% bioenergy; and 0.4% geothermal, CSP, and ocean energy (REN21, 2019) (González *et al.*, 2021).

Conditions for food drying

The typical drying rate for a solar food dehydrator is 0.25 kg/h at the start of the process, which depends on the design of the dehydrator and the climate of the location. If the drying rate is much lower than this number, it is possible that the air temperature or air velocity is too low or the moisture content of the product is too high (Blanco Cano and Valldecabres Sanmartín, 2016).

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Generally, the temperature of the dryer should be 10-15°C above ambient temperature, while in artificial (fuel-fired) dryers it can be up to 60-70°C or higher.

On the other hand, the relative humidity of the air entering the dryer should be less than 60% to absorb water from the food. Each food or product requires an airflow with specific conditions.

Target

To develop an efficient solar dehydration system for vegetables, fruits and meats through a process with quality materials and control devices.

Materials and methods

The research was carried out by identifying the needs of the population living in poverty, and from there determining which project is viable for the entities in Mexico, whose population is in this situation of energy marginalization. With the information gathered and analyzed, the engineering design of the prototype was carried out and later the development of the system, including the ad hoc mechatronic mechanisms for its proper operation.

The work that led to the project was developed in an interdisciplinary manner, covering the areas of knowledge related to the project's objective (Environment and Development, Renewable Energies and Mechatronics).

Development Results and Analysis

Operation of the solar dehydrator

A solar collector is an equipment designed to capture solar radiation and convert it into heat, to transfer it by convection processes to fluids such as air that circulates through this system in a natural or forced way.

The present device for food preservation through dehydration based on the use of energy from the sun for the natural drying process of fruits, vegetables and animal proteins after harvesting, with technological basis and integrating emerging technologies for the preservation of micronutrients necessary for the feeding of the personnel.

With high social responsibility for the care of the environment and the socioeconomic potentialization of the inhabitants of vulnerable areas of a given region, based on scientific and technological knowledge in agribusiness and renewable energy for the development of projects through heat transfer and fluid mechanics is a low cost system for the agro-industrial, livestock and forestry sector.

It contributes to reduce the generation of CO_2 eq, compared to a conventional dehydrator that uses electricity or gas for its operation, and it is also a source of income for the family economy and the region where it is used.

For the design of the dehydration system, a decision matrix was established to analyze the parameters that govern the quality of the solar food dehydrator. This information was obtained from the needs, climatic conditions of the study area and the predominant natural, livestock and agroindustrial resources in Hidalgo, in addition to the engineering issues that are relevant to solar dehydrators such as heat transfer and fluid mechanics, considering the updraft solar dehydrator as the best option.

The design parameters that were considered high priority to effectively meet the needs in the municipalities considered high and very high marginalization in the state of Hidalgo -in a first stage- and then replicate them throughout the entity. Six key design parameters of approach were considered to obtain the required temperature and humidity for food dehydration, considering that with these parameters, the quality function would cover the needs of the end users.

Product cost

Materials should be accessible, low cost and widely used in the region.

Function

It must be functional at all levels required by the end users with the capacity to dry fruits, vegetables predominant in each region - bananas, tomatoes, apples, oranges, mangos, papaya, beef, pork, chicken - among others. With zero contamination of the food product inside the apparatus by insects and the same waste, and having the capacity to move the dehydrator to the sunniest areas by adults.

Safety

Its construction should be considered for the yard of a house or site where it can be operated mainly by adults without risk, so its weight should be light, without sharp or pointed edges; to avoid injury to users. Toxic or hazardous materials shall be excluded to ensure maintenance of edible micronutrients.

Reliability

The dehydrator is a great investment for a family in a low-income community; when the dehydrator performs its function, success is achieved and a product in conditions to feed the users and the sale of surplus dehydrated products is assured; therefore, the quality and cleanliness of the products and the apparatus is basic to avoid mold growth in a dehydration period of two days or less, through easy routine maintenance procedures that a mother of a family can perform on a daily basis.

Quality

Having a low budget solar dehydrator does not mean that it affects the quality of the design, the materials must be non-toxic, aesthetically pleasing, with a useful life of at least five years and that it fulfills the objectives and functions of dehydration in a short time.

Operating instructions

It will be delivered with a manufacturing manual and instructions for operation, functioning and basic maintenance, which are key factors for successful dehydration. The specifications of the device allow its construction in the place of use by the operators and specifically by rural women, this means that the training and instructions must be clear, concise and with a language that ensures its functionality and daily operation.

Manufacturing process

For the construction of the solar dehydrator, the following Mexican Official Standards related to the development of the project were considered - NOM-OO1-SEDE-2012, NOM-086-SSA1-1994, Goods and services.

Food and non-alcoholic beverages with modifications in their composition; nutritional specifications and NOM-044-FITO-1995, Establishing phytosanitary requirements and specifications for the importation of nuts, processed and dehydrated vegetable products and by-products.

For the construction of the dehydrator we used low-cost raw materials of the best quality whose components are for the casing, mechanics, control and power electronics, design and computer modeling software, electronic design, electronic control card -based on microcontrollers and graphic interface, which allows monitoring variables of interest to ensure optimal and correct dehydration.

The materials used are: Arduino Mega 250, 3.5" TFT display, DHT11 temperature, humidity and solar UV sensor Ml8511, relay relay module, solid state Ss, Channels 2nd, push botton 2 pins, power supply switching power supply voltage 12V 10A 120W, male DC connector, fan extractor turbine blower 12v - 24 Volts Pc Game, power adapter Jack 5.5mm X 2. 1mm, ceramic capacitor capacitor 22pf arduino pic, phenolic copper plate Pcb 10x10 cm, ferric chloride for electrical circuits 220ml, cable to connect or UTP cable, 12 gauge AWG cables 30m, connector strip Header, gray plastic mosquito netting 1.05 Mt Fiero 44960, diffuse green LED 5 mm, terminal block 2 pins, pitch 200, 5.08 mm, epoxy paint colares black, white and gray, potentiometer 1k 3 pins 15 mm, Pic 18F4550 microcontroller, cold silicone.

Results

Dehydration system

The high performance hybrid system that uses energy coming from the sun converting it into natural heat energy to perform the dehydration or natural drying process with temperature and humidity control, free of contaminating agents of different foods at low cost.

Figure 1 shows the side view of the dehydrator.

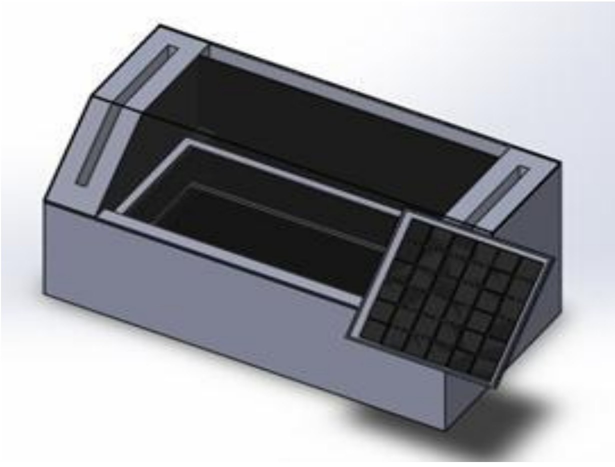

Figure 1 Side view of the dehydrator
Source: Own Elaboration

Figure 2 shows the inside view of the apparatus and Figure 3 shows the front of the hybrid system.

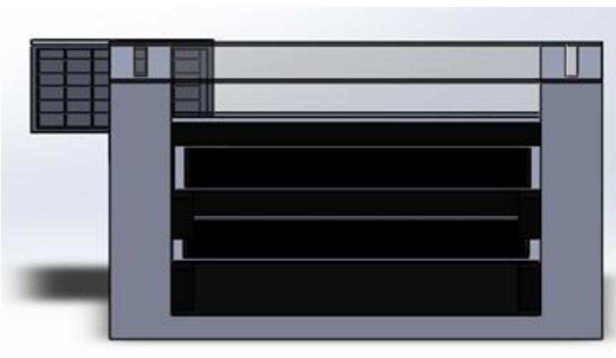

Figure 2 View of the inside of the dehydrator where the feed grids are located
Source: Own Elaboration

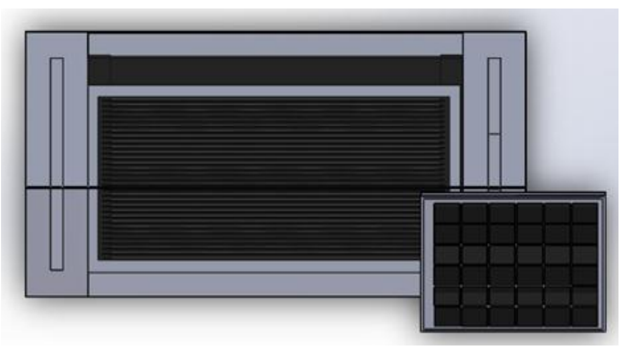

Figure 3 Front view of the dehydrator
Source: Own Elaboration

Monitoring system

The humidity and temperature monitoring system helps to make the drying process in the dehydrator more efficient, by recording and controlling inside the drying chamber and depending on the values of each of the variables, the fan is activated to maintain the temperature and humidity required for each food.

The connection circuit was elaborated using an arduino with free access software. Figure 4 shows the control variables monitoring circuit diagram.

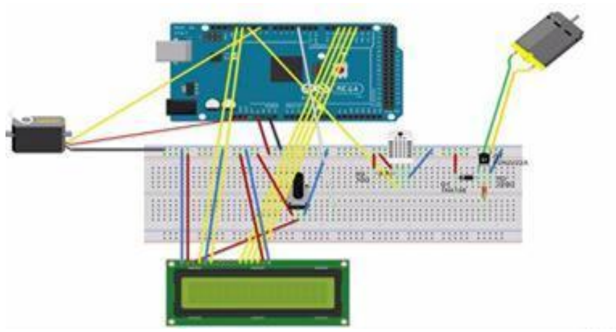

Figure 4 Diagram of the circuit developed for humidity and temperature monitoring
Source: Own Elaboration

Figure 5 shows an example of the dehydration process of duces.

Figure 5 Dehydration of jams and jellies
Source: Own Elaboration

The following foods have been dehydrated: apple, mango, cucumber, banana, broccoli, tomato, potato, and jelly candy and oatmeal. Table 1 shows the characterization of the products to be dehydrated.

Product	mini (g)	ms (g)	H initial (%)	H recommended (%)	T maximum permissible (°C)
Handle	15	5	67	15	65
Broccoli	5	2	60	6	65
Cucumber	3.5	1.5	57	8	75
Banana	5	1.8	64	15	70
Tomato	10	2	80	8	65
Papa	5	1.7	66	13	75
Note: Slices of approximately 0.5 cm thick.					

Table 1 Characterization of the products to be dehydrated
Source: Own Elaboration

Taking these data into account, the dehydrator characterization was carried out and the following data were obtained.

Characterization of the solar dehydrator					
Day 1: 03/05/2022					
Time	T. environment (ºC)	H. environment (%)	T. input to the chamber (ºC)	H. camera input (%)	Caudal del colector (m3/s)
11:00	24	27	38	13	4.19
12:00	25	25	39	58	5.12
13:00	27	31	43	65	5.6
14:00	25	45	42	77	5.89
15:00	21	60	36	95	5.89
16:00	20	69	35	94	4.65
Prom	23.67	42.83	38.83	67	5.22

Table 2 Process characterization of the prototype dehydrator day 1
Source: Own Elaboration

Duration of the test was 5 hours from 12:00 to 16:00 hours.

Solar radiation 5.15 kWh/m² in Tulancingo de Bravo, Hidalgo, Mexico.

With an initial sample weight of 43.5 g and a final sample weight of 14g.

With a Yield of 32.18%, a Drying Ratio of 30.7 g/hour, and a Drying Rate of 30.7 g/hour. Several tests were carried out on different days and at different times, Table 3 shows the results of the characterization of the dehydration process of different products.

Food dehydration process					
Product	mini (g)	ms (g)	H. initial (%)	H. recommend (%)	T. maximum permissible (°C)
Handle	35	20	43	12 - 15	65
Broccoli	2	1.5	25	6	65
Cucumber	5	2	60	8	75
Banana	5	2	60	15	70
Tomato	10	2	80	8	65
Potato	10	5	50	13	75
Approximately 0.5 cm thick slices					

Table 3 Result of the food dehydration process
Source: Own Elaboration

Characterization of the solar dehydrator					
Day 2: 04/05/2022					
Time	T environment (ºC)	H environment (%)	T entrance to the chamber (ºC)	H in drying chamber (%)	Collector flow rate (m³/s)
10:00	25	26	38	47	3.87
11:00	25	25	40	40	4.18
12:00	25	31	42	46	5.12
13:00	25	45	39	77	5.59
14:00	21	60	50	55	5.89
15:00	20	69	36	53	5.89
16:00	20	70	45	52	5.89
Prom	23	46.57	41.43	52.86	5.20

Table 4 Process characterization of the day 2 solar dehydrator prototype
Source: Own Elaboration

The duration of the test was 6 hours from 10:00 am to 4:00 pm.

Solar radiation 5.2 kW/m². Tulancingo de Bravo, Hidalgo, Mexico.

Initial sample weight 67g, final weight 32.5g.

Yield 48.51%.

Drying rate 61,583 g/hour.

Figure 5, below, shows a sample of the result of dehydration of fruits and vegetables.

Figure 5 Example of dehydrated vegetables and fruits day 2 in a time of 6 hours
Source: Own Elaboration

Direct sunlight should be avoided as it bleaches the color and reduces the level of vitamins A and C. Drying temperature should be controlled to avoid overheating and deterioration (Espinoza, 2016).

Air circulation around the product to be dehydrated is very important, since it evacuates the moisture already extracted, maintaining a dry environment, which accelerates dehydration. For the case study, forced circulation was used because a fan was used as an electrical means to force air movement; this system is suitable for large and complex systems; a photovoltaic panel was used as external energy supply in addition to the energy coming from the sun.

The drying performance of the dehydrator with a sample of 110.5 g was 40% and an average drying rate of 51.14 g/h, easily accessible, making it an innovative system that contributes to the social and economic development of highly marginalized municipalities in the state of Hidalgo, the country and abroad in vulnerable situations.

Conclusions

The indirect solar dehydration system with insulating materials, concentrators and low-cost heat transporters controlling the temperature and humidity for fruits and vegetables that are found in most of the municipalities and localities in isolated areas of precarious economic conditions, the values obtained throughout the study have shown that solar radiation is more than enough to perform an adequate dehydration process for drying the foods described above without affecting their nutrients, even when the average temperature is at 20°C, drying of fruits and vegetables is obtained.

The solar dehydrator achieves a 35.74% temperature increase over a conventional dehydrator, confirming that this dehydrator gives the dehydration results.

Based on the results of the tests carried out, it is possible to contribute both to access to food for the vulnerable population and, if accompanied by greenhouse production strategies, to increase the intake of seasonal fruits and vegetables and to strengthen the nutritional status of families.

These alternatives add to the care of the environment with products from the region, considering the seasonal climates, the productive vocation of the place, making it possible to program and then dehydrate them.

Finally, promote the recovery of sowing-cropping-harvesting practices that have been carried out in the localities over time, and incorporate them as training for family members and reactivate these cultural traditions in rural production, achieving comprehensive attention to the problem of food security and that the population itself has new ways to address it for their benefit.

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Experimental analysis to identify colored noises in electrical systems

Análisis experimental para clasificar ruidos de colores en sistemas eléctricos

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Abstract

The main objective of this paper is to identify the several types of color noise existing in electrical systems, a methodology is proposed for the identification of color noise using a data acquisition system and calculating the power spectral density, this methodology is applied experimentally in three systems achieving to determine the color noise present.

Color noise, Experimental process, Spectral slope

Resumen

El objetivo principal de este trabajo es identificar los diferentes tipos de ruidos de color existentes en los sistemas eléctricos, se propone una metodología para la identificación de los ruidos de colores utilizando un sistema de adquisición de datos y calculando la densidad espectral de potencia, esta metodología se aplica de manera experimental en tres sistemas logrando determinar el ruido de color presente.

Pendiente espectral, Análisis de Ruido, Ruido de colores

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1. Introduction

Noise is present in measurement systems and causes disturbances or fluctuations in the signals due to its random nature, Vasilescu (2005) mentions that the IEEE standard dictionary establishes and classifies noise by its origin: internally (from the system itself) and externally or interference (from another place and mixed with the signal of interest), both generate contamination in the signal and, to eliminate it, a filter is normally used, hence the importance of identifying the type of noise so that the proposed filter is adequate.

The work presented by Zhivomirov (2018) classifies noise into colours according to the behaviour of its spectral slope, also known as the power law, which is proportional to the reciprocal of the frequency f^α. This is done by estimating the power spectral density.

The generation of coloured noise has been studied for a couple of decades, Corsini & Saletti (1988), Saletti (1986), Kasdin (1995) and Halford (1968) have provided different methods to create and analyse its behaviour. The modelling of an RC circuit with a current source with added white noise, which is used to generate other types of coloured noise and the analysis of pink noise are presented in the works of Keshner (1982) and Gruber (1986), finally, Murao *et al*. (1992) show the use of logarithmic and anti-logarithmic amplifiers for its generation.

There are applications of coloured noises: Pettai (1984) explains the different types of noises and their sources, including heat-generated noise. In the area of neuroscience, Galán (2009) applies low-amplitude colour noise for deep brain stimulation in order to control neuronal excitability efficiently. On the other hand, Bryson & Johansen (1965) reduce the amplitude of colour noise in dynamic systems using the Kalman filter.

In the electrical area there are several works, Ott (1988) makes an extensive study of noise in electronic systems: he determines its presence in passive elements, active noise devices and noise in digital circuits. Coloured noise is used by Mahdi (2018), which presents investigations of 1/f noise fluctuations with different temperatures applied to a tunable laser diode configuration.

Also, Levinshtein & Rumyantsev (2010) demonstrate the presence of 1/f noise in different semiconductor devices and Nabati & Farnoosh (2021) have applied coloured noise generation in RLC-type circuits in a simulated manner. Most of the works described above only present the generation and simulation of coloured noises, without performing the experimental part of measurement and analysis. In this work, three systems are analysed (the sensor of a level control system, the current of a frequency converter and the voltage in the capacitor of an RLC circuit fed by a programmable voltage source) in order to detect and classify the types of colour noise present experimentally.

This work is divided in the following way, section 2 presents the methodology for the identification of the colour noise, section 3 shows the results obtained experimentally and section 4, the conclusions.

2. Methodology

a. Colour noise classification

The classification of coloured noise depends on the power spectral density (PSD) of a measured signal and is determined by the following equation:

$$PSD \propto \frac{1}{f^{\alpha}} \tag{1}$$

Where f is the frequency in Hz and α is an integer value bounded between -2 and 2, depending on the value of α the noise is classified in the colours red, pink, white, blue and violet, each colour noise has different amplitudes depending on its frequency, these amplitudes increase or decrease, which can be plotted by a PSD where the slope shows the increase or decrease of decibels for each decade of frequency. Table 1 shows the properties of the above-mentioned coloured noises.

Noise Colour	**Value of α**	**Pending (dB/dec)**
Red	Partition 1	-20
Pink	Partition 2	-10
White	Partition 3	0
Blue	Partition 4	10

Table 1 Properties of coloured noises.

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There are different ways to determine the PSD of a signal that is in the time domain, the one used in this work is the Welch averaged periodogram, defined as a non-parametric spectral estimator based on the classical periodogram that divides the signal spectrum into equal segments, develops a classical periodogram for each segment and determines an average of them.

The advantage of using the Welch averaged periodogram is that it allows overlap between segments, reduces the variance of the powers and maintains good resolution as a function of frequency. This is obtained using Matlab software and the methodology to determine it is as follows:

1. Divide the measured signal into equal segments (by default it is 8).
2. Perform the overlap or superimposition between segments (by default, 50% is considered).
3. For each segment, calculate the fast Fourier transform and square the magnitude to determine the power spectra.
4. Average the power spectra to obtain the averaged Welch periodogram.

Finally, the proposed methodology to determine the type of colour noise experimentally is:

1. Analyse the noise of the DAQ (Data Acquisitions System) system.
2. Measure the variables of the system, taking into account that the sampling frequency must be at least 100 times the highest frequency.
3. Calculate the PSD of the variable to be analysed considering the sampling frequency.
4. PSD analysis (the increment or decrement value in db/dec).
5. Classify the type of colour noise present.

a. Experimental systems

In this work, measurements on three systems are presented: the MPCT process control system, a variable frequency drive applied to a three-phase motor and a series RLC circuit fed with a programmable voltage source. A description of the electrical system as well as the data acquisition system is given in this section.

i. **Process Control System (PPCS)**

The MPCT shown in Figure 1 is a system that allows to control process variables such as: temperature, pressure, flow and level, the signal to be analysed is the voltage generated by the level sensor, which is a differential pressure sensor that produces a voltage proportional to the value of the level of the tank.

Figure 1 Process control system

The DAQ to be used is NI-Crio-9068 with the NI-9220 module, which is programmed using LabVIEW software in the FPGA and HOST interface, the level sensor signal is a dc signal proportional to the tank level, for the analysis a sampling frequency of 100 kHz was selected, the measured data are stored in a file in TDMS format, for subsequent analysis in the frequency domain in Matlab and display the PSD of the measured signal. Figure 2 shows the front panel of the HOST interface where the graph of the measured values in real time can be observed.

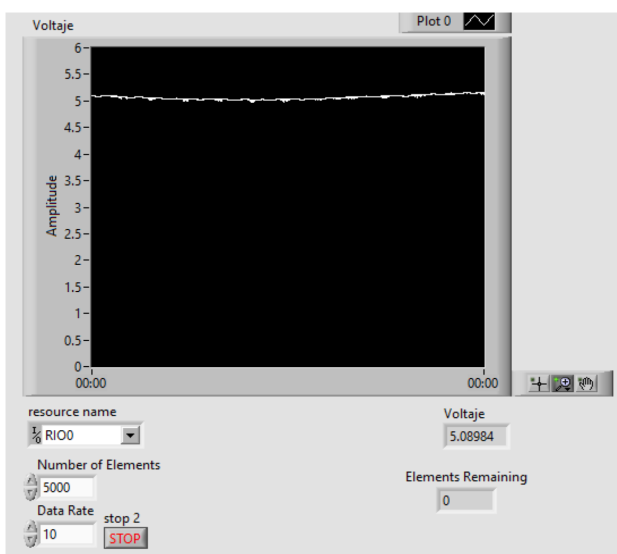

Figure 2 Host interface front panel

i. Frequency inverter applied to a three-phase motor

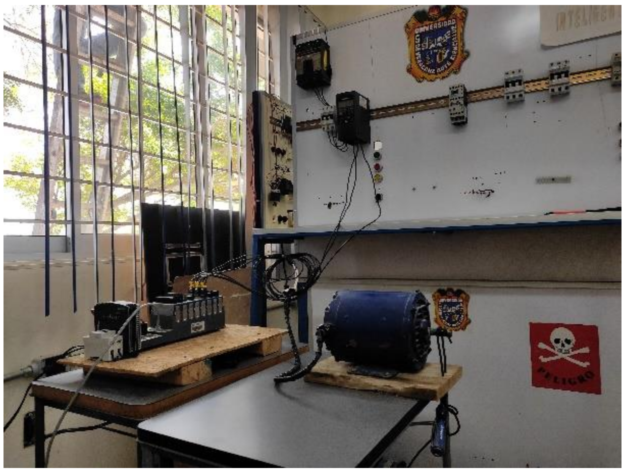

Figure 3 Three-phase motor speed control system

A frequency inverter is a device for controlling the speed of electric motors. The equipment used is the "Micromaster 420 inverter", which is connected to a three-phase motor and its parameters are shown in Table 2. The signal to be analysed is the electric current, which contains noise produced by electronic components such as IGBTs. Figure 3 shows the frequency inverter, the motor used and the data acquisition system, which is the NI Crio-9068 connected to the NI 9246 readout card.

Variable	Value
Voltage	220 C
Current	1.8 A
Frequency	60 Hz
Power	1180 hp
Speed	1800 rpm

Table 2 Three-phase motor parameters

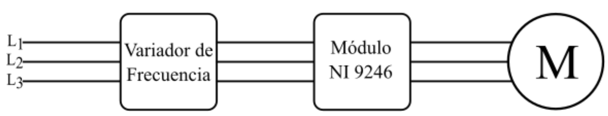

Figure 4 Wiring diagram used for noise analysis

The DAQ used is programmed in the two interfaces of the LabVIEW software, whose front panel of the Host is shown in Figure 5. The signals to be analysed are the currents of the three-phase motor, with three different frequencies 40, 50 and 60 Hz working at full load, for the analysis a sampling frequency of 50 kHz was selected.

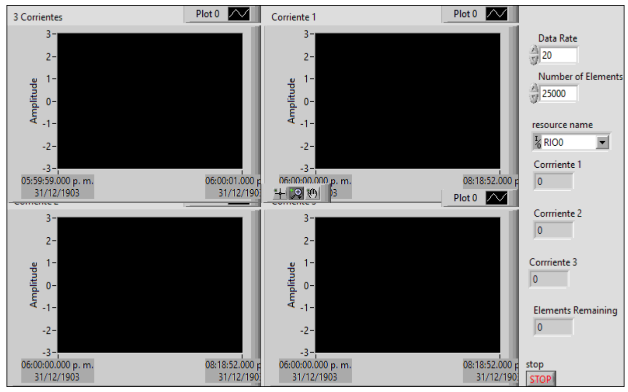

Figure 5 Front panel for taking current readings

i. Serial RLC circuit connected to a programmable power source

The voltage source used is the "Programmable AC/DC Power Source APS-1102", this equipment provides voltages of up to 400 Vdc and 280 Vrms with output signals in DC, AC sinusoidal or square and with variable frequency. The purpose of using this equipment is to detect the type of colour noise generated by its electronic components, the physical connection of the data acquisition system connected to the serial RLC circuit is shown in Figure 6.

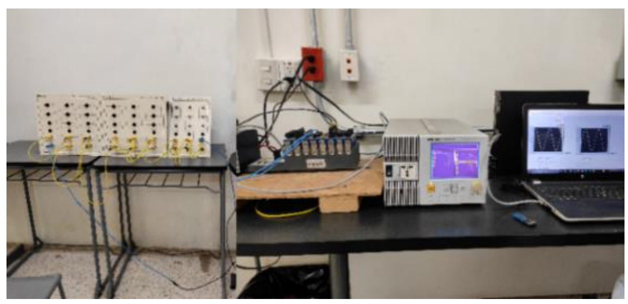

Figure 6 Data acquisition system connected to the RLC circuit.

An RLC circuit is a second order linear system that is usually used as an analogue filter configured in a range of frequencies, it is formed by a resistor (R), an inductor (L) and a capacitor (C), the values selected for each element are in Table 3. The signal to be analysed is the voltage on the capacitor and the inductor current, in order to check the noise generated by the external power supply and the passive components of the circuit.

Variable	Value
Resistance (R)	546.23 Ω
Inductor (L)	1 H
Capacitor (C)	571.43 nF

Table 3 RLC circuit elements

The series RLC circuit has the particularity of acting as a second order low-pass filter, allowing frequencies below the cut-off frequency f_c to pass through and attenuating those above it. The cut-off frequency is determined by the transfer function of the system and is given by equation (2), substituting the selected values for the RLC circuit we obtain a cut-off frequency of $f_c = 210.5419\ Hz$.

$$f_c = \frac{1}{2\pi\sqrt{LC}}\ Hz \quad (2)$$

The DAQ to be used is a Crio 9068, with the 9246 and 9242 cards to measure current and voltage respectively, the voltage and frequency configurations to be analysed are presented in Table 4, for the analysis a sampling frequency of 50 kHz was established, the graphs of the measured data are presented in Figure 7.

No.	Waveform	**Input voltage (V_{rms})**	**Frequency (Hz)**
1	Sine	200	50
2	Sine	200	60
3	Square	150	20
4	Square	250	180

Table 4 Programmable source configurations

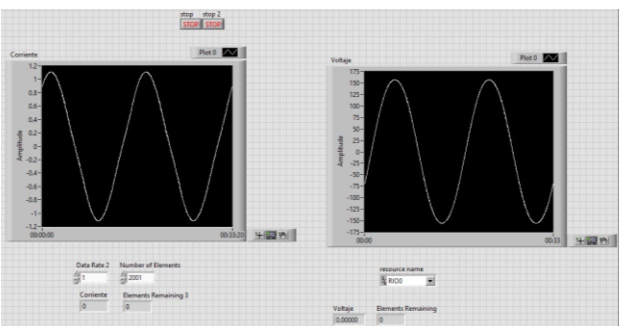

Figure 7 Host interface for taking current and voltage readings

3. Results

The results of the measurements performed on the DAQ without connection to any system, the MPCT system, the variable frequency drive and the RLC circuit with a programmable voltage source are described. First a brief explanation of the time domain results is given and then their PSD is analysed to determine the noise colour based on their spectral slope and Table 2.

a. DAQ measurements

Figure 8 shows the measurements made to the NI-9220 module without connection, on the left shows the noise signal in the time domain, where you can see that has a sinusoidal shape with an amplitude ranging between -0.02 and 0.03, on the right is the PSD, which shows that the spectral slope is 0 value, therefore, the noise generated by the dc voltage reading module is white.

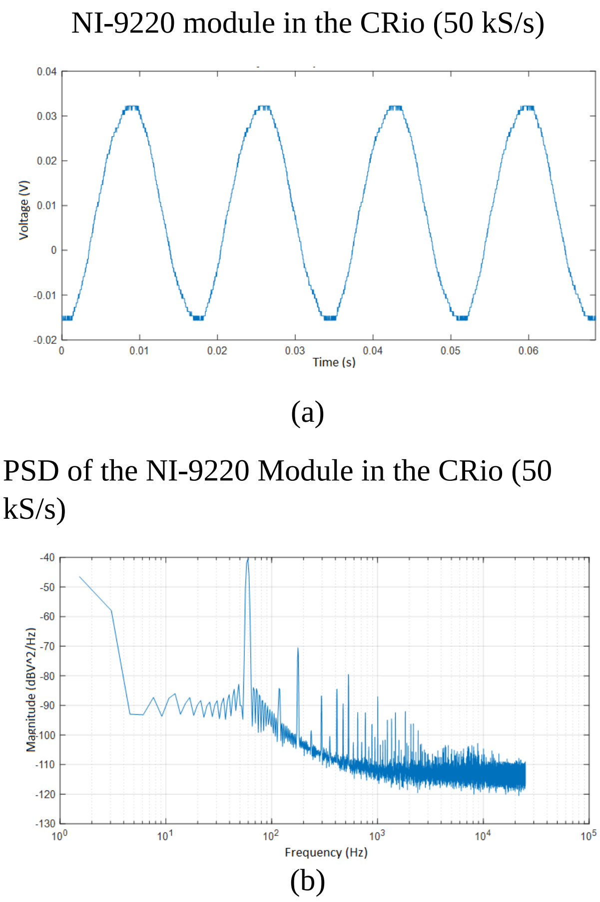

Figure 8 Measurement of the DAQ-9220

Figure 9 shows the measurement of the 9242 module without being connected to a system, in the time domain there is a lot of randomness of the measured signal, from the PSD it is observed that the power remains constant, which indicates that the noise produced is white.

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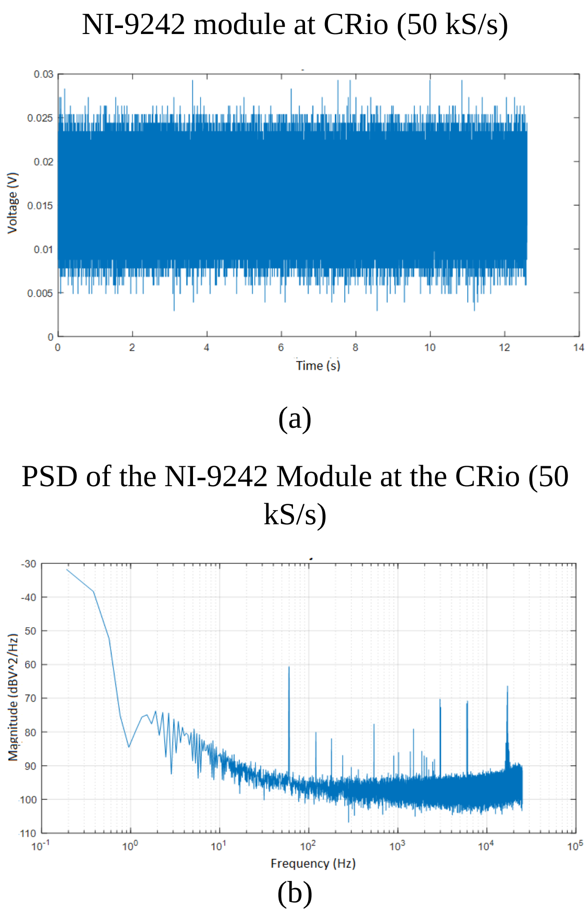

Figure 9 Measurement of the DAQ-9242

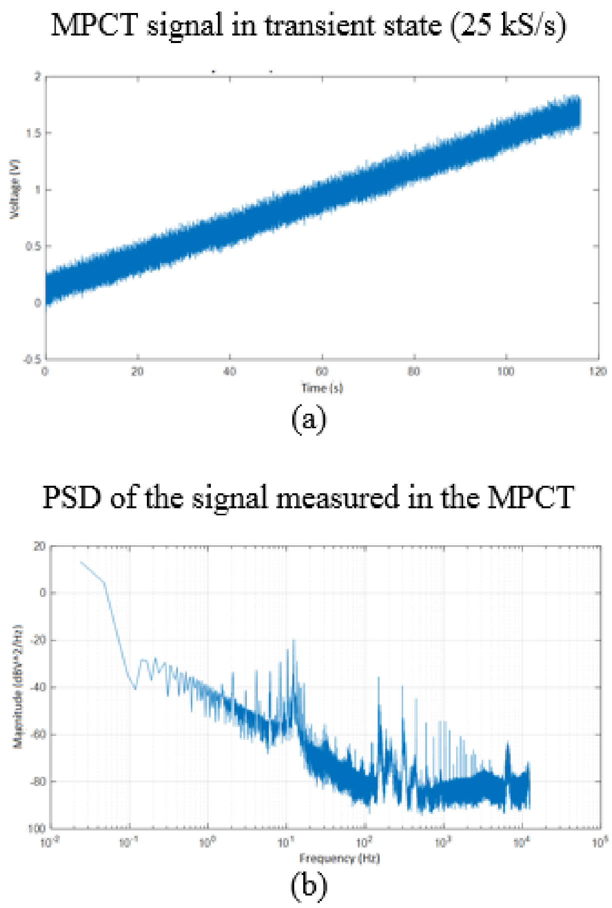

Figure 10 MPCT in transient state (25 kS/s)

b. Process Control System (MCPT)

The MPCT results are shown in two cases: the transient state, referred to the process where the water level is at 0 and rises until it reaches the reference level of the system and the steady state, given when the reference value has been reached and the water level does not vary, the reference value used for this system was 50 cm level.

Figure 10 (a) shows the signal measured in transient state in the time domain sampled at a frequency of 25 kS/s for a time span of 70 s, it is observed that the tank level signal is very noisy, but it is not possible to classify the type of noise present, therefore, it is necessary to analyse it in the frequency domain.

Figure 10 (b) shows the MPCT measurement in transient state, where the PSD decreases by -20 db/dec (red noise) at low frequencies (up to 100 Hz), at high frequencies the PSD remains flat (white noise).

To demonstrate that the sampling frequency is independent of the noise present in the system, a sampling frequency of 50 kS/s was used. In the PSD of the signal measured at higher frequency is shown in Figure 11 (b), where it is observed that the spectral slope has a value of -20 db/dec, the colour noise present is red and as in Figure 10 (b), presents a white noise at high frequencies (slope value 0), therefore, it is concluded that the MPCT system in transient state presents a red noise regardless of the sampling frequency at which the DAQ is configured.

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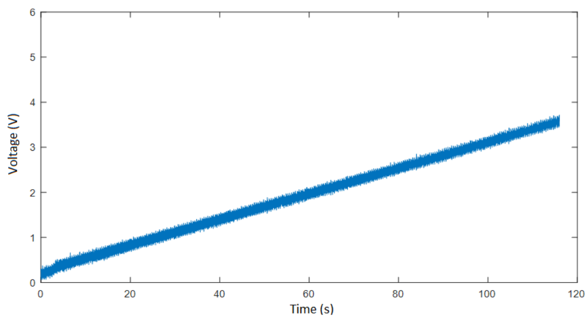
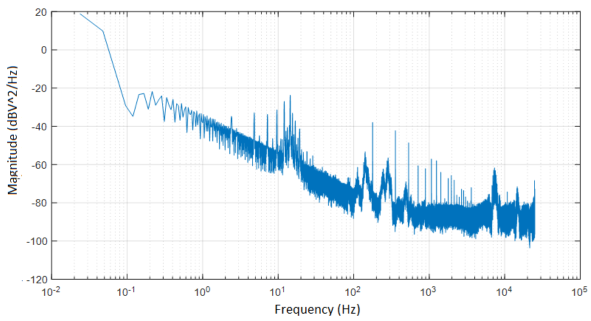
MPCT signal in transient state (50 kS/s)



(a)

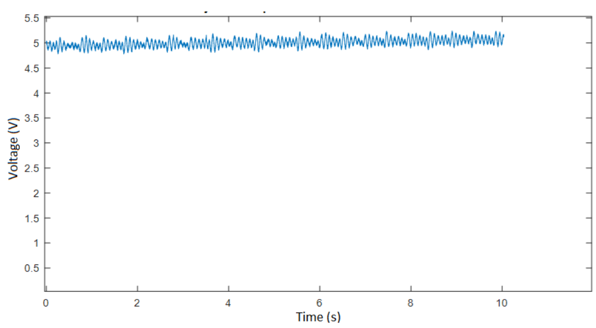
PSD of the signal measured in the MPCT



(b)

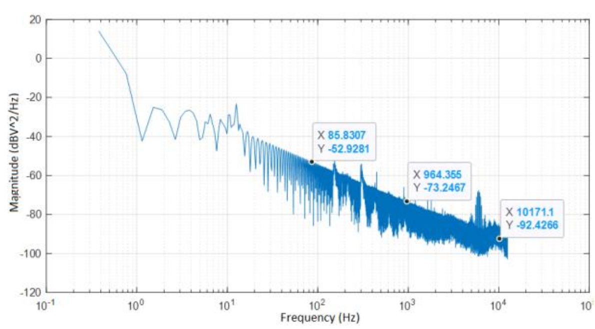
Figure 11 MPCT in transient state (50 kS/s)

Steady state MPCT signal (25 kS/s)



(a)

PSD of the signal measured in the MPCT



(b)

Figure 12 Steady-state MPCT (25 kS/s)

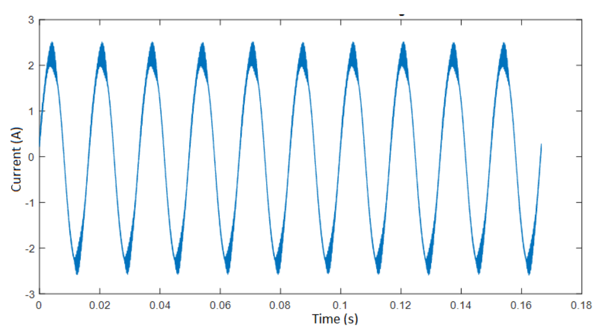
Figure 12 (a) shows the results of measuring the system in steady state at 25 kS/s, the measured value stays around 5V (proportional to the 50 cm level). Figure 12 (b) shows that the PSD has a slope that decreases by 20 db/dec, which is characteristic of red noise. Therefore, it is concluded that in steady state and transient the noise present in the system is red.

c. Frequency inverter

The analysis of the noise present in the frequency inverter is carried out by measuring the motor current, only the results of a single phase are shown because the three measured signals are the same.

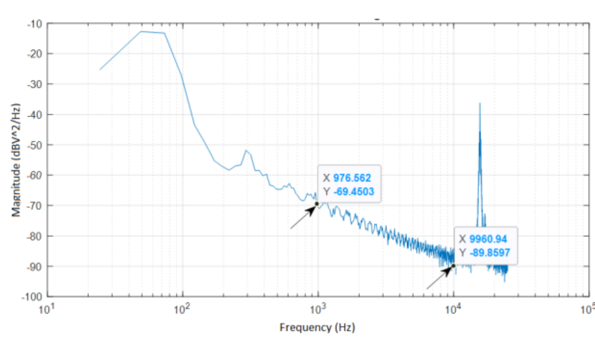
The tests carried out at the frequencies of 60, 50 and 40 Hz are shown in Figures 13 to 15 respectively, where the graphs at the top represent the signal in the time domain and the figures at the bottom are the PSD. It is observed the existence of noise in the current signal in the time domain, being more noticeable in the peak of the sine wave signal, however, this is not enough to classify the type of noise.

Signal in the time domain (60 Hz)



(a)

Spectral Power Density



(b)

Figure 13 Single-phase measurements of motor current under load (set to 60 Hz)

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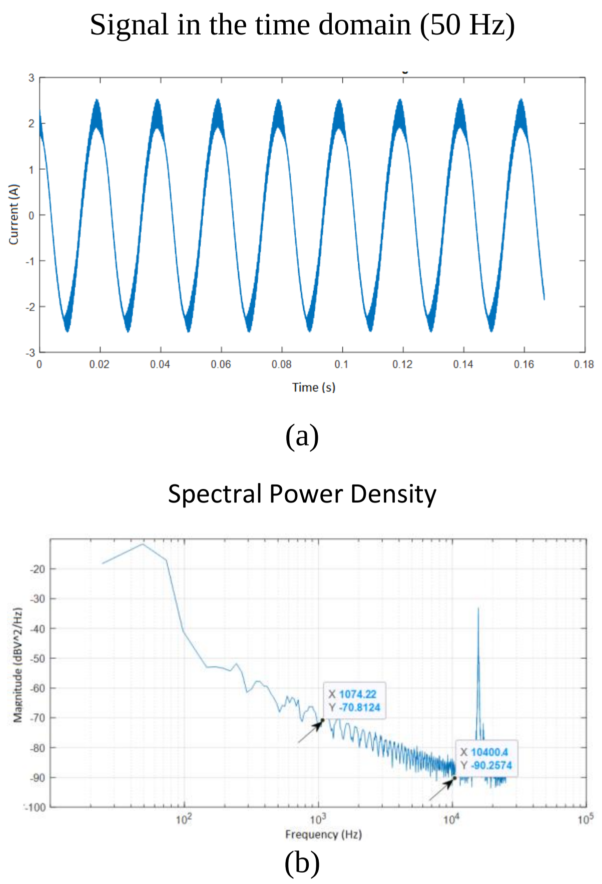

Figure 14 Single-phase measurements of motor current under load (set to 50 Hz)

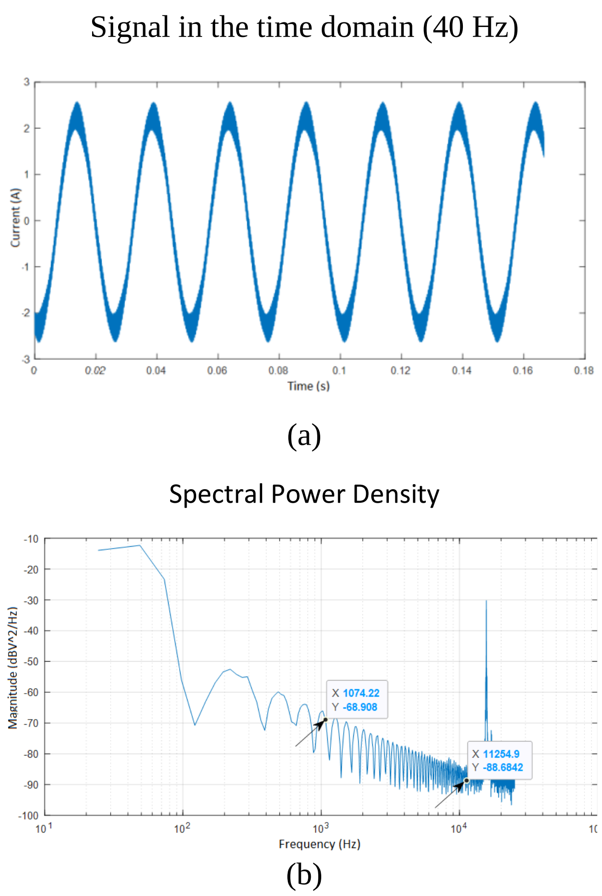

Figure 15 Single-phase measurements of the motor current under load (set at 40 Hz)

Analysing the signal in the frequency domain, it is observed that the power is reduced by 20 db/dec, this value is typical of the red noise. Therefore, after analysing the PSD of Figures 13 to 15, it can be concluded that, regardless of the operating frequency of the frequency inverter, the red noise is present.

d. Serial RLC circuit connected to a programmable source

In this section, the measurements made on the circuit with different input voltages, frequencies, and signals are analysed, as shown in Table 2. In the voltage and current signals obtained in the serial RLC circuit no noise is observed in the analysis in the time domain, however, the study of the same signals in the frequency domain is observed that, even when the amplitude is very low can be classified in a colour.

The results of measurement 1 are shown in Figures 16 and 17, where the signal voltage measured on the capacitor and the current of the RLC circuit are shown in the time domain, at the bottom of each Figure is its PSD. When analysing the spectral slopes, it can be seen that the noise presented by the external source signal is red, this is due to the fact that the noise power decays in 20 db/dec.

Figures 18 and 19 show the results of measurement 2, in this case, from the PSD the 60 Hz component associated to the input signal can be observed, in the same way as the first measurement, the noise present in the system is red, this is due to the fact that the PSD power is reduced by 20 db/dec.

The results of the third measurement are shown in Figures 20 and 21, in this case, the graphs in the time domain are slightly modified by the capacitive and inductive components, its load in the first half cycle and discharge in the second cause the signal measured and supplied by the voltage source are different, in the right column are observed the PSD corresponding to the voltage and current, they present a greater fluctuation, but the red noise can still be detected by the analysis of the spectral slope. Figures 22 and 23 show the graphs corresponding to the fourth measurement, unlike the previous case, the waveform is affected in the current, the PSD of voltage presents a decrease of 20 db/dec preserving the red noise colour, however, the PSD of current is reduced by 10 db/dec, value belonging to the pink noise.

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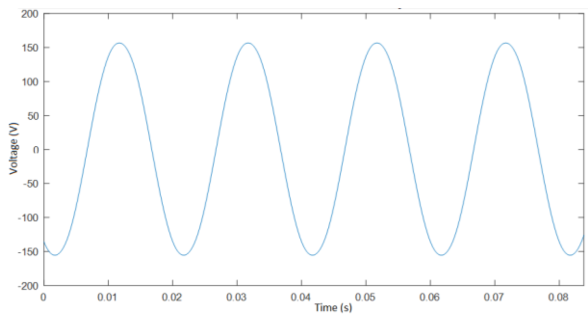
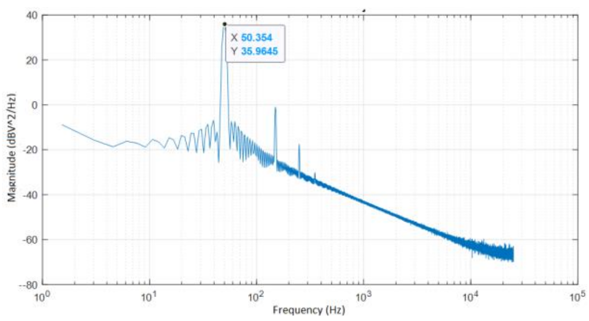
$\boldsymbol{V_i = 200\ V_{RMS},\quad f = 50\ Hz}$

Time domain voltage



(a)

Spectral Power Density

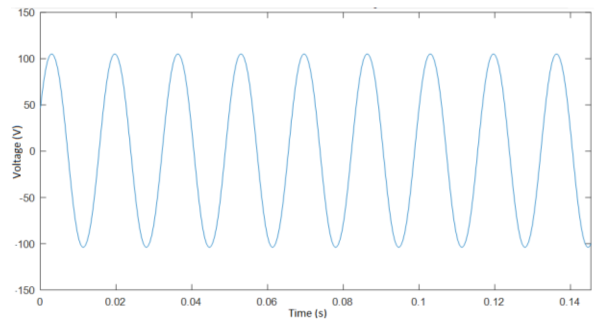


(b)

Figure 16 Capacitor voltage of the circuit fed with 200 Vrms at 50 Hz (sine wave signal)

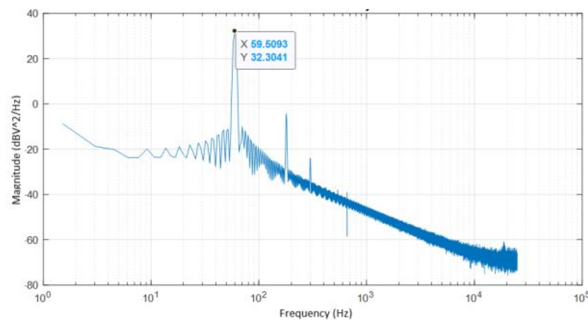
$\boldsymbol{V_i = 200\ V_{RMS},\quad f = 60\ Hz}$

Time domain voltage



(a)

Spectral Power Density

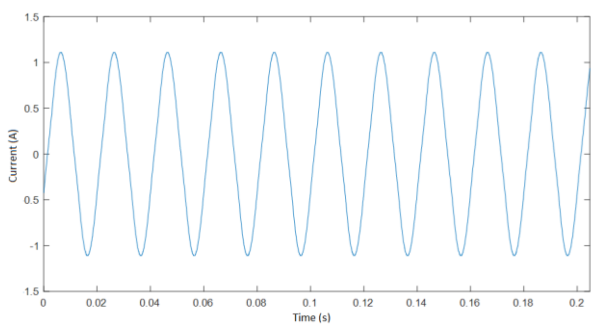


(b)

Figure 18 Capacitor voltage of the circuit fed with 200 Vrms at 60 Hz (sine wave signal

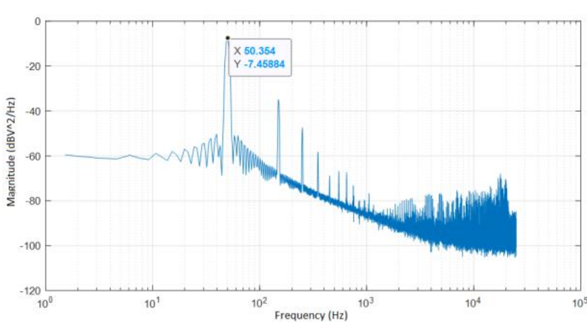
$\boldsymbol{V_i = 200\ V_{RMS},\quad f = 50\ Hz}$

Corriente en el dominio del tiempo



(a)

Densidad Espectral de Potencia

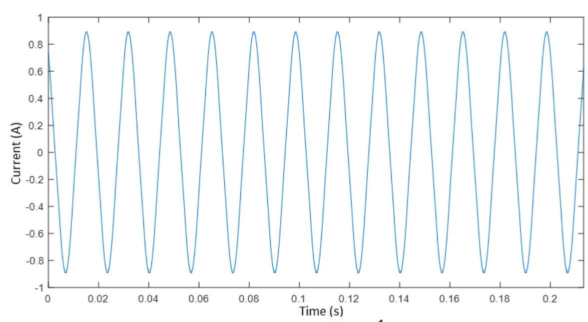


(b)

Figure 17 Current in the circuit fed with 200 Vrms at 50 Hz (sine-wave signal)

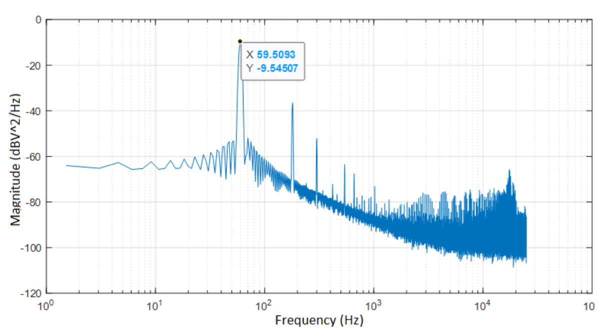
$\boldsymbol{V_i = 200\ V_{RMS},\quad f = 50\ Hz}$

Time domain current



(a)

Spectral Power Density



(b)

Figure 19 Current in the circuit fed with 200 Vrms at 60 Hz (sine-wave signal)

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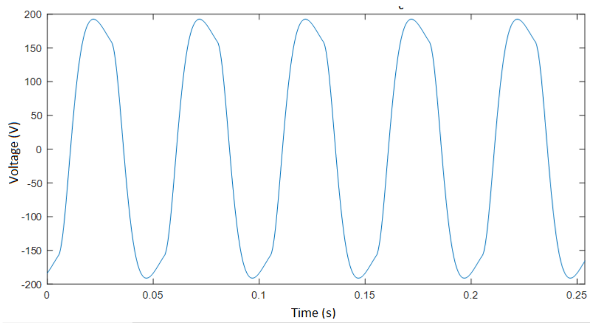
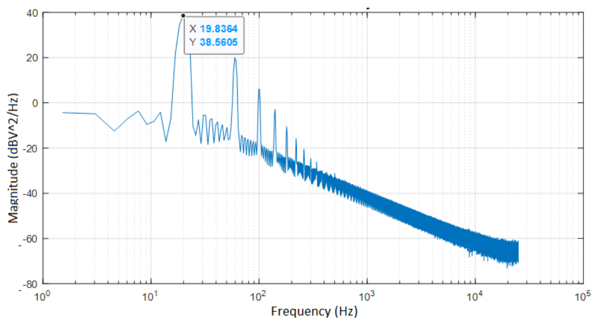
$V_i = 150\ V_{RMS}, \quad f = 20\ Hz$

Time domain voltage



(a)

Spectral Power Density

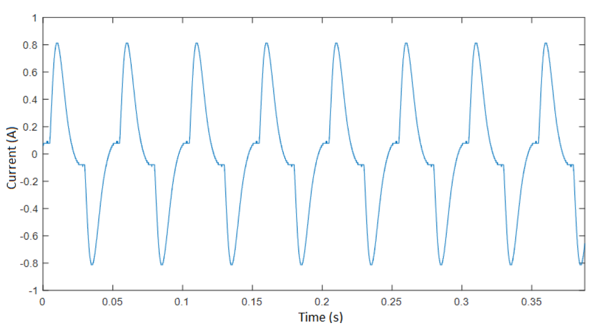


(b)

Figure 20 Capacitor voltage of the circuit fed with 150 Vrms at 20 Hz (square signal)

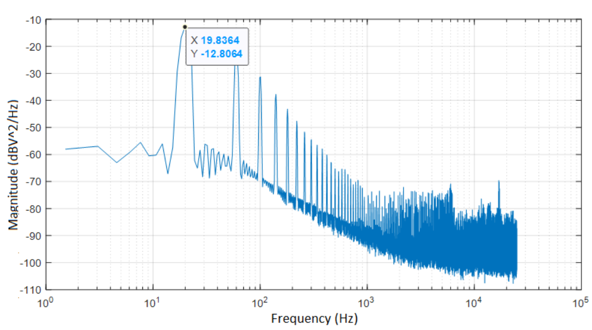
$V_i = 150\ V_{RMS}, \quad f = 20\ Hz$

Time domain current



(a)

Spectral Power Density

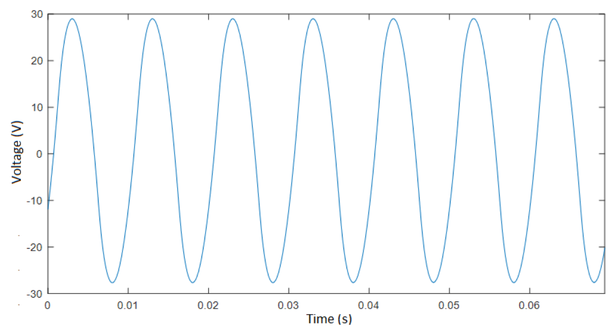


(b)

Figure 21 Current in the circuit fed with 150 Vrms at 20 Hz (square signal

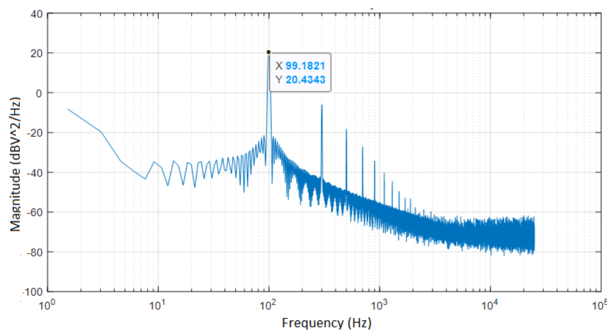
$V_i = 200\ V_{RMS}, \quad f = 100\ Hz$

Time domain voltage



(a)

Spectral Power Density

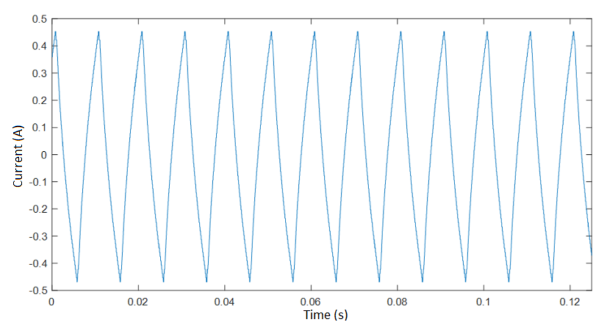


(b)

Figure 22 Voltage at capacitor of circuit fed with 200 Vrms at 100 Hz (square signal)

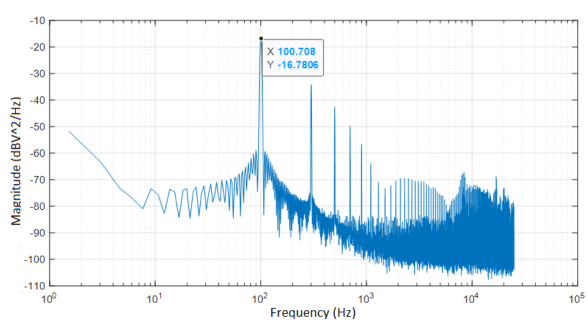
$V_i = 200\ V_{RMS}, \quad f = 100\ Hz$

Time domain current



(a)

Spectral Power Density



(b)

Figure 23 Current in the circuit fed with 200 Vrms at 100 Hz (square signal)

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4. Conclusions

After performing the measurements and analysing the power spectral density of the signals, it is concluded that the electrical systems contain noise (in greater or lesser quantity) and can be of different colours. To detect the type of colour noise it is not necessary to generate or simulate them, from the PSD it is possible to observe the increase or decrease of decibels per decade and from this, classify it into a colour. It is possible that some system generates a noise that is not appreciable in the time domain, the analysis of the PSD belonging to the frequency domain can detect the type of colour noise present in the system even when its amplitude is very small any electrical equipment has colour noise present, this could be verified in the three experimentally analysed systems.

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Abstract (In English, 150-200 words)

Objectives
Methodology
Contribution

Keywords (In English)

Indicate 3 keywords in Times New Roman and Bold No. 10

Abstract (In Spanish, 150-200 words)

Objectives
Methodology
Contribution

Keywords (In Spanish)

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† Researcher contributing as first author.

Introduction

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General explanation of the subject and explain why it is important.

What is your added value with respect to other techniques?

Clearly focus each of its features

Clearly explain the problem to be solved and the central hypothesis.

Explanation of sections Article.

Development of headings and subheadings of the article with subsequent numbers

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Including graphs, figures and tables-Editable

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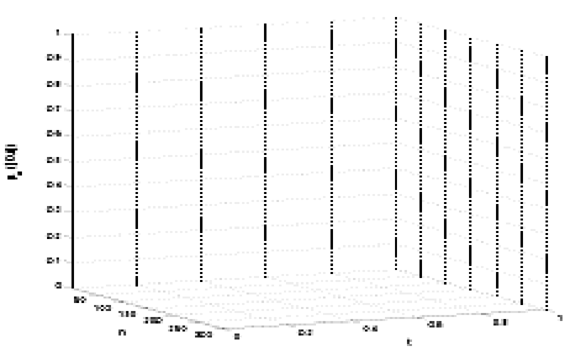

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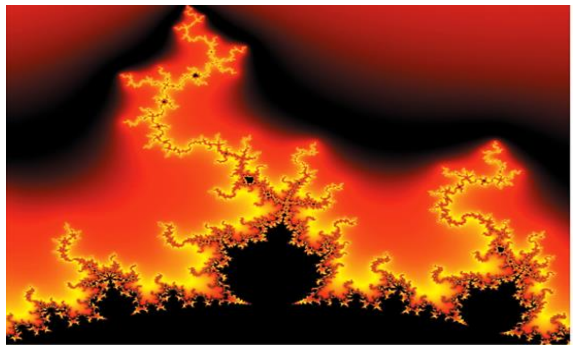

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