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Simplified method based on an intelligent model to obtain the extinction angle of the current for a single-phase half wave controlled rectifier with resistive and inductive load

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ABSTRACT

With the aim of calculating the extinction angle of the current of a single-phase half wave controlled rectifier with resistive and inductive load, present work shows a method to obtain a regression model based on intelligent methods. This type of circuit is a typical non-linear case of study that requires a hard work to solve it by hand. To create the intelligent model, a dataset has been obtained with a computational method for the working range of the circuit. Then, with the dataset, to achieve the final solution, several methods of regression were tested from traditional to intelligent types. The model was verified empirically with electronic circuit software simulation, analytical methods and with a practical implementation. The advantage of the proposed method is its low computational cost. Then, the final solution is very appropriate for applications where high computational requirements are not possible, like low-performance microcontrollers or web applications.

1. Introduction

Since semiconductors emerged in electronic field, one of the most researched circuit has been the rectifier. It is well known that the function of rectifiers, in general terms, is to obtain a continuous signal from an alternate signal [11,17]. These circuits are very common in applications like DC power supplies [24], peak signal detectors [16], and so on.

The basic rectifier is one of the most traditional circuits to learn electronic in the first courses [17]. Despite this, this type of schema could not be easy to solve and obtain its parameters. Fundamentally, the

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difficulty depends on: the number of phases of the source, the characteristics of the load and whether it is of controlled type or not [11]. A more specific example of this fact is the controlled rectifier with resistive and inductive load. Due to the inductive component of the load, the current through it, is not in phase with voltage [11]. The lag in phase between the voltage and the current is known as extinction angle [24]. This parameter is essential, for instance, to know the power applied to the load [24].

Usually the extinction angle is obtained analytically solving a nonlinear equation with iterative methods [11,24]. Typical methods to obtain a solution are: Trust-region dogleg [6], Trust-region-reflective [5] or Levenberg–Marquardt [14,19,21]. With these methods it is possible to achieve good results in general terms with relatively few iterations.

Taking into account the fact that the operating range of the single-phase half-wave controlled rectifier for resistive and inductive load is known, it is possible to obtain the results of the angle extinction for the range [11,24]. This is possible due to the fact that the value does not depend on other parameters like voltage peak, frequency and so on [11]. With the dataset is possible by applying regression and then obtaining automatically the extinction angle.

Traditional approaches for regression are based on Multiple Regression Analysis (MRA) methods [31]. MRA-based methods are well-known, among others, because they are being applied in many fields. It is well known that these methods have limitations [3,31]. There are limitations associated with MRA-based methods, such as the inability of MRA to adequately deal with interactions between variables, nonlinearity, and multicollinearity [13,15,31]. More recently SoftComputing (SC) based methods have been proposed as an option to overcome the above limitations: in [22], the authors propose a novel Bayesian regression method via nonlinear dimensionality reduction. A fast and robust model selection algorithm for multi-input multi-output support vector regression is developed in [18]. Even, with the emerging proposals for regression based on SC, many real problems are solved better than with the traditional techniques. In [12], an integration of nonlinear independent component analysis and support vector regression for stock price forecasting is made. [20] shows a novel logistic regression models to aid the diagnosis of dementia. In [1] a correlation analysis is made between the obtained features and the number of holes made with the tool, with the aim to identify which of these features can be used for estimating the tool condition. Ref. [23] describes a model to predict the energy generated by a solar thermal system. A study explores the quality monitoring experiment by three existing neural network approaches to data fusion in wireless sensor module measurements in [25].

The aim of this research is to develop an intelligent model that allows obtaining extinction angle of the single-phase half-wave controlled rectifier for resistive and inductive load. As an alternative to the traditional techniques, taking into account all the explained, a novel approach is proposed. Many traditional and SoftComputing techniques have been tested in order to obtain the best fitness of the created model.

This research is structured as follows. After the present introduction, it starts with a brief description of the single-phase half-wave controlled rectifier with resistive and inductive load, putting in highlight the extinction angle phenomenon. Afterwards, the novel system is presented, followed by the intelligent model approach. Next section shows the results of the different regression methods and the model chosen. Finally, a practical implementation and conclusions are exposed.

2. Single-phase half-wave controlled rectifier for resistive and inductive load

The single phase half wave controlled rectifier circuit with resistive and inductive load is shown in Fig. 1.

The load (resistance *R1* and inductance *L1*) is fed by the voltage source *V1* via a thyristor *X1*. The principal characteristic of the circuit is that the current is not in phase with the voltage. This fact is due to the inductive component of the load. The firing pulse is applied to the gate of the thyristor *X1* (trigger pin) at an instant defined as α. It remains in the ON state until the load current tries to be a negative value. This instant is defined as extinction angle β. The current $i(\omega t)$ is defined by Eq. (1), where V_m is