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Presentation of the Content

In the first chapter we present, *Change points in the hazard function of survival models*, by MUÑOZ-VARGAS, Blanca Xochilt, JUÁREZ-HERNÁNDEZ, Bulmaro and REYES-CERVANTES, Hortensia Josefina, with adscription in the Benemérita Universidad Autónoma de Puebla, as next article we present, *Implementation of a Quantitative Method to determine the Degree of Satisfaction of the Physics Laboratory Service within the Faculty of Electrical Mechanical Engineering of the Veracruzana University in the Poza Rica - Tuxpan Region*, by CHAGOYA RAMÍREZ, Jorge Alberto, LAGUNA-CAMACHO, Juan Rodrigo, CHAGOYA-RAMÍREZ, Julio Cesar and PURATA-MARTÍNEZ, Estefanía, with adscription in the Universidad Veracruzana en Poza Rica Veracruz, as next article we present, *WhatsApp conversation analysis as a means of motivation for teaching in data science*, by NAVARRERE-ARIAS, Dulce J., HERNÁNDEZ-GARCÍA, Héctor Daniel and PÉREZ-BAUTISTA, Mario, with adscription in the Instituto Tecnológico Superior del Occidente del Estado de Hidalgo, as last article we present, *Steady-state simulation model of a smart load based on the electric spring implemented in Simulink*, by RICO-VELA, José Luis, TAPIA-TINOCO, Guillermo, FIGUEROA-GODOY, Fernando and LOZANO-LUNA, Alfonso, with adscription in the Instituto Tecnológico Superior de Irapuato.

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Change points in the hazard function of survival models

Puntos de cambio en la función de riesgo de modelos de supervivencia

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Abstract

In this work, a chronological presentation of the main results and applications of the different investigations that analyze the problem of the change point in the hazard function of survival models is made, these include the constant hazard function by parts and Cox-type regression models with change points.

Survival analysis, Hazard function, Change points

Resumen

En este trabajo se hace una presentación de manera cronológica de los principales resultados y aplicaciones de las diferentes investigaciones que analizan el problema del punto de cambio en la función de riesgo de modelos de supervivencia, estos incluyen a la función de riesgo constante por partes y modelos de regresión tipo Cox con puntos de cambio.

Análisis de supervivencia, Función de riesgo, Puntos de cambio

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Introduction

The problem of testing and estimating the change points has attracted much attention in the literature, one of the most studied models in the change point problem is the normal model (univariate or multivariate), this is because the normal model is the most common model in practice. However, the change point problem has also been studied in models: exponential, gamma, regression, and survival, to name a few. In Survival Analysis, the simplest model is the constant hazard function, which corresponds to the exponential distribution and has been widely studied, however, in most applications this model is not the most appropriate, so it is use other distributions such as Weibull, log-normal, log-logistic, Gamma, Generalized Gamma, etc. for better settings. Another alternative to have better adjustments was to introduce a change point to the hazard function. The first hazard function that was studied with a change point was the constant hazard function, that is, the hazard is equal to a constant until a certain unknown moment from which the hazard is equal to another constant. This model is different from the one studied by (Hinkley, 1970) who considered a change point in a sequence of random variables.

Next, different studies of change points in the hazard function of survival models are presented, in some cases the original notation is changed to have homogeneity of notation. This work is organized as follows, in section 2 survival models with a constant hazard function by parts are presented, in section 3 some models with a non-constant hazard function with change points are shown and Cox-type regression models with change points are presented in section 4. Finally, section 5 presents the conclusions.

Constant hazard function by parts

One of the first studies that includes a change point in the hazard function of a survival model is that of (Matthews & Farewell, 1982) who studied the time-to-failure model with constant hazard function by parts with a change point, so the hazard function is given by

$$h(t) = \begin{cases} \lambda_1, & si\ t \leq \tau \\ \rho\lambda_1, & si\ \tau < t, \end{cases}$$

(function $\lambda(\cdot)$ of equation (1) of (Matthews & Farewell, 1982)) and the parameters $\lambda_1 > 0$, $\rho > 0$ and $\tau > 0$ have to be estimated. The parameter τ is called the change point. Since the asymptotic likelihood standard inference cannot be applied, they cited a numerical method to calculate maximum likelihood estimators, they simulated the distribution of the likelihood ratio statistic for the null hypothesis of the hypothesis set

$$H_0: \rho = 1\ \&\ \tau = 0 \text{ vs } H_1: \rho \neq 1\ \&\ \tau > 0,$$

and they applied this model to data from patients with acute non-lymphoblastic leukemia. As a result, they obtained that, for uncensored time samples, certain percentiles of the simulated null distribution of the likelihood ratio statistic, $2\hat{\Lambda}_0$, are close to the percentiles of the distribution $\chi^2_{(2)}$, which would be the distribution asymptotic of $2\Lambda_0$ if the asymptotic likelihood ratio theory could be applied. Also, they found that the procedures for uncensored data can be applied to censored data.

Later, (Nguyen, Rogers & Walker, 1984) also studied the survival model with a constant hazard function by parts with a change point expressing the hazard function as

$$h(t) = aI(0 \leq t \leq \tau) + bI(\tau < t), \qquad (1)$$

where $I(A)$ is the indicator function of the set A. In this case the parameters $a > 0$, $b > 0$ and $\tau > 0$ have to be estimated, the latter being the change point parameter. They considered the density function as a combination of two exponential densities (one truncated to the right in τ and the other lagged in τ) with unknown weights that depend on the parameters to be estimated and showed that the log likelihood function, $l(\cdot)$, is unbounded when $b = 1/(\mathrm{t}_n - \tau)$ and τ is close to t_n, where t_n is the longest observed lifetime and n is the sample size, and if $a > b$, $l(\cdot)$ is bounded. Furthermore, for τ known (Nguyen, Rogers & Walker, 1984) calculated the maximum likelihood estimators of the reciprocals of a and b, denoted by $A_n(\tau)$ and $B_n(\tau)$, respectively, which depend of τ. It can be verified that these expressions are recursive in terms of n. While for unknown τ, they obtained a strongly consistent estimator of τ, $\hat{\tau}_n$, examining a stochastic process with which $A_n(\hat{\tau}_n) \to 1/a$ and $B_n(\hat{\tau}_n) \to 1/b$ both with probability 1. Finally, they showed the behavior of the estimators via simulation.

Matthews & Farewell (1985) eliminated the singularity identified by (Nguyen, Rogers & Walker, 1984) in the log-likelihood function for the constant hazard rate model by parts with a change point (1) adequately defining the likelihood function as

$$L(a,b,\tau)=\left[\prod_{i=1}^{n-1}\{e^{-at_i}(e^{a\epsilon}-e^{-a\epsilon})\}\right]$$

$$\times\left\{e^{-a(t_n-\epsilon)}-e^{-a\tau-b(t_n+\epsilon-\tau)}\right\}, \qquad (2)$$

when $t_n-\epsilon<\tau<t_n+\epsilon,\ t_1<\cdots<t_n$ are the order statistics of the random sample and $n>1$ is any sample size. The Equation (2) is due to the fact that the product of the values of the probability density function in the observations must be considered as an approximation to the true probability, then the contribution to the likelihood corresponding to an observed value t_i is proportional to $F(t_i+\epsilon)-F(t_i-\epsilon)$, i.e., the probability that the observation t_i belongs to a small interval, that probability is finite for $i=1,\dots n$.

Matthews, Farewell & Pyke (1985) studied the problem of testing a constant hazard rate against a constant hazard rate by parts that involves a single change point in which the hazard rate is reduced. They expressed the hazard function as

$$h(t)=\begin{cases}\lambda, & si\ 0\le t<\lambda\\ (1-\xi)\lambda, & si\ \tau\le t,\end{cases} \qquad (3)$$

(function $\lambda(\cdot)$ of equation (1) of (Matthews, Farewell & Pyke, 1985)) where $0\le\xi<1$, $\lambda>0$ and $\tau\ge 0$. Thus, τ is a change point parameter for the hazard rate and the parameters to be estimated are λ, ξ and τ. They showed that the asymptotic significance level for the hypothesis test

$$H_0:\xi=0 \text{ vs } H_1:\xi\neq 0, \qquad (4)$$

based on the maximum score statistics involves the solution to the problem of the first step time for an Ornstein-Uhlenbeck process, for this it is assumed that $\tau\in[\tau_l,\tau_u]$ with τ_l and τ_u known. Finally, they applied their results to data from non-Hodgkin lymphoma patients.

Yao (1986) considered the model (1) and eliminated the problem of the unbounded logarithmic likelihood function by proposing the constraint $\tau\le t_{(n-1)}$ where $t_{(n-1)}$ is the $(n-1)$-th statistic of order of observed lifetimes. It was calculated the restricted maximum likelihood estimators for τ, a and b, denoted by $\hat{\tau}$, $\hat{a}$ and $\hat{b}$ respectively, showed that $\hat{\tau}$ is consistent, derived the limit distributions of $\hat{\tau}$, $\hat{a}$ and $\hat{b}$ and showed that $\hat{\tau}$, $\hat{a}$ and $\hat{b}$ are asymptotically independent.

The model (3) was also studied by (Yao, 1987), he proposed a test to contrast the null hypothesis of a constant hazard function against the alternative of a change point in the constant hazard function by parts (hypothesis set (4)). It was showed that this problem is related to a quality control problem (mentioned as Problem B), due to this relationship he proposed a statistical test for (4) that is based on a test with a Bayesian approach to Problem B. The main advantages of this test are its computational simplicity and the availability of the theory of the distribution of small and large samples.

Worsley (1988) also studied the hypothesis set of constant hazard function against a change point in the constant hazard rate by parts at an unspecified time. The author stated the hazard function as follows

$$h(t)=\begin{cases}\lambda_1, & si\ t\le\tau\\ \lambda_2, & si\ \tau<t,\end{cases}$$

(function $\lambda(\cdot)$ of the first equation of (Worsley, 1988)) where $\lambda_1>0$ and $\lambda_2>0$ are the hazard rates and $\tau>0$ is the change point. Since the likelihood ratio is unbounded, the author provided alternatives for eliminating the singularity (in which the change point is assumed to belong to an interval and in artificially censoring the largest observation) and he found the exact null distribution of a statistic of restricted likelihood ratio test.

This distribution is not affected by type II censorship but strongly depends on the interval in which the change point is assumed to belong. He also compared exact percentage points with simulated percentage points reported in the literature. Finally, he applied his results to data from patients with acute non-lifoblastic leukemia that (Matthews & Farewell, 1982) had previously studied.

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Chang, Chen & Hsiung (1994) considered hazard rate models with a change point that allows random censorship in which

$$h(t) = \beta + \theta I(\tau \leq t)$$

(function $\lambda(\cdot)$ of equation (1.1) of (Chang, Chen & Hsiung, 1994)) where $\beta > 0$, $\beta + \theta > 0$ and $\tau > 0$ is the parameter of change point. They proposed a change point estimator by examining a Nelson-Aalen type functional estimator in the context of counting processes and established the consistency and asymptotic distribution of the proposed estimator.

Chen & Baron (2014) studied the model with a constant hazard function $h(t) = \lambda_0$ until an unknown time τ, the change occurs in time τ and $h(\cdot)$ changes to a new value λ_1 and it stays that way thereafter. Therefore,

$$h(t) = \lambda_0 I(t \leq \tau) + \lambda_1 I(\tau < t),$$

(function $\lambda(\cdot)$ of equation (1) of (Chen & Baron, 2014)) where $\lambda_0, \lambda_1 > 0$ and $\tau > 0$ is the change point, the main parameter of interest. They proposed a new alternative estimation procedure based on the Kaplan-Meier estimation of the survival function followed by the least square estimation of the change point and established strong consistency of all estimators. The authors applied their methods to data from a clinical trial of the strong-drug treatment program.

Goodman, Li & Tiwari (2011) studied the following survival model whose hazard function is constant in parts

$$h(t) = \begin{cases} \alpha_1, si\ 0 \leq t \leq \tau_1, \\ \alpha_2, si\ \tau_1 < t \leq \tau_2, \\ \vdots \\ \alpha_{k+1}, si\ \tau_k < t, \end{cases}$$

(function $\lambda(\cdot)$ of equation (1) of (Goodman, Li & Tiwari, 2011)) where $0 = \tau_0 < \tau_1 < \cdots < \tau_k < \infty$ are the change points, k the number of change points in the model and α_j the value of the hazard function between the times τ_{j-1} and τ_j. They proposed a maximum likelihood estimate by profiles and based on the independence of the estimates of α_j and τ_j that (Yao, 1986) showed, they proposed a Wald-type test statistic only for the parameters of the hazard rate (α_j) while treating the parameters of the change point (τ_j) as fixed, that is, the set of hypotheses that test is

$$H_0: \alpha_{k-1} - \alpha_k = 0 \text{ vs } H_1: \alpha_{k-1} - \alpha_k \neq 0.$$

In addition, they proposed a model selection algorithm that uses sequential tests for the constant hazard model by parts, this method is based on the data and allows estimating not only the number of change points in the hazard function, but also where they occur those changes and developed an alpha spending scheme such that the maximum number of change points, k, need not be prespecified. Finally, they conducted simulation studies that confirm the validity of the proposed test and applied their methods to test the change points in the hazard rates of prostate cancer patients.

Majumder & Mitra (2019) proposed a test to detect trend changes in hazard functions. The testing problem is H_0: constant failure rate vs H_1: bathtub shaped failure rate. Test statistics based on a weighted integral approach are constructed using a measure of deviation from exponentiality. They exploit the theory of the L-statistic to obtain the exact and asymptotic distributions of their statistics and establish the consistency of the test. Finally, a simulation study and applications to real-life data sets are presented to illustrate their results.

Non-constant hazard function with a change point

In many applications, the hazard function is not constant before or after the change point, so a model is needed that encompasses other possibilities. Wu, Zhao & Wu (2003) extended the model with a constant hazard function with a change point and studied the model with a hazard function given by

$$h(t) = [\beta + \theta I(t > \tau)]\lambda_0\left(t; \underline{\gamma}\right), \quad (5)$$

(function $\lambda(\cdot)$ of equation (1.2) of (Wu, Zhao & Wu, 2003)) where $\lambda_0\left(\cdot;\underline{\gamma}\right)$ is a continuous baseline hazard function that depends on an unknown parameter vector $\underline{\gamma}$. The model (5) covers many important models commonly used in Survival Analysis, such as the models exponential ($\lambda_0\left(x;\underline{\gamma}\right)=1$), Weibull ($\lambda_0\left(x;\underline{\gamma}\right)=x^{\gamma}$), extreme ($\lambda_0\left(x;\underline{\gamma}\right)=e^{\gamma x}$) and log-logistics ($\lambda_0\left(x;\underline{\gamma}\right)=x^{\gamma_1}/(1+\gamma_2 x^{\gamma_1+1})$). Considering a random sample with random censorship, the authors proposed a non-parametric estimator of the change point in the context of counting processes. In addition, they showed that both the change point estimator and the other estimators are consistent.

Brazzale, et al. (2019) studied the survival model with a decreasing hazard rate before the change point and a constant hazard rate after the change point given by

$$h(t)=h_1(t)I(t<\tau)+\lambda I(t\geq\tau),$$

where $\lambda>0$, $\tau\geq 0$ is the change point, $h_1(\cdot)$ is a continuous hazard function before the change point and the hazard function is also continuous at the change point, that is, $h_1(\tau)=\lambda$. They presented a new method for estimating the change point that is based on fitting a regression to the p values of the hazard rate tests in small time intervals. In the end, they presented three examples of real data that describe the survival patterns of seriously ill patients, whose mortality rates persist beyond hospital discharge.

Cox-type regression models with change points

The proportional hazard or Cox model is used to study the relationship between survival time and covariates, which can be constant or time-dependent, and can be studied using parametric and semi-parametric methods. The semi-parametric proportional hazards model proposed by (Cox & Oakes,1984) has been widely adopted in clinical trials with time-to-event results to compare an experimental versus standard care treatment. A key assumption in the Cox model is that the hazard ratio function is a constant over time, which is often violated, as there will be a lag period before the experimental treatment reaches its full effect. For example, the Kaplan-Meier estimates of survival curves in many oncology clinical trials with two treatment arms overlap at the start of the treatment period up to a certain time point and then begin to separate, indicating that the constant hazard ratio assumption may have been violated and there may be a change point in the hazard ratio function (He, Fang & Su, 2012).

The semiparametric transformation models have been proposed as a broad class of regression models and includes the proportional hazards and proportional odds models as special cases. The other useful and flexible alternative is the Aalen's additive risk model, which allows the influence of covariates on a hazard function to vary separately and nonparametrically through time. Although allowing greater flexibility than the proportional hazards model, the number of covariates that can be handled by Aalen's model is quite limited. To reduce the number of functions needed to be estimated, McKeagues & Sasieni (1994) introduced a partly parametric version of Aalen's model, called the partly Aalen's additive hazards model, where the influence of some covariates varies nonparametrically over time and that of the remaining covariates is restricted to be constant in time (Shen, 2020).

Other extensions of the Cox model have been investigated in the literature, for example, the two-step regression model studied by (Anderson & Senthilselvan, 1982)

$$h\left(t,\underline{z}\right)=\begin{cases}\lambda_0(t)\,exp\left(\underline{\alpha}'\underline{z}\right), si\ t\leq B\\ \lambda_1(t)\,exp\left(\underline{\gamma}'\underline{z}\right), si\ B<t\end{cases}$$

(function $\lambda(\cdot)$ of equation (3) of (Anderson & Senthilselvan, 1982)) where $\lambda_0(\cdot)$ and $\lambda_1(\cdot)$ are unknown functions, $\underline{z}$ is a vector of covariates, $\underline{\alpha}$ and $\underline{\gamma}$ refer to the dependence of the hazard function in $\underline{z}$ to short and long term, respectively, and B is a change point. Other extensions to the proportional hazard model that also include change points in the hazard function are presented below.

Liang, Self & Liu (1990) considered the model

$$\mathrm{h(t)}=\lambda_0(\mathrm{t})\exp\{(\beta+\theta\mathrm{I}(\mathrm{t}\leq\tau))\mathrm{Z}+\underline{\gamma}'\underline{X}\}$$

(function $\lambda(\cdot)$ of equation (1) of (Liang, Self & Liu, 1990)) where $\lambda_0(\cdot)$ is the underlying hazard rate, Z is a variable believed to be related, possibly with different magnitudes, to the survival time, $\underline{X}$ is a vector of covariates whose effects do not vary in time and τ is a change point in time that belongs to the interval $[a, b]$ with known a and b. They proposed a maximum score test statistic for the hypothesis game

$$H_0: \theta = 0 \text{ vs } H_1: \theta \neq 0,$$

and applied their results to a data set from a longitudinal study of hypertension.

Luo & Boyett (1997) studied the following model

$$h(t) = \lambda_0(t) \exp\{\beta_0 I(X \leq \theta_0) + \underline{\alpha}_0' \underline{Z}\} \quad (6)$$

(function $\lambda(\cdot)$ of equation (1) of (Luo & Boyett, 1997)) where X is a one-dimensional covariate and $\underline{Z}$ is p-dimensional, in this model a constant is added after reaching a threshold. The parameters to be estimated are θ_0, β_0 and $\underline{\alpha}_0$. They test consistency of partial maximum likelihood estimators. Finally, they applied the above method to a cohort of patients with lineage B leukemia treated at St. Jude Children's Research Hospital.

Luo, Chen & Boyett (1996) also studied the model (6), presented asymptotic distributions for maximum likelihood estimators, and applied their results to simulated data and data of patients treated for newly diagnosed acute lymphoblastic leukemia.

Pons (2003) introduced the model

$$h(t) = \lambda_0(t) \exp\{\underline{\alpha}' \underline{Z}_1(t) + \underline{\beta}' \underline{Z}_2(t) I(Z_3 \leq \zeta) + \underline{\gamma}' \underline{Z}_2(t) I(Z_3 > \zeta)\},$$

(function $\lambda(\cdot)$ of equation (1.1) of (Pons, 2003)) where the influence of a covariate jumps in a certain limit ζ. In this case, the author showed that the estimator of the change point parameter is n-consistent, the estimators of the regression parameters are $n^{1/2}$-consistent and established the asymptotic distributions of the estimators.

He, Fang & Su (2012) studied the following change point model

$$\beta(t) = \begin{cases} \beta_1, si\ 0 \leq t \leq \tau_1, \\ \beta_2, si\ \tau_1 < t \leq \tau_2, \\ \vdots \\ \beta_{k+1}, si\ \tau_k < t, \end{cases}$$

where $\beta(\cdot)$ is the logarithmic function of the hazard ratio, $0 = \tau_0 < \tau_1 < \cdots < \tau_k < \infty$ are the change points, k is the number of change points in the model and β_j is the value of the logarithm of the hazard ratio between the time points τ_{j-1} and τ_j. They proposed maximizing the partial log likelihood function to obtain the estimators and a sequential test procedure to determine the number of change points in the logarithmic function of the hazard ratio.

Dupuy (2006) studied the following hazard model with a change point:

$$h(t|\underline{Z}) = (\alpha + \theta I(t > \tau)) \times \exp\{\left(\underline{\beta} + \underline{\gamma} I(t > \tau)\right)' \underline{Z}\} \quad (7)$$

(function $\lambda(\cdot)$ of equation (3) of (Dupuy, 2006)) where $\alpha > 0$, $\alpha + \theta > 0$ and τ is an unknown change point in time; furthermore, $\underline{\beta}$ and $\underline{\gamma}$ are unknown regression coefficients. He also considered the following hazard function, which allows the covariates to be time dependent, which often appear in the survival analysis literature:

$$h(t|\underline{Z}) = (\alpha + \theta I(t > \tau)) \times exp\{\left(\underline{\beta} + \underline{\gamma} I(t > \tau)\right)' \underline{Z}(t). \quad (8)$$

It was obtained consistent estimators for the models (7) and (8). He showed that under some established conditions, the estimators converge in probability, this is tested by the modern empirical process theory.

Later, Palmeros, Tajonar & Juárez (2011) developed the case of time-dependent covariates since (Dupuy, 2006) only mentions that should be considered to carry out the demonstrations in this case.

Palmeros (2012) proposed the following combined parametric model:

$$h(t|Z, \underline{X}) = (\alpha + \theta I(t > \tau)) \lambda \zeta (\lambda t)^{\zeta - 1} \exp\{[\beta + \gamma I(t > \tau)] Z + \underline{\rho}' \underline{X}\},$$

where $\alpha > 0$, $\alpha + \theta > 0$, $\lambda > 0$, $\zeta > 0$, τ is the change point parameter, $\beta \in \mathbb{R}$, $\gamma \in \mathbb{R} - \{0\}$ and $\underline{\rho} \in \mathbb{R}^q$ is the regression coefficient, Z is the covariate in charge of recording a treatment and $\underline{X} \in \mathbb{R}^q$ is a vector of other risk factors associated with the event of interest. It was developed the estimation process and demonstrated the consistency of the proposed estimators.

Gandy, Jensen & Lütkebohmert (2005) studied the following variant of the Cox model with a smooth change point at an unknown limit $h_i(t, \underline{\theta}) = \lambda_0(t) R_i(t) \exp\{\underline{\beta}_1' \underline{Z}_{1i}(t) + \beta_2 Z_{2i} + \beta_3 (Z_{2i} - \xi)^+\}$, (function $\lambda_i(\cdot)$ of (Gandy, Jensen & Lütkebohmert, 2005)) where $\underline{\theta} = \left(\xi, \underline{\beta}'\right)'$ with $\underline{\beta} = \left(\underline{\beta}_1', \beta_2, \beta_3\right)' \in \mathrm{B} \subset \mathbb{R}^{p+2}$ is the vector of the regression parameters and $\lambda_0(\cdot)$ is the baseline hazard function and $R_i(\cdot)$ is a process that only takes values 1 or 0 indicating whether an individual is at risk or not. The change point is indicated by ξ, which is a parameter that belongs to a compact interval $[\xi_1, \xi_2]$ of known parameters ξ_1 and ξ_2. It is assumed that the true value of the parameter, $\underline{\theta}_0 = \left(\xi_0, \underline{\beta}_0'\right)'$, where $\underline{\beta}_0 = \left(\underline{\beta}_{10}', \beta_{20}, \beta_{30}\right)'$, is identifiable, with $\beta_{30} \neq 0$. In this model $\underline{\theta}_0$ is estimated by the value $\underline{\hat{\theta}}_n$ that maximizes the logarithm of the partial likelihood. Finally, The authors showed that under some conditions there exists a neighborhood Θ_0 of $\underline{\theta}_0$ such that if $\underline{\hat{\theta}}_n$ belongs to Θ_0, it follows that $\underline{\hat{\theta}}_n$ converges in probability to $\underline{\theta}_0$ when $n \longrightarrow \infty$.

The model proposed by (Jensen & Lütkebohmert, 2008) is an additional extension of the one suggested in (Gandy, Jensen & Lütkebohmert, 2005). Now more than a single change point is allowed to be in the model, the covariates are time dependent, and the counting process can jump more than once. The model involves m change points and p ordinary covariates (without change points), and is given as follows $h_i(t, \underline{\theta}) = \lambda_0(t) R_i(t) \exp\{\underline{\beta}_1' \underline{Z}_{1i}(t) + \underline{\beta}_2' \underline{Z}_{2i}(t) + \underline{\beta}_3' \left(\underline{Z}_{2i}(t) - \underline{\xi}\right)^+\}$, (function $\lambda_i(\cdot)$ of equation (1) of (Jensen & Lütkebohmert, 2008)) where $\underline{\theta} = \left(\underline{\xi}', \underline{\beta}'\right)'$ with $\underline{\xi} \in \Xi \subset \mathbb{R}^m$ and $\underline{\beta} = \left(\underline{\beta}_1', \underline{\beta}_2', \underline{\beta}_3'\right)' \in B \subset \mathbb{R}^{p+2m}$. Here $\underline{\xi}$ and $\underline{\beta}$ are the vectors of change points and regression parameters, respectively, $\lambda_0(\cdot)$ is the basal intensity and $R_i(\cdot)$ is a process that takes only the values 1 and 0 to indicate if the subject is at risk or not. For brevity, it is considered $\lambda_i(t, \theta) = \lambda_0(t) R_i(t) \exp\{\underline{\beta}' \underline{\tilde{Z}}_i\left(t; \underline{\xi}\right)\}$, where $\underline{\tilde{Z}}_i\left(t; \underline{\xi}\right) = \left(\underline{Z}_{1i}'(t), \underline{Z}_{2i}'(t), \left(\left(\underline{Z}_{2i}(t) - \underline{\xi}\right)^+\right)'\right)'$. It is assumed that the vector of change points belongs to a known rectangle $\Xi \coloneqq [\xi_{11}, \xi_{21}] \times [\xi_{12}, \xi_{22}] \times \ldots \times [\xi_{1m}, \xi_{2m}]$. The assumption that the values $\xi_{11}, \xi_{21}, \xi_{12}, \xi_{22}, \ldots, \xi_{1m}, \xi_{2m}$ are known is not a big restriction in real applications. The fundamental parameter $\underline{\theta}_0$ of this Cox-type model can be estimated with the value $\underline{\hat{\theta}}_n$ that maximizes the logarithm of the partial likelihood. It was showed that the estimators of the regression parameters and of the change points are $\sqrt{n}$-consistent, they demonstrated asymptotic normality and applied their model to three sets of data: actuarial, primary biliary cirrhosis (PBC) and electric motors.

Conclusions

The problem of the point of change has been studied in different types of models, in particular, in survival models. The first survival model with a change point that was studied was the one that has a constant hazard function in parts with a change point, in this case the log-likelihood function is unbounded when the change point is close to the larger observed time, so different studies were carried out with alternatives to eliminate this problem and later the model with several change points was studied. Since in most cases constant hazard is not adequate, change points were also included in other types of hazars functions, among which are those corresponding to Cox-type regression models, by introducing change points in these models defined different hazard functions since the point of change can occur at an unknown time or depend on a covariate. Another alternative that has been studied is the continuous hazard function with a change point, since a sudden change is not very realistic for most applications.

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As a result of all these studies, there is a variety of survival models with change points, in the majority, the estimation is based on the likelihood function, although recently other options have been explored and algorithms have been proposed that allow the identification of more than one change point.

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Article **Journal-Mathematical and Quantitative Methods**

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Implementation of a Quantitative Method to determine the Degree of Satisfaction of the Physics Laboratory Service within the Faculty of Electrical Mechanical Engineering of the Veracruzana University in the Poza Rica - Tuxpan Region

Implementación de un Método Cuantitativo para determinar el Grado de Satisfacción del Servicio del Laboratorio de Física dentro de la Facultad de Ingeniería Mecánica Eléctrica de la Universidad Veracruzana en la Región Poza Rica - Tuxpan

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Abstract

It is important to mention that educational quality and excellence within any Higher Education Institution lies in the importance of implementing continuous improvement in each of its different departments or areas, that is why constant analysis and self-evaluations of the services provided offered within it take on more and more importance, these are carried out in order to locate areas of opportunity in which it is necessary to implement strategies that help to achieve the desired levels of quality. This research is an analysis study focused on the services provided by the Physics Laboratory to its users of the Faculty of Electrical Mechanical Engineering of the Universidad Veracruzana in Poza Rica Veracruz, Mexico, using an applied opinion survey. to a sample of 169 people, which allows identifying the indices of each of the services that are provided, the results obtained provide relevant data that will later be used for the design of an improvement plan that allows generating actions that favor the continuation being a quality educational institution.

Quality, Education, Continuous improvement.

Resumen

Es importante mencionar que la calidad y excelencia educativa dentro de cualquier Institución de Educación Superior radica en la importancia de implementar la mejora continua en cada uno de sus diferentes departamentos o áreas, es por eso, que los análisis y autoevaluaciones constantes de los servicios que se brindan dentro de ella toman cada vez más importancia, estos se llevan a cabo con el fin de localizar áreas de oportunidad en las cuales se necesite implementar estrategias que coadyuven a conseguir los niveles de calidad deseados. La presente investigación, es un estudio de análisis enfocado a los servicios que presta el Laboratorio de Física a sus usuarios de la Facultad de Ingeniería Mecánica Eléctrica de la Universidad Veracruzana en Poza Rica Veracruz, México, utilizando para ello una encuesta de opinión aplicada a una muestra de 169 personas, la cual permite identificar los índices de cada uno de los servicios que en él se prestan, los resultados obtenidos aportan datos relevantes que posteriormente servirán para el diseño de un plan de mejora que permita generar acciones que favorezcan a continuar siendo una institución educativa de calidad.

Calidad, Educación, Mejora continua.

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General Objetive

Implement a Quantitative Method that generates new knowledge about the degree of satisfaction of the service provided by the Physics Laboratory within the Faculty of Electrical Mechanical Engineering of the Universidad Veracruzana in the Poza Rica - Tuxpan Region, through the application of a survey or questionnaire.

Particular Objetives

- Interpret the data obtained on the degree of satisfaction of the teams within the physics laboratory.
- Analyze the qualification given to the Physics Laboratory for the services provided in it.
- Identify areas of opportunity from the conclusion of results.

What is the importance of knowing the degree of satisfaction of the service in the Physics Laboratory?

Talking about the Physics Laboratory is to mention the basic needs for any Educational Program, this given the importance for each of the users who develop different academic practices within it, that is why the research carried out seeks to know the impact generated by the degree of satisfaction in each of the areas analyzed, all this in order to continuously improve as an Academic Institution, since the Faculty of Electrical Mechanical Engineering of the Veracruzana University in the Poza Rica-Tuxpan region is a recognized and accredited academic entity in each of its educational programs for its academic quality before the AC Engineering Teaching Accreditation Council in Mexico. In the same way, it is important to know the areas of opportunity in which improvements can be implemented based on a previous investigation, which is carried out on a sample of a certain number of users that support the data of each of the results obtained.

Background

Within the research works, it is important to mention if any exploration was previously carried out or carried out in the area or department where the current research is being carried out.

In particular, the Faculty of Electrical Mechanical Engineering of the Poza Rica - Tuxpan Region, is characterized by being an Institution of Higher Education (IES) in which a large amount of work, research and prototypes of an endless application of knowledge are developed, But not only the engineering part is the one that is worked on, one of the fundamental aspects in the correct functioning of the Faculty lies in the importance of Management, that is why this type of work helps to achieve the goals set internally.

As antecedents within the analysis of degree of satisfaction in the Faculty of Electrical Mechanical Engineering, we can consider the following publications:

- "Analysis of the Service of the Computing Laboratory of the Faculty of Mechanical and Electrical Engineering at the Universidad Veracruzana in Poza Rica Veracruz, Mexico" which was published in the "Higher Education Magazine, December 2020, Vol.4, No.12, 12-19.

- Analysis of the mechanical and electrical laboratory service at the faculty of electrical mechanical engineering of the Universidad Veracruzana in Poza Rica Veracruz, Mexico, indexed in Journal University Management June 2021, Vol. 5 No.13 6-13.

Methodology

The research carried out starts from the implementation of a quantitative method, in this case a survey or questionnaire, which consists of a set of questions regarding one or more variables to be measured (Chasteauneuf, 2009), on the other hand it can be mentioned that it is based on the selection of a probabilistic sample, since these have many advantages; Perhaps the main one is that the size of the error in our predictions can be measured (Sampieri Hernández, 2014, p. 177), we can propose the application of the survey from the identification of the segment to be evaluated, later it was possible to determine the procedure to follow In this case, having a finite population it was easier to dictate or establish the steps to follow.

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To determine the sample size, it was necessary to implement the following formula:

$$n = \frac{k^2 N\ p\ q}{[e^2(N-1)]+[k^2 p\ q]} \quad (1)$$

Where:

k: Confidence Level.
N: Population.
p: Probability of an event occurring.
q: Probability that an event will not occur.
e: Maximum accepted estimation error.

It is important to detail the analysis procedure step by step since every process has an order, then Figure 1 describes each of the stages carried out.

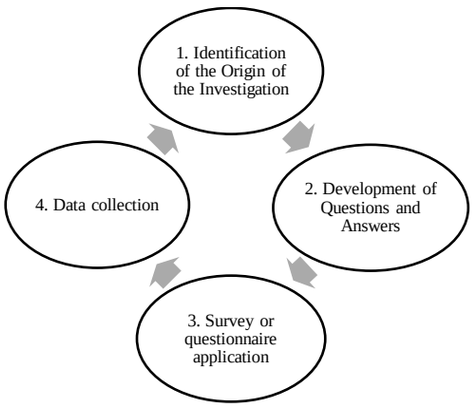

Figure 1 Phases of research development
Source: Own Elaboration

Identification of the Origin of the Investigation

Establishing the purpose of an investigation and identifying each of the variables that may exist within the aspects to be evaluated is one of the priority points for any investigation.

Derived from the aforementioned, this work arises from the need to generate a new knowledge of the current state of the degree of user satisfaction, through an analysis that provides data that allows identifying the aspects in which it can be improved in terms of service provided by the Physics Laboratory of the Faculty of Electrical Mechanical Engineering, likewise, locate each area of opportunity that is available and in which later improvement designs based on strategies are generated, all this in order to continuously improve as an institution .

Development of Questions and Answers.

The establishment and formulation of questions arises from an analysis based on each of the services that can be evaluated through a degree of satisfaction and with which the Physics Laboratory of the Academic Entity has, Figure 2 breaks down each of the services that were taken into account for your evaluation.

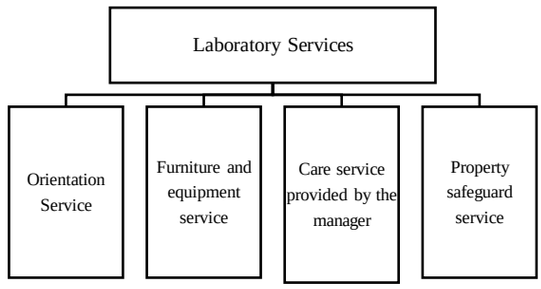

Figure 2 Physics Laboratory Services
Source: Own Elaboration

Once the measurable services were identified through a degree of satisfaction, it was decided to include complements that could strengthen the present analysis, taking important points such as the evaluation of the application of the internal regulations of the Laboratory, this due to the fact that a correct application of the rules and regulations of a certain space encourages a good service of this

Subsequently, each of the questions that make up this survey was carried out.

The answers that were taken into account for each question are based on their own, standardized and homogenized criteria, where the Excellent answer is considered the most favorable and the Bad answer is considered the least favorable.

Once the questions and answers of our questionnaire were established, the process continued to continue. Figure 3 shows the order of the questions, the possible answers and the structure presented by the survey.

It is important to mention that the implementation of the survey or questionnaire has the purpose of collecting concrete, accurate data and in the case of question 6 criteria that promote improvements or are of great importance to generate improvement or acquisition strategies in the areas, equipment and furniture within the Physics Laboratory.

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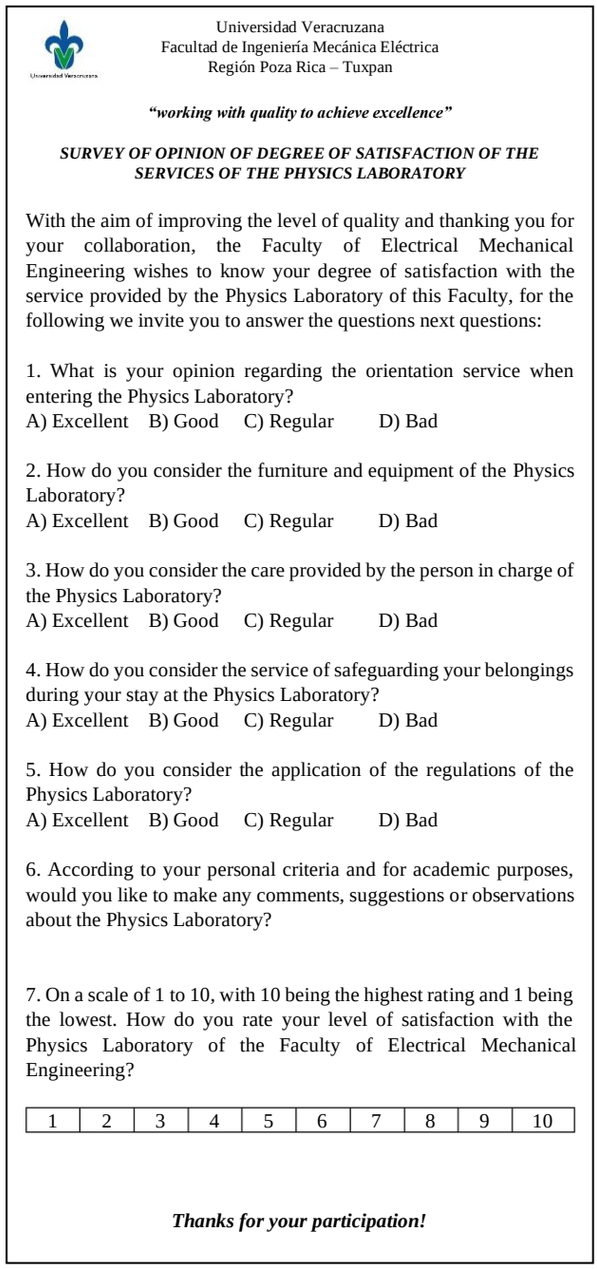

Universidad Veracruzana
Facultad de Ingeniería Mecánica Eléctrica
Región Poza Rica – Tuxpan

"working with quality to achieve excellence"

SURVEY OF OPINION OF DEGREE OF SATISFACTION OF THE SERVICES OF THE PHYSICS LABORATORY

With the aim of improving the level of quality and thanking you for your collaboration, the Faculty of Electrical Mechanical Engineering wishes to know your degree of satisfaction with the service provided by the Physics Laboratory of this Faculty, for the following we invite you to answer the questions next questions:

1. What is your opinion regarding the orientation service when entering the Physics Laboratory?
A) Excellent B) Good C) Regular D) Bad

2. How do you consider the furniture and equipment of the Physics Laboratory?
A) Excellent B) Good C) Regular D) Bad

3. How do you consider the care provided by the person in charge of the Physics Laboratory?
A) Excellent B) Good C) Regular D) Bad

4. How do you consider the service of safeguarding your belongings during your stay at the Physics Laboratory?
A) Excellent B) Good C) Regular D) Bad

5. How do you consider the application of the regulations of the Physics Laboratory?
A) Excellent B) Good C) Regular D) Bad

6. According to your personal criteria and for academic purposes, would you like to make any comments, suggestions or observations about the Physics Laboratory?

7. On a scale of 1 to 10, with 10 being the highest rating and 1 being the lowest. How do you rate your level of satisfaction with the Physics Laboratory of the Faculty of Electrical Mechanical Engineering?

1	2	3	4	5	6	7	8	9	10

Thanks for your participation!

Figure 3 Satisfaction degree survey
Source: Own Elaboration

Survey or questionnaire application

For the application of the survey it was necessary to identify the total size of Population N, which was 593 students belonging to the different Educational Programs offered in this Academic Entity, however, it is important to mention that 145 of these belong to the Enrollment S19 and 147 to Enrollment S20, which have not been able to carry out activities related to this laboratory, all this due to the current health situation, therefore 292 students were discarded for the present research work, our final population being N = 301 students.

Subsequently, it was ruled that the Confidence Level would be: k = 95% (1.96), p = 50% (Because it is unknown), q = 50% (Because it is unknown) and e = 5%, in such a way that, when inserting the data to the formula raised at the beginning, it is as follows:

$$n = \frac{(1.96)^2(301)(.5)(.5)}{[(.05)^2(301-1)]+[(1.96)^2(.5)(.5)]} \quad (2)$$

$$n = \frac{289.08}{[0.75]+[0.96]} \quad (3)$$

$$n = 169.05 \quad (4)$$

The final sample size was 169 users assigned to the Faculty of Electrical Mechanical Engineering. It is important to mention that the procedure for the application of the survey was carried out at the time of completing the registration within the Microsoft Forms platform, after that it was shared in different study groups, which allowed it to be answered remotely It should be noted that participation in this research was voluntary.

Data collection

In this phase, the opinion results of the surveys were quantitatively analyzed, the results of each question yield relevant information about the objective set out with this analysis, then the results of the frequency indices are shown in each item of each one. of the questions.

Question 1 assesses the service received upon admission to the Laboratory.

1. What is your opinion regarding the orientation service when entering the Physics Laboratory?		
Answers	Opinions	Porcentage
Excellent	41	24%
Good	78	46%
Regular	39	23%
Bad	11	7%
Total	169	100%

Table 1 Values recorded in question 1
Source: Own Elaboration

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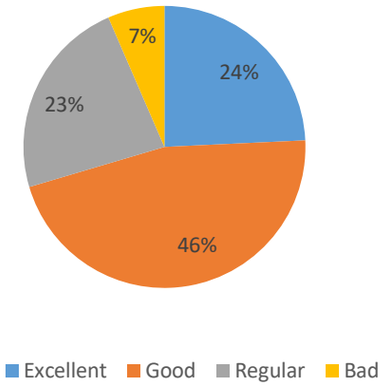
1. What is your opinion regarding the orientation service when entering the Physics Laboratory?



Resultados → Excellent: 41 people, Good: 78 people, Regular: 39 people, Bad: 11 people

Graphic 1 Results of question 1
Source: Own Elaboration

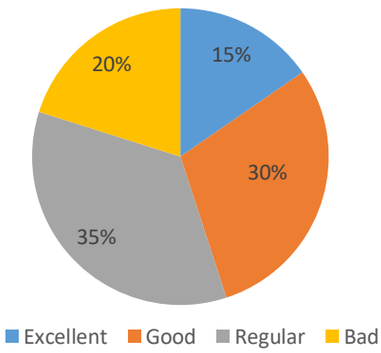
Interpretation of the data obtained in question 1:

It is determined that the orientation service at the time of entering the Physics Laboratory is "Good". Question 2 of the survey refers to the state of the furniture and equipment found within the Physics Laboratory.

2. How do you consider the furniture and equipment of the Physics Laboratory?		
Answers	Opinions	Porcentage
Excellent	26	15%
Good	50	30%
Regular	59	35%
Bad	34	20%
Total	169	100%

Table 2 Values recorded in question 2
Source: Own Elaboration

2. How do you consider the furniture and equipment of the Physics Laboratory?



Resultados → Excellent: 26 people, Good: 50 people, Regular: 59 people, Mala: 34 people.

Graphic 2 Results of question 2
Source: Own Elaboration

Interpretation of the data obtained in question 2:

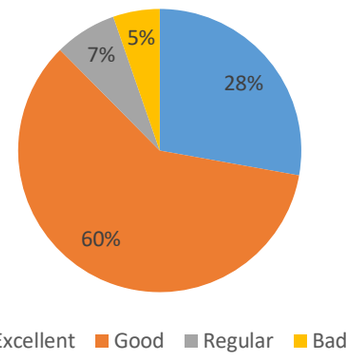
The equipment and furniture of the Physics Laboratory is determined to be "Regular".

Question 3 shows a more personalized approach when evaluating the care provided by the person in charge of the Physics Laboratory.

3. How do you consider the care provided by the person in charge of the Physics Laboratory?		
Answers	Opinions	Porcentage
Excellent	47	28%
Good	101	60%
Regular	12	7%
Bad	9	5%
Total	169	100%

Table 3 Values recorded in question 3
Source: Own Elaboration

3. . How do you consider the care provided by the person in charge of the Physics Laboratory?



Results → Excellent: 47 people, Good: 101 people, Regular: 12 people, Bad: 9 people.

Graphic 3 Results of question 3
Source: Own Elaboration

Interpretation of the data obtained in question 3:

It can be established that the care provided by the person in charge of the Physics Laboratory is "Good".

On the other hand, in question 4 the service of the safeguarding of belongings is evaluated during the stay that the user has within the Laboratory.

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4. How do you consider the service of safeguarding your belongings during your stay at the Physics Laboratory?		
Answers	Opinions	Porcentage
Excellent	5	3%
Good	36	21%
Regular	91	54%
Bad	37	22%
Total	169	100%

Table 4 Values recorded in question 4
Source: Own Elaboration

Results → Excellent: 5 people, Good: 36 people, Regular: 91 people, Bad: 37 people.

Graphic 4 Results of question 4
Source: Own elaboration.

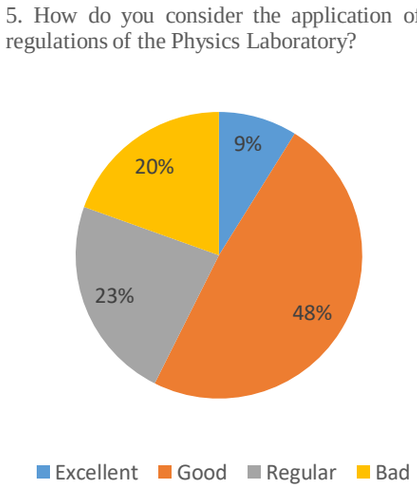
Interpretation of the data obtained in question 4:

The survey participants consider that the safeguarding of their belongings during their stay in the Physics laboratory is “Regular”.

Undoubtedly, the regulatory part of any space contributes considerably to providing a good service, since it encourages the proper use of the facilities and everything that is found in them, that is why, question 5 considers the part regulations of the Physics Laboratory.

5. How do you consider the application of the regulations of the Physics Laboratory?		
Answers	Opinions	Porcentage
Excellent	15	9%
Good	82	48%
Regular	39	23%
Bad	33	20%
Total	169	100%

Table 5 Values recorded in question 5
Source: Own Elaboration



Results → Excellent: 15 people, Good: 82 people, Regular: 39 people, Bad: 33 people.

Graphic 5. Results of question 5
Source: Own Elaboration

Interpretation of the data obtained in question 5:

It is determined that the application of the regulations in the Mechanical and Electrical Laboratory is "Good".

Among the questions asked, question 6 was formulated in order to obtain information through comments, suggestions or observations regarding the Physics Laboratory, it is important to mention that said question was established in order to collect data that later allow the design of improvements based on antecedents, which well formulated could be implemented within it. Table 6 contains the responses obtained.

6. According to your personal criteria and for academic purposes, would you like to make any comments, suggestions or observations about the Physics Laboratory?
The users participating in the survey state within their needs: – Acquisition of New Furniture and Equipment. – Increase of practices within the laboratory. – Material available for practices. – • Creation of a Manager for both shifts.

Table 6 Values recorded in question 6.
Source: Own Elaboration

Interpretation of the data obtained in question 6:

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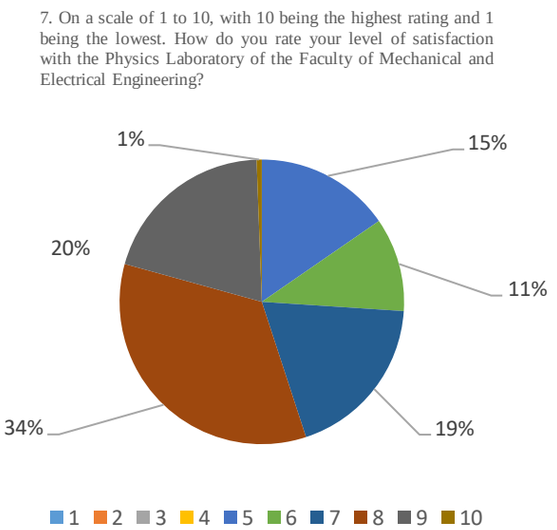
As previously mentioned, the purpose of this question is to obtain information based on direct opinions of the user, at the time of the interpretation of the answers it was possible to arrive at the analysis of a generation of research lines, which to give continuity to the This work can generate improvement designs and in turn considerably increase the desired quality levels. Finally, it is of the utmost importance for any Institution to have facilities that cover and satisfy the needs of each individual belonging to the Academic Community, in this case those belonging to the Faculty of Electrical Mechanical Engineering, that is why it is posed in the question number 7 qualify the degree of satisfaction that the user has regarding the Physics Laboratory.

Below is each of the ratings assigned by the 169 survey participants.

Qualification	Frequenci
1	0
2	0
3	0
4	0
5	26
6	18
7	32
8	58
9	34

Table 7 Values recorded in question 7
Source: Own Elaboration



Graphic 6 Results of question 7
Source: Own Elaboration

Interpretation of the data obtained in question 7:

Given the importance of obtaining current and realistic knowledge about the Laboratory's qualification, all this for academic purposes can be established that 34% of the sample considers that the degree of satisfaction provided is equivalent to an qualification of 8.

Importance of the Data Obtained.

The importance of the data obtained lies in the analysis of the basic elements of the information obtained.

Each of the results obtained in the present work, generate a real perspective of the degree of satisfaction of the users who go to the Physics Laboratory of the academic entity, in turn it is considered that the research is acceptable due to the favorable responses obtained, However, given the current demand of the educational world, it is necessary to design strategies that promote continuous improvement in each of the evaluated aspects, which in due course can be implemented in order to increase the levels previously obtained and thus achieve the desired quality to later achieve excellence.

Conclusions

Derived from the investigation it is concluded:

– This research generates new current knowledge of the degree of satisfaction of the services provided in the Physics Laboratory.

– This work opens the possibility of creating analysis of each of the areas of the Faculty of Electrical Mechanical Engineering, this in order to implement strategies that allow solving the problems that are obtained.

– After making each of the conclusions in the respective questions, we can identify that there are areas of opportunity in which to work later.

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Finally, it is important to highlight that the time invested in this work achieves the scope established at first, which lies in generating new knowledge within this area, on the other hand, one of the limitations with which it had to be dealt with. It is focused on the current health situation, all this because the students are taking each of their classes remotely, however, every Educational Institution has to adapt to certain conditions, likewise, the Faculty of Electrical Mechanical Engineering is characterized for being a dependency accredited by quality organizations that guarantee the quality of its educational programs and the teaching that is taught through them, in the same way to highlight that the line of work to be followed as an Institution of Higher Education is to work with quality to achieve excellence.

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WhatsApp conversation analysis as a means of motivation for teaching in data science

Análisis de conversaciones de WhatsApp como medio de motivación para la enseñanza en ciencia de datos

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Abstract

Both social networks and instant messaging systems have grown in the last decade, becoming an important means of acquiring and disseminating information in different domains, such as business, entertainment, politics, among others. This case study aims to analyze the motivation for learning the discipline Data Science (DS) within the population of engineering students in computer systems in the seventh semester of the Technologic Superior del Occidente del Estado de Hidalgo (ITSOEH), the experiment it consisted of applying a survey in two moments, at the beginning and end of the Introduction to Data Science course within a Likert scale, this to measure the degree of motivation of the students in the area of SD. First, different WhatsApp conversations were obtained and then an analysis was carried out through the statistical language R and the RStudio development environment, the data was examined using graphs to visualize the behavior of the conversation participants. The results of the case study show that students are aware of the power of data for large companies, but are unaware of the use of data generated by our fingerprint when browsing the internet and using applications.

Data Science, Instant messaging, Fingerprint on the internet

Resumen

Tanto las redes sociales como los sistemas de mensajería instantánea han crecido en la última década, llegando a ser un medio importante para adquirir y difundir información en diferentes dominios, como negocios, entretenimiento, política, entre otras. Este caso de estudio tiene como objetivo analizar la motivación sobre el aprendizaje de la disciplina Data Science (DS) o Ciencia de Datos, dentro de la población de estudiantes de ingeniería en sistemas computacionales de séptimo semestre del Tecnológico Superior del Occidente del Estado de Hidalgo (ITSOEH), el experimento consistió en aplicar una encuesta en dos momentos, al inicio y final del curso Introducción a la Ciencia de Datos dentro de una escala de Likert, esto para medir el grado de motivación de los alumnos ante el área de DS. Primero se obtuvieron diferentes conversaciones de WhatsApp para posteriormente realizar un análisis por medio del lenguaje estadístico R y el entorno de desarrollo RStudio, se examinaron los datos mediante gráficas para visualizar el comportamiento de los participantes de la conversación. Los resultados del caso de estudio muestran que los alumnos conocen el poder de los datos para las grandes empresas, pero desconocen el uso de los datos generados por nuestra huella digital ante la navegación de internet y uso de aplicaciones.

Ciencia de Datos, Mensajería instantánea, Huella digital en internet

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Introduction

Data science (DS) is an interdisciplinary field that is responsible for the extraction of knowledge in data. This discipline is supported by Big Data, which consists of storing, processing and analyzing large volumes of data with computer science technologies. Data science is changing the traditional ways of doing things in business, health, politics, education, and in a myriad of fields (Mayer-Schonberger & Cukier, 2013). The objective that data science achieves is in the search for models that describe patterns and behaviors from the data in order to make decisions or make predictions.

Data science feeds on various data as inputs, either from networks of sensors and devices, or from the activity of users on the internet (Batty et al., 2012). Much of this data provides personal information about people's daily activities. People leave a digital trail, either voluntarily or involuntarily when we carry out activities on the internet or on our devices.

We leave our fingerprint when using our mobile phone to pay for services, such as electricity, water, connectivity service, telephone rental and a myriad of processes that we carry out such as online purchases, page views and even the places we visit, thus leaving a mark of personal activity (Calabrese et al., 2011). These data constitute an important source of raw material for the study of human behavior. We are experiencing an important data revolution, in which data acquires increasing value for companies (Marr, 2017).

Given the existence of different social networks as data providers in an indirect way, there is an open field to design data science courses that allow students to experience this data with the languages and tools used for real-world situations so that understand the importance of their digital footprint on the internet (Alonso, López , Font, & Manrique , 2010).

This work presents the practice carried out for the analysis of conversations made by the same students on the WhatsApp platform, implementing languages and tools for data science, and the experimental learning model, where the student learns through experimentation instead of being just receivers. liabilities of knowledge.

Much of the development of Experiential Learning theory (EL – Experiential learning) in recent years they have gained relevance due to the research of David A. Kolb (Kolb, 1983), where you specify the principles of your learning proposal. Exploring the explanatory power and utility of his theory in various disciplines and professions. In the scope of this case study, the Kolb cycle is applied to the field of study of data science (Jacobson & Ruddy, 2004).

According to Kolb, the experiential learning cycle involves four phases:

1. **Concrete Experience Capacity (CE):** be able to engage fully, openly and without prejudice in new experiences.
2. **Reflective Observation Capacity (OR):** be able to reflect on these experiences and observe them from multiple perspectives.
3. **Capacity for Abstract Conceptualization (AC):** be able to create new concepts and integrate your observations into logically sound theories.
4. **Active Experimentation Capacity (EA):** be able to use these theories to make decisions and solve problems.

Figure 1 Learning cycle through experience or Kolb's learning cycle
Reference source: https://www.actualidadenpsicologia.com/la-teoria-de-los-estilos-de-aprendizaje-de-kolb/

The following section details the application of each of the phases of the cycle in the developed practice.

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Methodology

In the first instance, in order for the students to understand the R language and the steps of experience-based learning, exercises that have no relation to the world around them were replicated in order to control the results.

For the practice, the participation of 19 students from the educational program of computer systems engineering in the specialty of data science was given the web page "Analysis of chats in WhatsApp: Part 1 - Text analysis and Data visualization with R ", with the aim of understanding and implementing the published code having as a data source their own conversations on the platform and thus obtaining some graphs in order to be able to be analyzed in order to understand the behaviors of individuals.

Description of Practice

Taking into account that nowadays any device that collects data, these can be measured with the appropriate knowledge and tools, the practice consisted of identifying and selecting the conversations to be analyzed to transfer them from the mobile phone to your personal computer. Subsequently, a reading and preparation of the data was carried out through the R language, it should be noted that for this practice messages sent in the years 2020 and 2021 were analyzed, segmenting them by seasons of the year.

Once the data has been prepared and segmented, the following types of graphs to be obtained were defined:

1. Frequency of daily messages.
2. Frequency of messages by day of the week.
3. Frequency of messages by time of day.
4. Who has sent the most messages?
5. What are the most used emojis in chat?
6. Most used emojis in chat, by user
7. What are the most used words in the chat?
8. Most used words in chat, by user

In order for the students to have meaningful learning from practice, in addition to being able to recreate a real situation, the phases of Kolb's experimental cycle were applied as follows:

1. **Concrete Experience Capacity (CE):** The students identified personal WhatsApp conversations that they wanted to analyze between 2020 and 2021.
2. **Reflective Observation Capacity (OR):** The students implemented code in the R language to visualize findings in their conversations.
3. **Capacity for Abstract Conceptualization (AC):** The students looked for a way to execute different personal conversations through WhatsApp instant messaging to obtain defined graphs that describe the behavior of the actors in the conversation.
4. **Active Experimentation Capacity (EA):** The students concluded by finding patterns in the conversations; taking into account the graphs obtained, moods, romantic relationships, type of communication between people, icons and words most used by people in the conversation.

Once the methodology for learning under experience and the practice to be carried out has been defined, we take the case study on the motivation that this practice leaves in students to study the specialty in data science, for this a survey was carried out that It was applied to the 19 students in two stages: before carrying out the practice and after having carried it out. The foregoing in order to measure interest in the specialty.

Results

From the practice, the students obtained 8 graphs from the personal conversations extracted from WhatsApp, in which the following was shown.

1. Frequency of daily messages

The students determined that there are some months in which they have more communication, in this case due to the relationship that people have, they conclude that in the months of August and September there was more communication derived from the beginning of classes, however, in summer there is activity between the people involved, see figure 2.

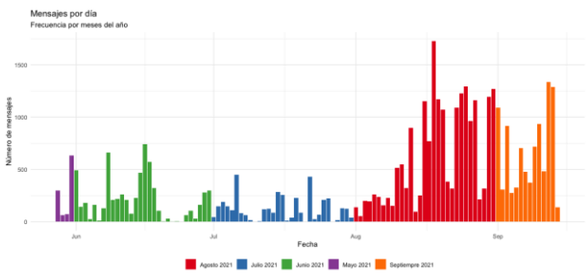

Figure 2. Messages per day, dividing the data by season of the year
Source of consultation: Own Elaboration

2. Frequency of messages by day of the week

In personal relationships there are behavioral behaviors to follow, it is very common for these behaviors to only be noticed in person, but at the time of having a written communication between two or more people we can analyze the constancy of communication and determine behavior patterns, for example, in figure 3 it can be seen that the interaction of people with days, Saturdays, Sundays and Thursdays.

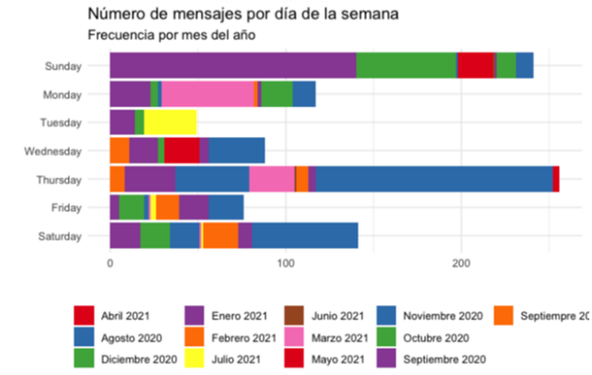

Figure 3 Frequency of messages per day, dividing the data by season of the year
Source of consultation: Own Elaboration

3. Frequency of messages by time of day

As I have seen from a conversation, we can determine how frequent the daily messages are, but it can also be determined at what time of day this interaction takes place. In figure 4 it is possible to observe the communication occurs between 10:00 and 11:00.

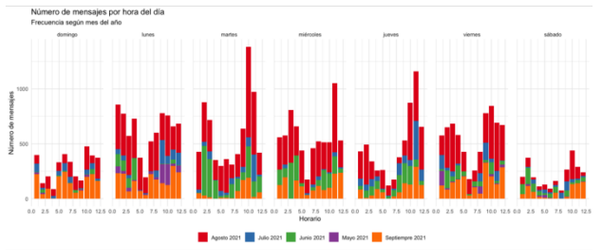

Figure 4 Number of messages per hour of the day. Frequency according to the season of the year
Source of consultation: Own Elaboration

4. Who has sent the most messages?

In this section you could give an indication about the personality of the individuals involved in the conversation. We could intuit who is more impatient of the two. As can be seen in graph 5, person 1 is the one who sends the most messages to person 2.

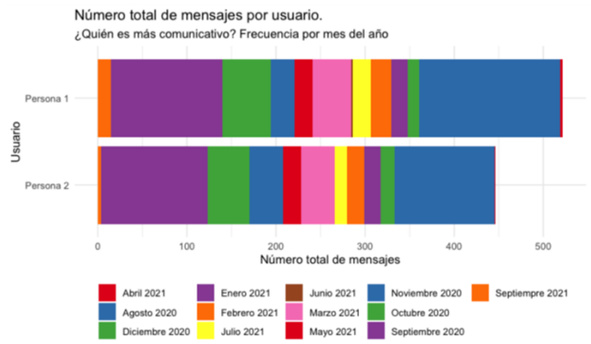

Figure 5 Total number of messages per user, dividing the data by season of the year
Source of consultation: Own Elaboration

5. What are the most used emojis in chat?

Now we have in figure 6 which have been the most used emojis in chat by our users, remember that in these times an emoji says more than a thousand words.

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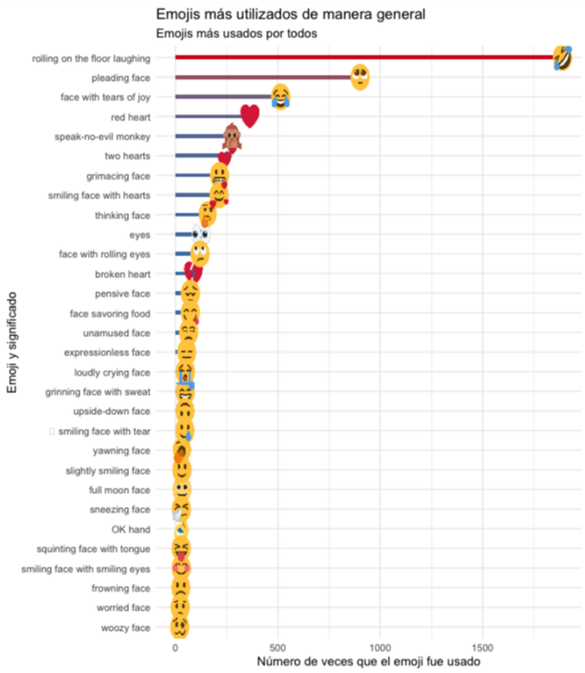

Figure 6 Emojis most used during conversation
Source of consultation: Own Elaboration

6. Most used emojis in chat, by user

Now figure 7 shows the top 8 emojis most used by user.

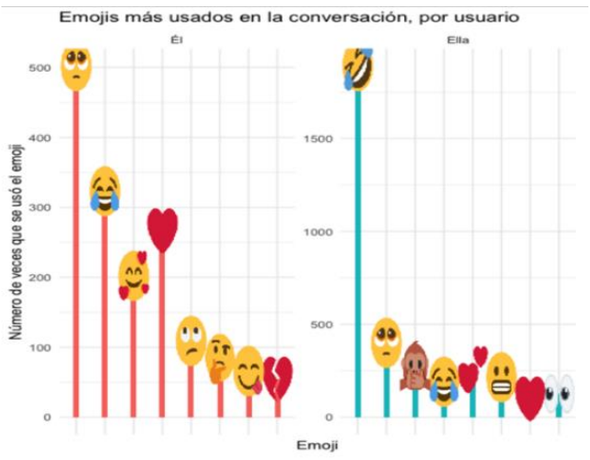

Figure 7 Most used emojis in conversation per user
Source of consultation: Own Elaboration

7. What are the most used words in the chat?

As was done with emojis, we can analyze the frequency of words used in the conversation. In this part, a classification of words was carried out, all those that were wanted to discriminate were added to a set of words, since they are not relevant, such as articles, pronouns, etc. In figure 8 we can see the type of language used by individuals and determine that it is an informal language, as it occurs in a conversation with friends.

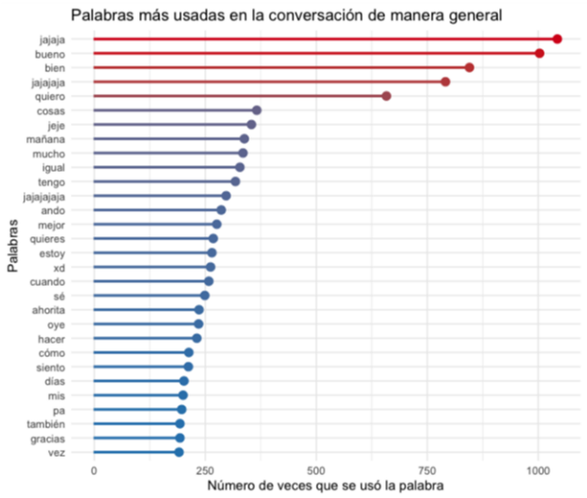

Figure 8 Words most used in conversation in a general way
Source of consultation: Own Elaboration

8. Most used words in chat, by user

In this part we could say that regardless of the relationship between two people, the richness of each person's language can be determined, as we see in figure 9, the variation in vocabulary is not variable between the two people.

Figure 9 Words most used by user in the conversation
Source of consultation: Own Elaboration

Now in order to know the perception of the specialty students of Data Science in the 7th semester of the Systems Engineering career about the motivation to continue learning in the area of Data Science, a survey was used that, as shown He explained, it was applied at the beginning and at the end of the implementation of the practice, it allowed to evaluate the impact of exposing students with minimal knowledge of the Data Science area to the interaction with activities related to this area.

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The items used in the survey are related to the aspects of motivation and satisfaction of the students around working with tools, technology, techniques and theories related to the area of Data Science. The survey was implemented in a Google form, which consisted of 10 multiple-choice questions on the Likert scale (totally agree, even totally disagree).

The case study was applied to 19 students in the subject Introduction to Data Science of the Computer Science Engineering career at ITSOEH. As can be seen in graphs 10 and 11, the students responded positively regarding the use of the tools and techniques of Data Science since it motivates them to learn more about this discipline, and in satisfaction a response was obtained in the same positive way since the knowledge was approached in an attractive way, easy to use and to understand the operation of these tools.

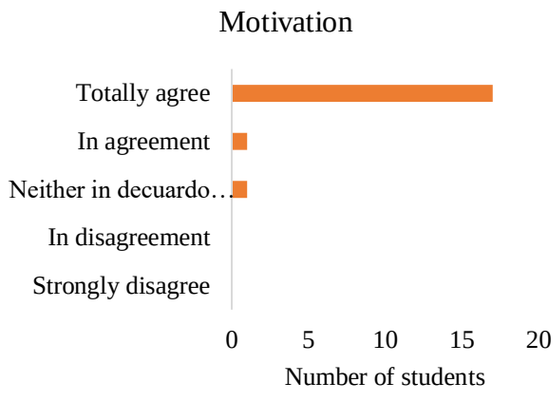

Figure 10 Student's perception of whether the use of tools and techniques typical of Data Science motivates them to learn more about this discipline
Source of consultation: Own elaboration

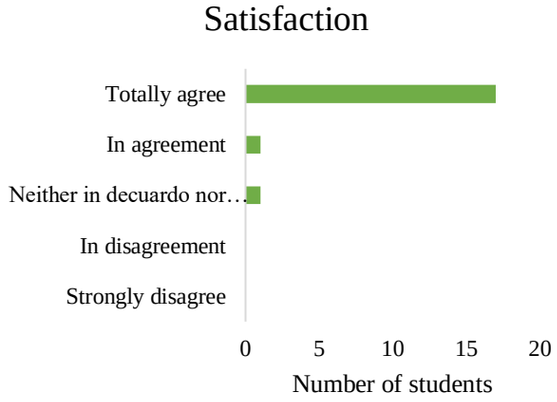

Figure 11 Perception of the student regarding their satisfaction with the techniques of Data Science
Source of consultation: Own Elaboration

Conclusions

Data Science has a wide field of application, the analysis of information shows patterns that we do not know at first glance, being able to represent data through graphs, in this case, describing people's conversations through various data, is representative to understand that data analysis is not only given in information that large companies use. Each element of our fingerprint contributes to this super set of data that allows us to define behavior patterns in society, in this way it is easy to profile users and offer a certain service, product or even to manipulate opinions. In this case study, it was achieved that the students of the specialty of data science, managed to motivate themselves and above all understand that this discipline is not only the task of large companies and that our digital trail together with that of other users is transformed into data valuable, representing large amounts of money.

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Article **Journal-Mathematical and Quantitative Methods**
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Steady-state simulation model of a smart load based on the electric spring implemented in Simulink

Modelo de simulación en estado estable de una carga inteligente basada en el resorte eléctrico implementado en Simulink

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Abstract

The Smart load simulation model based on the electric spring operation principle is presented. The proposed simulation model is implemented in the numerical software Simulink of Matlab and it is useful for the state stable analysis of the smart load. Proposal simulations show the effectiveness of the smart load to modify the power factor through of inductive, capacitive, active and complex power compensation.

Model, Simulation, Simulink

Resumen

En este trabajo se presenta el modelo de simulación de una carga inteligente basada en el principio de funcionamiento del resorte eléctrico. El modelo de simulación propuesto se implementa en Simulink de Matlab y es útil para el análisis en estado estable de la carga inteligente. Con los casos de estudio propuestos se muestra la efectividad de la carga inteligente para modificar el factor de potencia mediante la compensación de potencia inductiva, capacitiva, real y compleja.

Modelo, Simulación, Simulink

Citation: RICO-VELA, José Luis, TAPIA-TINOCO, Guillermo, FIGUEROA-GODOY, Fernando and LOZANO-LUNA, Alfonso. Steady-state simulation model of a smart load based on the electric spring implemented in Simulink. Journal-Mathematical and Quantitative Methods. 2021. 5-9:25-34.

† Researcher contributing as first author.

Introduction

Due to the stochastic nature of alternative energy sources and the large number of large-scale and small-scale power plants that will be built in the coming years as a result of the measures adopted by different countries with the purpose of improving the environment and creating sustainable development [1]- [4], the current control of power generated according to demand is not viable, causing instability in the current power system [5]. Due to this reason, smart grids with high penetration of renewable energy sources require solving a new control paradigm, which establishes that the system responds in real time allowing the generated power to follow the demand [6], within the specified operation and control limits. In the literature there are reported control techniques based on the measurement of the demanded load in time lapses of days or hours [7]-[9], use of energy storage to alleviate peak demand [10] and on-off control of smart loads [11]-[13], the first two of them cannot respond to power fluctuations in real time and the third one causes too much inconvenience to the consumer. In more recent research, a new smart load scheme based on electric spring has been proposed, which has been shown theoretically and practically in [14]-[17].

In these contributions, the working principle of the smart load, its control stages and the implementation of the smart load are shown. In addition, case studies that allow observing the behavior of the intelligent load for voltage control in single-phase power systems with high penetration of alternate energy sources are presented experimentally.

Returning to the principle of operation and the mathematical modeling presented in [16], in this work a simulation model of the intelligent load is proposed, this mathematical model is suitable for steady state analysis of the intelligent load and presents a useful tool for the interaction of the intelligent load with a power system.

Steady-state operating principle of the electric spring

Figure 1 is used to show the steady-state operating principle of the smart load when connected to a power system represented by the voltage source VF. The smart load consists of the electric spring VRE and a noncritical impedance Z.

The electric spring is modeled as an AC voltage source whose magnitude and phase angle can be controlled. The noncritical load can operate with unity power factor, forward or backward. Equation (1) corresponds to the complex power of each of the elements in Figure 1, with (SF, SZ, SRE), (PF, PZ and PRE) and (QF, QZ and QRE) being the complex, real and reactive powers of the source, non-critical load and electric spring respectively, while (θs, βs, Φs) is the power factor angle of each element. Equation (2) is obtained by performing power balance in the circuit and the signs (+,-) are associated with power consumption and power generation respectively.

The electric spring operates in eight different operating modes: inductive power compensation (+jQRE), capacitive power compensation (-jQRE), positive real power compensation (+PRE), negative real power compensation (-PRE), inductive and positive real power compensation.

(+jQRE and +PRE), negative inductive and real power compensation (+jQRE, - PRE), positive capacitive and real power compensation (-jQRE, +PRE) and negative capacitive and real power compensation (-jQRE, -PRE) [16].

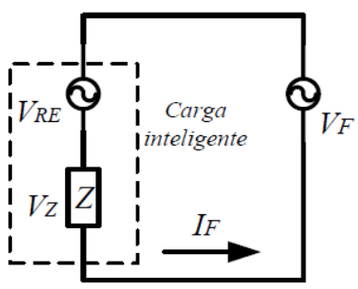

Figure 1 Schematic representation of the electric spring

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$$\begin{aligned} |S_F|\angle\theta_S &= \pm P_F \pm jQ_F \\ |S_Z|\angle\beta_S &= \pm P_Z \pm jQ_Z \\ |S_{RE}|\angle\Phi_S &= \pm P_{RE} \pm jQ_{RE} \end{aligned} \quad (1)$$

$$\begin{aligned} \pm P_F &= \pm P_{RE} \pm P_Z \\ \pm jQ_F &= \pm jQ_{RE} \pm jQ_Z \end{aligned} \quad (2)$$

Figure 2 shows the phasor diagrams illustrating the eight modes of operation of the electric spring. In all cases presented the VF source operates with unity power factor and the real and reactive power compensation is performed by the electric spring. Figure 2(a) corresponds to the inductive power compensation (+jQRE). It can be seen that in this mode of operation the real power consumed by the load is supplied by the source, while the reactive generated by the load are consumed by the electric spring.

Figure 2(b) corresponds to capacitive compensation, in this mode of operation the electric spring injects reactants (-jQRE). As seen in the phasor diagram the load is RL, therefore it consumes real power which is provided by the source and the reactants which are provided by the electric spring.

Figures 2(c) and 2(d) correspond to the positive (+PRE) and negative (-PRE) real power compensation mode of operation respectively. In the case of (+PRE) the electric spring consumes power, therefore the source must provide the power consumed by the load and the electric spring. However in (-PRE) the electric spring injects power, causing part of the power to be consumed by the load:

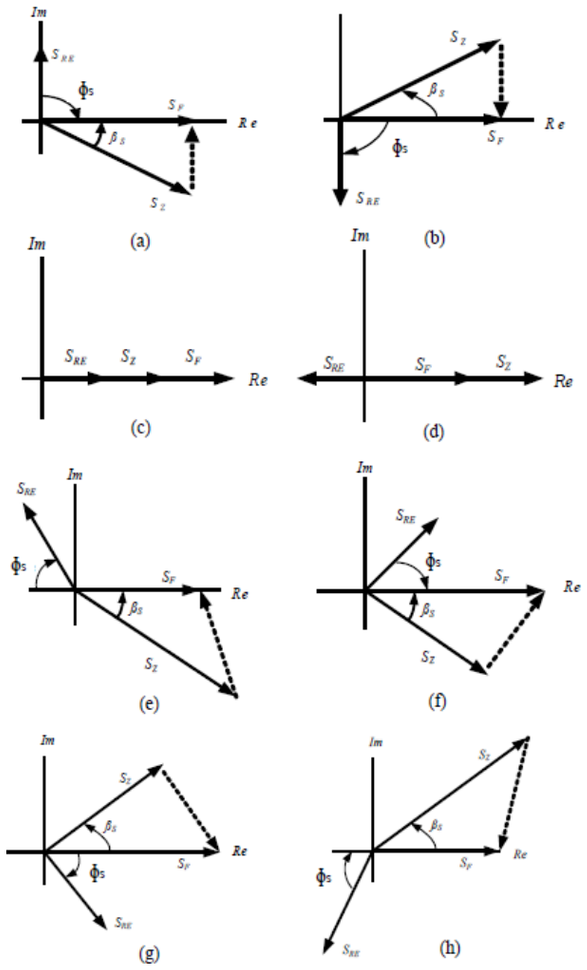

Figure 2 Intelligent load operating modes. a).-. (+jQRE), b).- (-jQRE), c).- (+PRE), d).- (-PRE), e).- (+jQRE, -PRE), f).- (+jQRE and +PRE), g).- (-jQRE, +PRE), h).- (-jQRE, +PRE), h). jQRE, -PRE)

Consumed by the load is contributed by the electric spring. Figure 2(e) shows the mode of operation of the electric spring with inductive and real power compensation positive (+jQRE and +PRE).

In this mode of operation the electric spring consumes real and reactive power, the real power being provided by the source and the reactive power by the load. Figure 2(e) shows the case in which the electric spring consumes reactive power and injects real power (+jQRE, -PRE).

For the capacitive compensation mode of operation, equation (3) is used to calculate IS, however the voltage is calculated with (5), which differs from (4) because now the angle of the electric spring is -π/2.

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Figure 2(f) shows the capacitive and positive real power compensation mode of operation (-jQRE, +PRE). In this mode the electric spring injects reactive power and consumes reactive power. Finally the (-jQRE, -PRE) mode, in this mode the electric spring injects both real and reactive power, i.e. the reactive power consumed by the load is provided by the electric spring and part of the real power consumed by the load.

Mathematical Formulation

In [16] the mathematical formulation for calculating the steady-state voltage magnitude and phase angle of the electric spring according to the mode of operation in which it is required to operate is reported.

To operate in inductive compensation mode, equations (3) and (4) are used. In this mode of operation the electric spring is seen by the system as an inductor since it consumes reactants. First, with (3) the source current is determined and with (4) the magnitude of the electric spring voltage is determined. The phase angle of the electric spring voltage must be π/2.

$$I_F \angle \theta_I = \frac{V_F}{R} \angle 0 \quad (3)$$

$$V_{RE} \angle \theta_v = XIs \angle \frac{\pi}{2} \quad (4)$$

Where:

VF source voltage

IF source current.

θI phase angle of the source current.

R load resistance.

VRE magnitude of electric spring voltage.

θv phase angle of the load voltage.

X load reactance.

$$V_{RE} \angle \theta_v = XIs \angle -\frac{\pi}{2} \quad (5)$$

Equations (6) and (7) are used to determine the voltage and phase angle of the electric spring to operate in positive real power mode of operation (Sz < SF), while (6) and (8) are used in negative power mode of operation (Sz > SF). In both cases initially the power to be injected by the source is calculated and subsequently the electric spring voltage is calculated.

$$I_s = \angle \theta_I = \frac{P_F}{V_F} \angle 0 \quad (6)$$

$$V_{RE} \angle \varphi_V = V_F - I_F R \angle 0 \quad (7)$$

$$V_{RE} \angle \varphi_V = I_F R - V_F \angle \pi$$

Where:

φv phase angle of the electric spring voltage.

If complex power compensation is required, equations (9), (10) and (11) are used. These equations allow calculating the voltage and phase angle of the electric spring to perform the change from an initial complex power PF1, QF1 (without electric spring) to a final power PF2, QF2 (with electric spring). They can also be used when you want to perform real power compensation (PF1 to PF2) keeping constant reactive power (QF1=QF2) or reactive power compensation (QF1 to QF2) keeping constant real power (PF1 = PF2).

$$I_{F2} \angle \theta_{I2} = \frac{\sqrt{P_{F2}^2 + Q_{F2}^2}}{V_F} \angle -\arctan\left(\frac{Q_{F2}}{P_{F2}}\right) \quad (9)$$

$$V_{s2} \angle \theta_{V2} = V_F \sqrt{\frac{P_{F2}^2 + Q_{F2}^2}{P_{F1}^2 + Q_{F1}^2}} \angle \left[\arctan\left(\frac{Q_{F1}}{P_{F1}}\right) - \arctan\left(\frac{Q_{F2}}{P_{F2}}\right)\right] \quad (10)$$

$$V_{RE} \angle \varphi_V = V_s \angle 0 - V_{o2} \angle \theta_{V2} \quad (11)$$

Simulation Model

Figure 3 shows the simulation model implemented in Simulink which corresponds to a single-phase power system. The system has the circuit topology of Figure 1. The voltage source (VF), the electric spring (VRE) and the non-critical load Z are connected in series. In addition, the "graph" blocks the "plotter" and "display" blocks and the display" blocks and the subsystems "measurements", "signals" and "measurements", "signals" and "power" subsystems.

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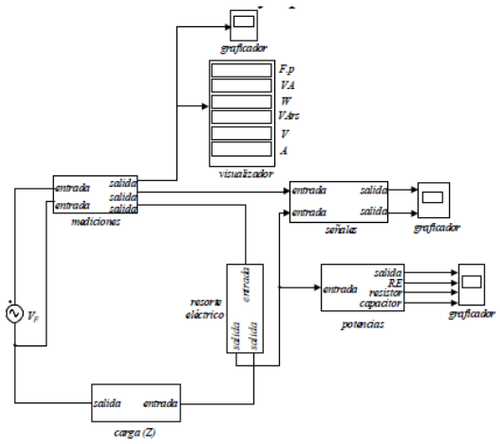

Figure 3 Simulation model

The "plotter" and "display" blocks allow to observe graphically and numerically the voltage, current, power factor and power signals of the VF source. The "measurements" subsystem allows to measure the voltage and current in each of the elements of the power system. The "signals" subsystem allows visualizing the behavior over time of the voltages and currents of each element.

Finally, the power subsystem is used to calculate the real, reactive and apparent power of each element of the power system.

Case Studies

The purpose of the case studies is to validate the simulation model with the eight modes of operation of the electric spring and the equations shown in the mathematical formulation section. Five case studies are presented. In the first two, inductive and capacitive inductive and capacitive compensation respectively, the third case shows the electric spring operating in the third case shows the electric spring operating in positive and negative real power and negative real power mode. In the last two cases of study, the electric spring performs the complex power complex power compensation, for which in the fourth in the fourth case of study, the reactive power is kept constant and the reactive power is kept constant and the real power is real power is modified, while in the last case study, the real power is the real power is kept constant and the reactive power is the reactive power is modified.

The parameters used in the simulation are shown in Table 1. VF is kept at 110 VRMS and with a frequency of 60 Hz. Z can be R, RL or RC depending on the case of study and the magnitudes are as shown in the table. The magnitude and phase angle of the electric spring are calculated with equations (3)-(11) according to the type of compensation.

In each case of study, the instantaneous voltages of the source (VF), the electric spring (VRE) and the Z load (VR, VC and VL) are presented, in addition to the current delivered by the source (IF), which is multiplied by a factor of 20 for better visualization of 20 for better visualization. Additionally, the voltage, current, power and power factor at which VF operates with the electric spring and without the electric spring are compiled in a table.

	Parámetro	Magnitud
Fuente de voltaje	V_F	$110V_{RMS}$ @60Hz
Carga	Z	R: 55 Ω RC: 52-38jΩ RL: 56 + 40jΩ
Resorte eléctrico	V_{RE}	Dependiendo el caso

Table 1 Simulation Parameters

Inductive power compensation.- In this case study the load Z = (52- 38j)Ω is used. 2 0o F I and 76 90o RE V are calculated with equations (3) and (4) respectively.

Figure 4(a) shows the voltages and current without the electric spring. It can be clearly observed that the voltage source operates with a different power factor than unity since IF overtakesVF, which is due to the type of load (RC). Figure 4(b) shows the operation of the electric spring in inductive mode, which is due to the type of load (RC).

This is determined by the phase angle between VRE and IF, which is 90o in retardation.

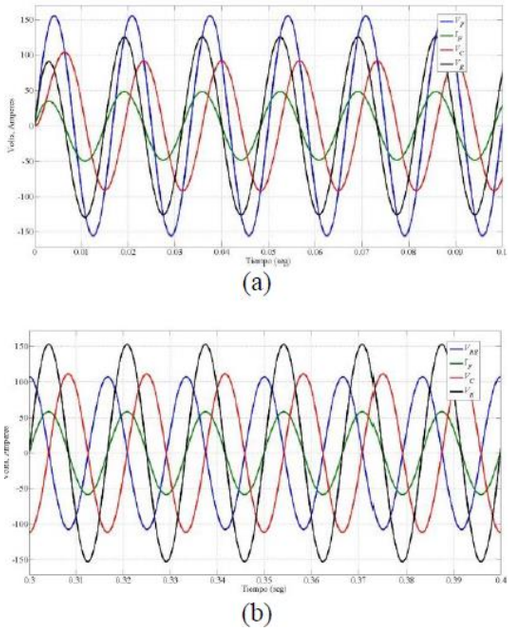

Figure 4 Inductive compensation +jQRE. a).- Without electric spring, b).- With electric spring.

Table 2 shows the conditions at which VF operated without the electric spring and how it modifies the power factor and consequently the reactive power when the electric spring is included. The P.F. is close to unity which is due to the fact that the reactive power delivered by the load is consumed by the electric spring.

	Sin resorte eléctrico	Con resorte eléctrico
F.P	+ 0.8074	+ 0.996
S_F	187.8 VA	228.4 VA
P_F	151.7 W	228.3 W
Q_F	110.8 Vars	6.044Vars
V_F	110 V	110 V
I_F	1.708 A	2.076 A

Table 2 Operation mode +jQRE

Capacitive compensation - In this case study the load Z = 56+40jΩ is used. Equations (3) and (5) are used to achieve the compensation and VF to operate with unity power factor, giving as a result 2 0o FI and 76 90o REV. Figure 5 shows the waveforms of the voltages and current with and without the electric spring.

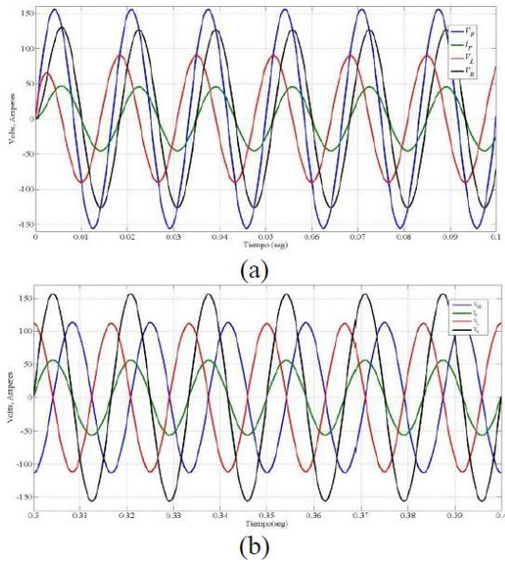

Figure 5 Capacitive compensation -jQRE. a).- Without electric spring, b).- Without electric spring, c).- Without electric spring, d). b).- With electric spring

It is clearly seen in Figure 5(a) that by not including the electric spring the current IF lags the voltage due to the load RL. On the other hand, in Figure 5(b) the electric spring operates in capacitive operation mode since IF is 90º ahead of VRE. Table 3 clearly shows the P.F correction made by the electric spring as the reactive power delivered by VF is close to zero. This is due to the fact that the reactive power consumed by VF is close to zero.

Because the reactive power consumed by the load is provided by the spring. is provided by the electric spring.

	Sin resorte eléctrico	Con resorte eléctrico
F.P	- 0.8137	-1
S_F	175.8 VA	217.4 VA
P_F	143.1W	217.4 W
Q_F	102.2 Vars	1.86 Vars
V_F	110 V	110 V
I_F	1.598 A	1.976 A

Table 3 Mode of operation -jQRE

Positive and negative real power compensation.- A purely resistive load Z= 55Ω is used for this case study. Figure 6(a) shows the voltages and current without the electric spring, it can be observed that they are in phase and VF = VR are in phase and VF = VR. Figure 6(b) shows the results operating the electric spring in positive real power mode.

To achieve such mode of operation, it is considered that the source provides a power PF = 180 W and with equations (6) and (7) we obtain 1.636 0o F I and 20.02 0o RE V. Figure 6(c) presents the results when the electric spring operates in negative real power compensation mode. To to achieve this mode of operation VRE must maintain an offset with IF of 180º as shown in the figure. In this mode of operation PF = 270 W is considered and with equations (7) and (8) we calculate 2.454 0o F I and 25 180 RE V. Without electric spring the power at the load PZ = 220 W, in positive real compensation mode PZ = 147.2 W and in negative real operation mode PZ = 331.4W.

The results reported in Table 4 show how in all cases the unit power factor is operated with a unity power factor

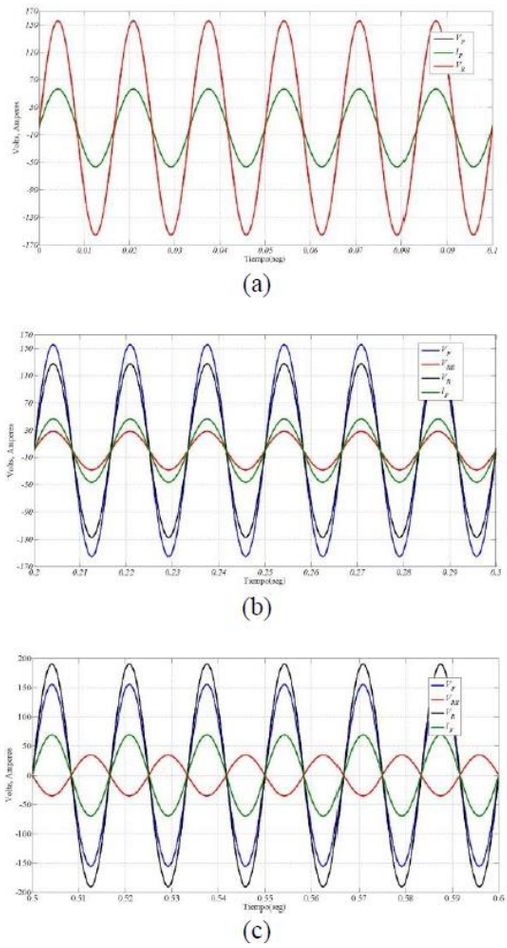

Figure 6 Real power compensation a).- Without electric spring, b).- With electric spring, c).- With electric spring, d). b).- With electric spring +PRE, b).- Without electric spring -PRE, c).- With electric spring +PRE, d). electric spring -PRE

In addition, in the positive real power compensation mode positive real power compensation mode PF>PZ, while in negative real power compensation mode PF<PZ PF<PZ, this is due to the fact that part of the power that part of the power consumed by the load is provided by the electric spring. is provided by the electric spring.

	Sin resorte eléctrico	Potencia real positiva	Potencia real negativa
F.P	1	1	1
S_F	220 VA	180 VA	270 VA
P_F	220 W	180 W	270 W
Q_F	0 Vars	0 Vars	0 Vars
V_F	110 V	110 V	110 V
I_F	2 A	1.637 A	2.48 A

Table 4 Power Compensation +PRE, PRE

Complex power compensation with constant real power - In this case study the appropriate voltage and phase angle are calculated to perform the complex power compensation keeping constant the real power delivered by the electric spring.

For this case study a load RL with values Z = 56+40j Ω is considered. Without the electric spring VF operates with a power factor of 0.814 in lagging which corresponds to PF =143.13 W and QF =102.2 VAR, Figure 7(a) shows the voltages and currents without the electric spring. Figure 7(b) is divided into two periods, the first period being at $0.1 \leq t < 0.2$ sec. In this period the electric spring performs the compensation of positive real power and inductive power as it changes the source power factor from 0.814 to 0.7. To carry out the change in the power factor, equations (9)- (11) are used with the values PF = 143.13W, QS1=102.2 VAR and QS2=146.02 VAR, giving as a result 2 1.859 45.57 o FI , 2127.89 10.04 o Z V and 27.4 125.55 o RE V.

Subsequently at $t \geq 0.2$ sec the electric spring voltage takes a new value to modify the power factor to 0.9, therefore the electric spring will perform positive real power and capacitive power compensation. The theoretical values of power delivered by the source are PF = 143.13W, QS1=102.2 VAR and QS2=69.32 VAR, giving as a result when substituting in equations (9)-(11) 2 1.446 25.84 FI, 299.47 9.69 ZV 20.57 54.48 REV.

When analyzing the figures, the operation of the electric spring is the operation of the electric spring is clearly observed when it performs the compensation of real and inductive power IF real and inductive power compensation lags VRE, however, when performing real and capacitive real and capacitive compensation IF advances VRE. Table 5 shows how voltage source operates with different power factors power factors, all of them being lagging power factors. power factors in backward. It can also be seen that the theoretical values used to calculate the electric spring voltage are voltage of the electric spring are very close to those obtained by those obtained by simulation.

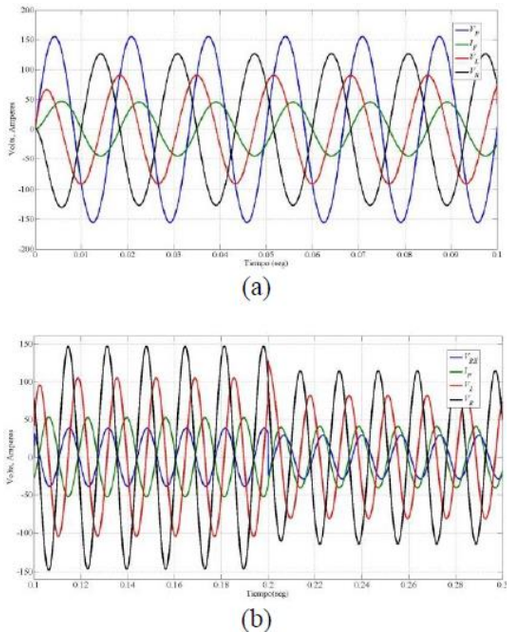

Figure 7 Complex power compensation a).- Without electric spring, b).- +PRE fixed and +QRE to -QRE rafter.

	Sin resorte eléctrico	Con resorte eléctrico,	Con resorte eléctrico,
F.P	-0.8137	-0.7	-0.9
S_F	175.8 VA	204.4 VA	159 VA
P_F	143.1 W	143.1 W	143.1 W
Q_F	102.2 Vars	146 Vars	69.31 Vars
V_F	110 V	110 V	110 V
I_F	1.598 A	1.858 A	1.445 A

Table 5 Complex power compensation with fixed +PRE and switching from +QRE to -QRE

Complex power compensation with constant reactive power

In this case study the appropriate voltage and phase angle are calculated to perform the complex power compensation keeping constant the reactive power delivered by the electric spring. For this case study an RC load with Z = 52-38j Ω values is considered.

Without the electric spring VF operates with a power factor of 0.807 in forward which corresponds to PF = 151.7 W and QF = -110.9 VAR, Figure 8(a) shows the voltages and currents without the electric spring. Figure 8(b) is divided into two periods, the first period being at $0.1 \leq t < 0.2$ sec. In this period the electric spring changes the F.P from 0.814 to 0.7. To carry out the change in the power factor, equations (9)- (11) are used with the values QF = -110.9 VAR, PS1=151.7 W and PS2=108.7 W, resulting in 2 1.412 45.57 or FI, 2 90.9 9.40 or ZV and 25.17 36.15 or REV.

Subsequently at $t \geq 2$ sec the electric spring voltage changes to modify the power factor to 0.9. The theoretical values of power delivered by the source are QF = -110.9 VAR, PS1=151.7 W and PS2=228.98 W, resulting when substituting in equations (9)-(11) 2 2.31 25.84 or FI, 2 148.93 10.33 or ZV and 45.24 10.33.

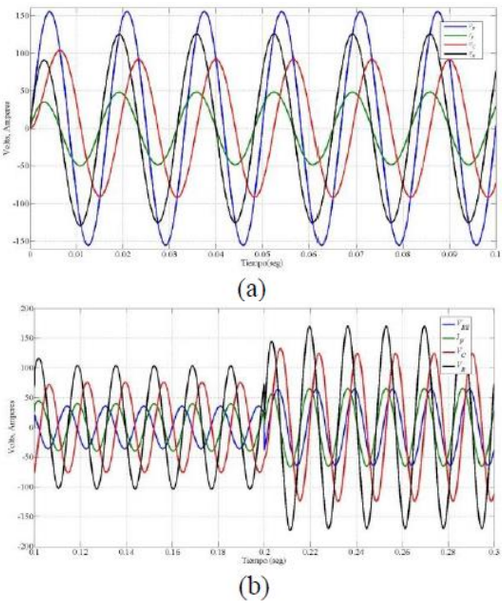

Figure 8 Complex power compensation a).- No electric spring, b).- +QRE fixed and +PRE change

When analyzing VRE and IF in Figure 8(b) it is clearly observed how the electric spring changes from a lagging power factor to a leading power factor, this with the purpose of modifying the P.F. of VF without modifying the reactive power consumed by the power consumed by the electric spring. Table 6 shows how the voltage source voltage source operates with the different power factors, all of them being power factors, all of them being forward power factors.

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Power factors in advance. In addition, it can be seen that the theoretical values of power and power factor of VF used to calculate the voltage VF power factor used to calculate the electric spring voltage are very close to those obtained by simulation. obtained by simulation.

	Sin resorte eléctrico	Con resorte eléctrico,	Con resorte eléctrico,
F.P	0.8074	0.7002	0.9002
S_F	187.9 VA	152.2 VA	255.3 VA
P_F	151.7 W	108.7 W	229.9 W
Q_F	-110.8 Vars	-110.8 Vars	-110.8 Vars
V_F	110 V	110 V	110 V
I_F	1.708 A	1.411 A	2.32 A

Table 6 Complex power compensation with +QRE and +PRE switching

Conclusions

The case studies shown in this work allow corroborating the principle of operation of the smart load and its mathematical foundation. The different modes of operation of the smart load were shown in the case studies.

The results obtained in the simulations are very close to those calculated theoretically and those reported in the literature. On the other hand, the simulation model and the mathematical formulation together present a useful tool for the steady state analysis of power systems, allowing the study of intelligent loads in more complex power systems.

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* Correspondence to Author (example@example.org)
† Researcher contributing as first author.

Introduction

Text in Times New Roman No.12, single space.

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

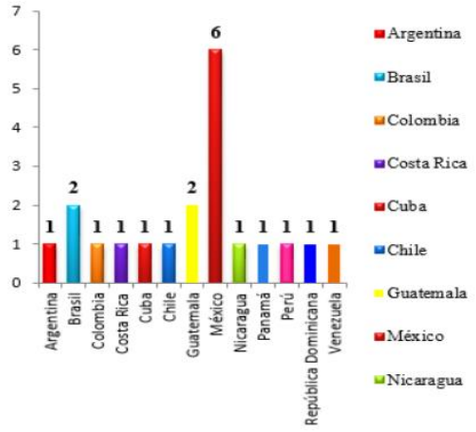
[Title No.12 in Times New Roman, single spaced and Bold]

Products in development No.12 Times New Roman, single spaced.

Including graphs, figures and tables-Editable

In the article content any graphic, table and figure should be editable formats that can change size, type and number of letter, for the purposes of edition, these must be high quality, not pixelated and should be noticeable even reducing image scale.

[Indicating the title at the bottom with No.10 and Times New Roman Bold]



Graphic 1 Title and Source (in italics)

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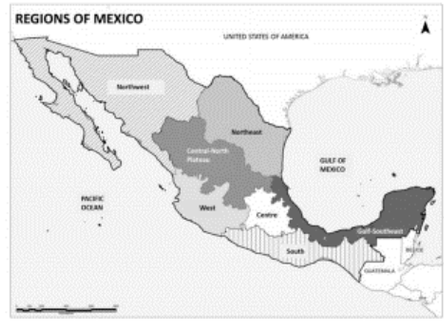

Figure 1 Title and Source (in italics)

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Products	Industry	Chocolate Business
Food and beverage provision services	Processed food	
	Cultural tourism	Commercial chocolate (national and international brands)
Cultural Services	Agroindustry	Museums of chocolate

Table 1 Title and Source (in italics**)**

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Each article shall present separately in **3 folders**: a) Figures, b) Charts and c) Tables in .JPG format, indicating the number and sequential Bold Title.

For the use of equations, noted as follows:

$$Y_{ij} = \alpha + \sum_{h=1}^{r} \beta_h X_{hij} + u_j + e_{ij} \qquad (1)$$

They must be editable and number aligned on the right side.

Methodology

Develop give the meaning of the variables in linear writing and important is the comparison of the used criteria.

Results

The results shall be by section of the article.

Annexes

Tables and adequate sources

Thanks

Indicate if they were funded by any institution, University or company.

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Use APA system. Should not be numbered, nor with bullets, however if necessary numbering will be because reference or mention is made somewhere in the Article.

Use Roman Alphabet, all references you have used must be in the Roman Alphabet, even if you have quoted an Article, book in any of the official languages of the United Nations (English, French, German, Chinese, Russian, Portuguese, Italian, Spanish, Arabic), you must write the reference in Roman script and not in any of the official languages.

Technical Specifications

Each Article must submit your dates into a Word document (.docx):

Article title
Abstract
Keywords

Article sections, for example:

1. Introduction
2. Description of the method
3. Analysis from the regression demand curve
4. Results
5. Thanks
6. Conclusions
7. References

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