algorithms

MDPI

Article

Parameter Tuning of PI Control for Speed Regulation of a PMSM Using Bio-Inspired Algorithms

Juan Luis Templos-Santos [1,*], Omar Aguilar-Mejia [2], Edgar Peralta-Sanchez [2] and Raul Sosa-Cortez [1]

[1] Departamento de Posgrado, Universidad Politécnica de Tulancingo, Tulancingo, Hidalgo C. P. 43629, Mexico; raul.sosa.cortes@gmail.com

[2] Departamento de Posgrado, UPAEP Universidad, Puebla C.P. 72410, Mexico; omar.aguilar@upaep.mx (O.A.-M.); edgar.peralta@upaep.mx (E.P.-S.)

* Correspondence: jluistsantos@gmail.com; Tel.: +52-775-111-7181

Received: 31 December 2018; Accepted: 9 February 2019; Published: 4 March 2019

check for updates

Abstract: This article focuses on the optimal gain selection for Proportional Integral (PI) controllers comprising a speed control scheme for the Permanent Magnet Synchronous Motor (PMSM). The gains calculation is performed by means of different algorithms inspired by nature, which allows improvement of the system performance in speed regulation tasks. For the tuning of the control parameters, five optimization algorithms are chosen: Bat Algorithm (BA), Biogeography-Based Optimization (BBO), Cuckoo Search Algorithm (CSA), Flower Pollination Algorithm (FPA) and Sine-Cosine Algorithm (SCA). Finally, for purposes of efficiency assessment, two reference speed profiles are introduced, where an acceptable PMSM performance is attained by using the proposed PI controllers tuned by nature inspired algorithms.

Keywords: PI controller; bio-inspired; speed control; PMSM; FPA; SCA; BBO; CSA; BA

1. Introduction

Recently, the permanent magnet synchronous motor (PMSM) has achieved notoriety in industrial applications (e.g., electric vehicles [1], computer numerical control machines [2], industrial robots [3]). Among its most relevant features are a fast dynamic response, compact size, high power density, high torque capacity and low losses due to heat dissipation, which make it highly efficient. The performance of the PMSM can be affected during operation by the non-linearity of the dynamic system, some parametric variations and bounded perturbations of the load torque, which the controller must be able to overcome in real-time operation by always considering the physical constraints of the machine [4–6].

In the literature, several speed-control schemes have been proposed for PMSM, where a proper performance in tasks of regulating the speed of the rotor is achieved [7–12]. Some controllers use adaptive schemes [8,13–15], artificial neural networks (ANNs) [5,11,12,16], sliding mode control (SMC) based techniques [17–20], and fuzzy logic [5,10], to name a few methods. Sliding-modes based control provides a high disturbance rejection and a low sensitivity to parametric variations. However, the well-known phenomenon of chattering is also presented, which leads to low precision, warm-up in electrical power devices and wear in motor's mechanical parts. With the use of fuzzy logic a good performance is presented but it has the problem that the fuzzification rules, the inference mechanism, and the defuzzification operations are not clear and, in addition, they demand high computational processing capacity. Where using ANNs, a large amount of data and various operating scenarios of the plant are required for offline training. Also, it's necessary to have a device with a high processing capacity to manipulate all of the data, resulting in greater cost and system complexity.

applied sciences

MDPI

Article

Fractional Order PI-Based Control Applied to the Traction System of an Electric Vehicle (EV)

German Ardul Munoz-Hernandez *,†, Gerardo Mino-Aguilar †, Jose Fermi Guerrero-Castellanos † and Edgar Peralta-Sanchez †

Benémerita Universidad Autónoma de Puebla (BUAP), Facultad de Ciencias de la Electrónica, Ciudad Universitaria, Puebla 72570, Mexico; gerardo.mino@correo.buap.mx (G.M.-A.); fermi.guerrero@correo.buap.mx (J.F.G.-C.); edgarps@ieee.org (E.P.-S.)

* Correspondence: gmunoz@ieee.org; Tel.: +52-222-255-8932

† These authors contributed equally to this work.

Received: 18 October 2019; Accepted: 26 December 2019; Published: 3 January 2020

check for updates

Abstract: This paper presents a design of a cruise control based on a fractional-order proportional and integral (PI) direct torque control applied to the traction system of an electric vehicle (EV). The paper also discusses the modeling, control design and simulation, resulting in a numerical simulator composed of detailed models of the main components: transmission system, induction motor, power electronics, control system, and vehicle dynamics. The simulation was developed in MATLAB/Simulink and will allow the estimation of the energy consumption of an EV under specific configurations. Simulation results show the efficiency of the designed control. These simulations were carried out using the velocity profiles given by the New Europe Drive Cycle (NEDC).

Keywords: electric vehicle (EV); traction system; DTC; dynamic simulation; fractional order control

1. Introduction

Among the many problems that have been considered important worldwide the two that stand out are pollution and overpopulation. Overpopulation has created high demands for transport, both short and long-distance, which increases the problem of pollution [1].

Electric motors consume half of the electric power generation, so increasing their efficiency impacts the saving of electric energy. Different control techniques that use digital systems (as well as new power electronics devices) have evolved in the works looking for improving the performance of electric motors [2].

These electric machines have also made progress in their design. Three-phase induction motors (IM) are normally used in the industrial sector, due to their simple design, high reliability and low cost. Frequency converters are traditionally used to control the speed and stop of induction motors with precision [3]. The control of the speed of the motors allows the saving of electrical energy. Therefore, the use of variable speed drives has been increased to control not only the speed, but also the torque, flow and position.

The majority of the vehicles that circulate around the world nowadays consume fossil fuels. These vehicles use internal combustion engines (ICE), with a performance of the transformation of energy from the fuel tank into mechanical energy of less than 30%, which represents a great loss. They also produce CO_2 and NO_x emissions into the atmosphere, which leads to a large localized pollution in large cities. In recent years, electric vehicles (EV) and hybrid electric vehicles (HEV) have proven to be an alternative as they are a clean, effective and ecologically friendly transportation system [4].

In an electric vehicle, its movement is provided by an electric motor that has batteries as its primary source of energy. Excluding the generation of electricity, EVs do not generate CO_2 and NO_x

Sliding Mode Observer Enhanced for Sensorless Permanent Magnet Synchronous Motor Control

Daniel Memije Garduño
SEPI ESIME ZACATENCO.
Instituto Politécnico Nacional
Ciudad de México, México
memijeg@alumno.ipn.mx
https://orcid.org/0000-0002-3879-2176

Oscar Carranza Castillo
Escuela Superior de Computo
Instituto Politécnico Nacional
Ciudad de México, México
ocarranzac@ipn.mx
http://orcid.org/0000-0003-4761-0757

Jaime José Rodriguez Rivas
SEPI ESIME ZACATENCO.
Instituto Politécnico Nacional
Ciudad de México, México
jjrodriguezr@ipn.mx
https://orcid.org/0000-0002-7679-3508

Rubén Ortega González
Escuela Superior de Computo
Instituto Politécnico Nacional
Mexico City. Mexico
rortegag@ipn.mx
http://orcid.org/0000-0002-3675-0992

Edgar Peralta Sánchez
Departamento de Ingenierías
Universidad Popular Autónima
del Estado de Puebla
Puebla, Mexico
edgar.peralta@upaep.mx

***Abstract*— A second order sliding-mode observer enhanced similar in structure and computational cost to a classical proportional-integral controller is proposed. This observer eliminates efficiently the chattering problem and preserves the robust properties of sliding mode. Owing to its advantages, the proposed observer is used for reconstructing the back electromotive force of a permanent magnet synchronous machine, it estimates the motor speed and position. These estimations are feedbacked in a vector control scheme, where the need for the mechanical position/speed sensor is eliminated. MATLAB™ simulations of the proposed observer demonstrate the accurate reconstruction and zero phase delay estimation of the back electromotive force. Experimental results of a sensorless speed control for a 7.46 kW permanent magnet synchronous motor validate the proposed observer. The advantages of the proposed observer are better compared to the sensorless control strategies LO and Q-SMO.**

Keywords*— *Sliding Mode Observer, Sensorless, Permanent Magnet Synchronous Machine

I. Introduction

The Permanent Magnet Synchronous Motor (PMSM) is widely used in variable speed systems due to its high power density, fast torque response, and high efficiency [1]. However, a high-performance control drive of a PMSM, such as vector control, requires accurate information on the position and speed of the rotor, which are commonly obtained by using an encoder, a resolver or a Hall effect sensor [2]. Unfortunately, these sensors increase the system complexity and cost, and are sensible to environmental constrains such as: temperature changes, vibrations, and electromagnetic noise [3].

The research in PMSM control has focused its attention on the elimination of the mechanical position/speed sensor (sensorless) due to the advantages that this presents, such as: reduced hardware complexity, lower cost, reduced size of the machine, greater immunity to magnetic noise, greater reliability and less maintenance [1]-[4].

The first attempts to implement sensorless control of a PMSM are based on open loop flux [5] and Back Electro Motive Force (BEMF) estimators [6], [7]. Unfortunately, those approaches lack of robustness since they are sensitive to integration offset and parameter variations.

Sensorless technology improved with the introduction of closed-loop flux and BEMF observers since they are robust to integration offset and parameters uncertainty. However, in the present time, the BEMF observer is most widely used. Despite its wide acceptance, sensorless control based on BEMF works only in the middle and high-speed regions because the amplitude of the BEMF is difficult to detect at low and zero speeds [8]-[12].

To overcome the BEMF method problems at low speeds, High Frequency Injection (HFI) sensorless algorithms have emerged, which allows the control of the PMSM at zero and low speed regions [12]-[15]. In addition, HFI and BEMF sensorless algorithms are complementary to each other, so by combining them it allows the sensorless PMSM control to operate throughout the motor speed range [12].

Even though the combination of HFI and BEMF has been used in some applications such as wind energy generation, this complication is not needed since these systems only operates in the middle and high-speed regions [4].

There are several techniques available to estimate the BEMF, such as Luenberger Observer [16], [17], Kalman filter [18], Sliding Mode Observer (SMO) [8]-[10], and neural networks [19], [20]. Nevertheless, SMOs have been the most successfully applied observers to estimate the BEMF.

Although first order SMOs have shown to be useful, these observers introduce chattering problems [10]. Commonly, quasi-sliding approaches or low pass filters are used for the elimination of chattering [21]-[23]. However, those solutions decrease the robustness properties of the SMO, introduce phase delay, and deteriorate the quality of the estimations [24].

978-1-7281-3666-0/19/$31.00 ©2019 IEEE

IETE JOURNAL OF RESEARCH, 2017
https://doi.org/10.1080/03772063.2017.1355270

Check for updates

Validating Analytical Model for Steady-State Can Losses in a Canned Permanent Magnet Motor

Ivan A. Hernandez[1], Edgar Peralta-Sanchez[2], J. Antonio Alvarez[3] and J. Carlos Olivares-Galvan[4]

[1]Departamento de Ingenieria Electrica, Universidad de Guanajuato-DICIS, Salamanca 36885, Mexico; [2]Decanato de Ingenierias, Universidad Popular Autonoma del Estado de Puebla, Puebla 72410, Mexico; [3]Facultad de Ingenieria, Universidad Autonoma de San Luis Potosi, San Luis Potosi 78290, Mexico; [4]Departamento de Energia, Universidad Autonoma Metropolitana de Azcapotzalco, Ciudad de Mexico 02200, Mexico

ABSTRACT
The canned permanent magnet motor (CPMM) is a more effective and safer technology as compared to the conventional motor pump when it comes to handling toxic, dangerous and corrosive liquids. This research work presents an electromagnetic analysis simulation and test validation of the analytical method in a steady-state condition for predicting the behaviour and can losses of these motors. The induced losses are computed in cans that are engaging both stator and rotor. Comparison between analytical method, finite element simulations and measured values are presented. This research contributes in the analysis and design of canned motor's pumps.

KEYWORDS
Canned motor; Eddy losses; Electromagnetic analysis; Finite element method; Induced losses; Permanent magnets; Pumps; Steady state

1. INTRODUCTION

Nowadays, the canned motors are commonly used when it comes to handling special liquids for it offers an effective and safe management for the total fluid. At the beginning, an outstanding use of this type of motor was pumping the primary coolant through a reactor core and its associated heat exchanger at nuclear plant systems. The equipment became prominent and commercial after this application and several studies and analytical models for the design stage were emerged. Consequently, losses computation and effective equivalent circuits were also developed [1,2]. The design, testing and measurement of eddy losses in canned permanent magnet motor (CPMM) are described in [3].

Methods for estimating stray losses and core losses in conventional pump motors are found in [4,5] and the characteristics of the canned motor are analyzed by combining 2D and 3D finite element method (FEM) simulation in [6,7]. In [8], the authors have analyzed and computed forces of the permanent magnet axial thrust balance structure in canned motor providing more appraisal and development tools for CPMM design.

In previous works [9,10], the development of an analytical method for predicting the steady-state response of pump motor containment was derived from an equivalent steady-state circuit model for analyzing the CPMM; however, FEM simulation was missing in order to validate the obtained analytical method. It can be noticed that [11] was focused in the importance of eddy current evaluation in the stator end of canned induction motor by using FE simulation. The paper is organized as follows: Section 1 introduces the importance of the electromagnetic analysis and can losses estimation in CPMM and the studies previously done. CPMM is completely leakage free, and a significant contribution has been made to maintain regulations in health and manage the fluid for safety. Therefore, Section 2 reviews the advantages of this electrical device and its steady-state performance. This research enriches the previous work done in [9,10] with 2D and 3D FEM simulations in Section 3. It provides a better panorama of the distribution of the magnetic flux inside the machine, especially in sealed cans since these are the distinctive characteristics of this device. Furthermore, this section provides the comparison between analytical, FEM simulations and experimental results. Section 4 provides the conclusions of the electromagnetic analysis performed to understand the operation of the CPMM and the comparative results to validate the analytical work. The paper contributes in the development of design techniques for CPMM devices and improves the steady-state knowledge of these devices.

Optimal Venturini Modulation for a Three-phase Four-Wire Matrix Converter

J. J. Rodriguez, R.M. Caporal, *Senior Member, IEEE,* E. Peralta, O. Carranza, *Member, IEEE* and R. Ortega

***Abstract*—This paper presents the direct and easy way to implement digitally an optimal Venturini modulation scheme for a 7.5 KVA, four-wires, matrix converter with balanced and unbalanced loads. In order to meet tight harmonic specification a single-stage LC input filter with a resistor connected in parallel with the inductor has been designed and at the output another single-stage LC filter is used. This enables stable output power and frequency over a wide range and at different load conditions. Experimental results obtained by using a DSP-FPGA system verify the effectiveness of the Venturini modulation scheme.**

***Keywords*— Matrix converter, four-step current commutation, Venturini modulation.**

I. INTRODUCIÓN

LA CONVERSIÓN bidireccional de corriente alterna en corriente alterna (CA/CA) se realiza tradicionalmente en dos etapas: rectificación e inversión de CA, requiriéndose de una etapa intermedia de corriente directa (CD) que utiliza capacitores como filtros. Sin embargo, la forma óptima de llevar a cabo esta conversión es por medio del uso de convertidores matriciales (CM) los cuales pueden llevar a cabo la conversión CA/CA directamente, gracias al uso de interruptores bidireccionales. Estos interruptores estas constituidos por dos transistores de potencia y dos diodos (ver Fig. 1). Además, al no tener la etapa de CD no requiere del uso de capacitores con lo que se disminuye el peso y volumen del convertidor [1-3].

Los CM de cuatro hilos se propusieron a inicios de 1990 [4] cuando se buscó una solución para que los CM tradicionales pudieran trabajar con cargas desbalanceadas o cargas no lineales [4-7]. Existen cargas que por su naturaleza generan un desbalance en la forma de la onda de corriente por fase de salida y es por esta razón que se requiere del hilo neutro, por donde fluyen las componentes de secuencia cero de las corrientes.

Las estrategias de modulación del ancho de los pulsos (PWM) para los CM deben permitir el control independiente de la magnitud y frecuencia de las tensiones de la salida, deben lograr alcanzar valores máximos en la relación de tensiones salida/entrada, satisfacer los requerimientos de bajo índice de distorsión armónica en las tensiones de salida y corrientes de

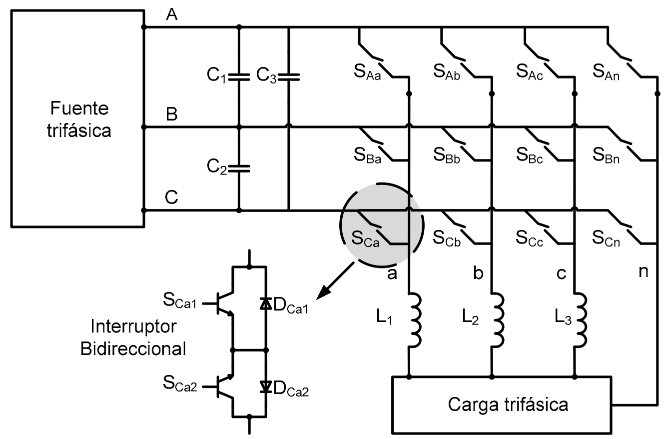

Figura 1. Convertidor Matricial 3x4.

de entrada, con mínimas pérdidas debidas a la conmutación. Además, la estrategia de modulación debe ser de fácil de implementar.

Debido a esto, los investigadores han desarrollado diversas estrategias de modulación para los CMs, entre las que se encuentran la modulación por vectores espaciales (SVM) [8-13] y la modulación de Venturini (VM) [14-17]. Estas dos modulaciones tienen características diferentes en cuanto a la operación bajo condiciones de carga desbalanceada y en la distorsión armónica que generan en las corrientes de entrada y tensiones de salida [18]. En [19] se comparan ambas modulaciones y se menciona que la VM puede operar a mayores frecuencias de conmutación en comparación con la SVM, ya que la carga computacional y por lo tanto los tiempos de cálculo se intensifican debido a que con la SVM un mayor número de vectores deben de ser generados. Además, gracias a que la VM puede operar a mayores frecuencias de conmutación, se pueden utilizar con mejor eficiencia filtros a la entrada y salida del CM. Cabe mencionar, que existen dos técnicas de modulación de Venturini, la modulación básica y la modulación óptima, sin embargo en este trabajo se ha seleccionado la modulación óptima de Venturini debido a que se tiene una mayor relación de tensiones de salida/entrada y porque genera una menor cantidad de armónicos [13].

II. CONVERTIDOR MATRICIAL 3X4

En la Fig. 1 se muestra un CM de tres entradas y cuatro salidas (3X4) formado por 12 interruptores bidireccionales, los cuales conectan las fases de salida y el neutro a, b, c y n con las fases de entrada A, B y C respectivamente. Los filtros de entrada y de salida están constituidos por capacitores, inductores y resistencias de amortiguamiento.

J. J. Rodríguez, SEPI-ESIME Instituto Politécnico Nacional, Ciudad de México, jjrodriguezr@ipn.mx

R. M. Caporal, Instituto Tecnológico de Apizaco, Tlaxcala, México, rmcaporal@ieee.org

E. Peralta, Universidad Popular Autónoma del Estado de Puebla, Puebla, edgar.peralta@upaep.mx

O. Carranza, SEPI-ESIME Instituto Politécnico Nacional, Ciudad de México, ocarranzac@ipn.mx

R. Ortega, SEPI-ESIME Instituto Politécnico Nacional, Ciudad de México, rortegag@ipn.mx

Kinetic energy recovery system based on a grid-tied three-phase power inverter for metro trains

Manuel Tlapa Juárez[1]
Edgar Peralta Sánchez[2]
Félix Quirino Morales[4]
Sergio Cardeña Moreno[5]
Universidad Popular Autónoma del Estado de Puebla
Puebla, México
Calle 21 Sur 1103, Barrio de Santiago, 72410 Puebla, Pue,
manuel.tlapa@upaep.mx[1]
edgar.peralta@upaep.mx[2]
felix.quirino@upaep.mx[4]
sergioalejandro.cardena@upaep.mx[5]

Juan Marcos Ruiz Dávila[3]
Coordinación de Desarrollo Tecnológico de la Gerencia de Ingeniería y Nuevos Proyectos del Sistema de Transporte Colectivo
Ciudad de México, México
Av. Ignacio Zaragoza No.614, Col. Cuatro Arboles, Del. Venustiano Carranza, Ciudad de México
jmrd1020@hotmail.com[3]

***Abstract*— This paper addresses the design of a kinetic energy recovery system. The energy recovery system is aimed to recover the energy regenerated by metro trains during their braking stage. The system is based on a grid-tied three-phase power inverter. Active and reactive power are injected into the grid by the power inverter when the train is regenerating energy. Synchronization of the power inverter to the grid is based on an SRF-PLL reference-frame technique. An energy management algorithm based on rules that determine the conditions under which the power is injected into the electrical grid is proposed. Finally, the results are validated by simulation in real time using a Hardware In The Loop system (Typhoon HIL 402) that is focused on power electronic applications.**

Keywords—Hardware In the Loop, PLL, Energy management, Grid-tied Inverters.

I. INTRODUCTION

Electric rail vehicles contribute to reduce pollutant emissions. Although these mass transit vehicles allow large reductions in terms of emissions, their energy efficiencies could be significantly improved. This improvement can be achieved through the implementation of kinetic energy recovery systems. The proposal of implementing energy recovery systems is feasible because most of the rectifying substations are not bidirectional, therefore it is impossible to return this energy to the electric grid and consequently it is used by other vehicles or wasted in braking resistors as heat [1].

The energy recovery system developed in this work is based on power inverters that independently of changing the voltage from DC to AC can inject active and reactive power into the electric grid by using a current control loop, where two important tasks are performed: compensation of the current error and generation of PWM to produce AC signals. To inject power into the electric grid, the control technique must enable a unity power factor, this means that current signals must be in phase with the grid voltage [2]. Fig. 1 shows a block diagram of the energy recovery system for a light rail vehicle.

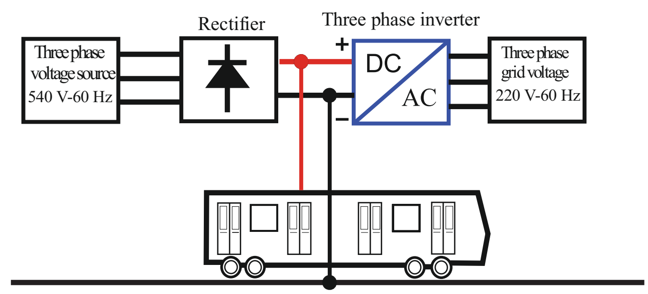

Fig. 1. Energy recovery system for a light rail vehicle.

The power injection of a grid-tied inverter into the electric grid is controlled by an energy management algorithm which defines the profile of the power to be sent to the grid. The energy management algorithms can be classified into rule-based methods and optimization-based methods. The rule-based strategy can be divided into deterministic rule-based methods and fuzzy-rule-based controllers [3], [4].

Another aspect to be considered is that the power flow of a grid-tied inverter requires a tracking of the phase voltage angle, amplitude and frequency. The most used and robust technique to achieve the above is by using a Phase Locked Loop (PLL) to carry out the synchronization properly [5].

In the literature related to grid-tied inverter synchronization, there are several synchronization methods among them the PLL method can provide accurate synchronization with a high degree of immunity and insensitivity to disturbances, harmonics, unbalances, sags/swells, and other types of distortions in the input signal. Synchronous Reference Frame PLL (SRF-PLL) is used

978-1-5386-5935-9/18/$31.00 ©2018 IEEE

Ingeniería Investigación y Tecnología, volumen XVII (número 1), enero-marzo 2016: 87-97
ISSN 1405-7743 FI-UNAM
(artículo arbitrado)
doi:10.1016/j.riit.2016.01.008

Modelo de capas para motores encapsulados de imán permanente con arranque en línea

Layer Model for Canned Line-Start Permanent Magnet Motors

Peralta-Sánchez Edgar
Universidad Popular Autónoma del Estado de Puebla
Departamento de Ingenierías
Correo: edgar.peralta@upaep.mx

Rodríguez-Rivas Jaime José
Instituto Politécnico Nacional
Escuela Superior de Ingeniería Mecánica y Eléctrica
Sección de Estudios de Posgrado e Investigación
Correo: jjrodriguezr@ipn.mx

Salazar-Amador María del Rubí
Universidad Popular Autónoma del Estado de Puebla
Departamento de Ingenierías
Correo: rubi.salazar@upaep.mx

Información del artículo: recibido: febrero de 2015, reevaluado: abril de 2015, aceptado: agosto de 2015

Resumen

En este artículo se describe el concepto de 'bomba encapsulada' y se desarrolla un análisis del motor encapsulado. El motor se integra en la bomba y es de *imanes permanentes* (IP) con arranque directo a la línea, cuenta con dos cápsulas de metal, una en el estator y otra en el rotor. La cápsula del rotor tiene doble función: actuar como elemento de inducción para el arranque directo a la línea y cubrir al rotor del líquido que se bombea. En el artículo se desarrolla un pseudomodelo analítico en 3D basado en la teoría de capas, el cual demuestra cómo el enfoque convencional para esta técnica puede modificarse para permitir adaptar los voltajes como alimentación de entrada y predecir la operación síncrona. El modelo se valida experimentalmente usando un prototipo de una motobomba de 10 kW, y se utiliza para estudiar la influencia de determinadas características de diseño tales como: el espesor de la cápsula del rotor, la fuerza magnetomotriz de los imanes del rotor y la longitud del saliente de la estructura de la cápsula del estator.

Descriptores:

- motor de arranque directo
- motor de imanes permanentes de arranque en línea
- bomba química sin sello

CEA comité español de automática

Revista Iberoamericana de Automática e Informática Industrial

Revista Iberoamericana de Automática e Informática industrial 00 (2019) 1–4

Crossref Similarity Check

www.revista-riai.org

Reducción de Armónicos en Sistemas de Generación Eólica con Controladores Resonantes en el Marco de Referencia Rotatorio *DQ*

Francisco E. Rodarte Gutiérrez [a], Jaime J, Rodríguez Rivas [a]*, Oscar Carranza Castillo [b], Rubén Ortega González [b], Edgar Peralta Sánchez [c]

[a] *Instituto Politécnico Nacional, Escuela Superior de Ingeniería Mecánica y Eléctrica, Ciudad de México, C.P. 07738, México*

[b] Instituto Politécnico Nacional, Escuela Superior de Cómputo, *Ciudad de México, C.P. 07738, México*

[c] Universidad Popular Autónoma del Estado de Puebla, *Departamento de Ingenierías, Puebla, C.P. 72410, México*

Resumen

En este trabajo se diseña un controlador resonante digital, que se caracteriza por realizar el seguimiento de señales periódicas, como las que aparecen en los armónicos de la corriente de salida de dos convertidores conectados por el bus de corriente directa (*back-to-back*), en un sistema de generación eólica. Esta técnica, al ser ejecutada en el marco de referencia síncrono (*dq*), permite implementar el control de la corriente del convertidor por el lado de red del *back-to-back*, con un alto nivel de rechazo a los armónicos de corriente en los pares de frecuencias 1+6*k* y 1-6*k* (*k* es un número entero). Los armónicos de corriente en el convertidor por el lado de la red, son producidos debido a la no linealidad del convertidor, y por la interacción con los armónicos de tensión de la red de alimentación. Los resultados obtenidos en este trabajo, pudieran ser implementados en sistemas de generación eólica que utilicen convertidores *back-to-back* con generadores síncronos de imanes permanentes o generadores de inducción doblemente alimentados. El esquema se implementó con un controlador resonante no ideal, con capacidad de funcionar aun cuando existen desviaciones en la frecuencia de la red. La finalidad de este trabajo es inyectar corrientes hacia la red eléctrica por medio de sistemas de generación eólica, con muy baja distorsión armónica, lo cual se logra mediante la implementación del control propuesto y de un apropiado diseño del filtro de red, que se utiliza como interfaz entre el convertidor y la red de alimentación.

Palabras Clave:
Generación Eólica, Convertidor del Lado de la Red, Controlador Resonante, Reducción de Armónicos.

Harmonic Reduction in a Wind Power System with Resonant Controllers in a Rotating Reference Frame *DQ*

Abstract

This work evaluates a digital resonant controller, which is characterized by monitoring periodic signals, such as those found in the harmonics of the output current, of two converters connected by the direct current bus (*back-to -back*) of a wind generation system. This technique, when executed in the synchronous reference frame (*dq*), allows implementing the control of the current of the converter by the grid side of the *back-to-back*, with a high level of rejection of the harmonics of current in 1+6*k* and 1-6*k* frequency pairs. The current harmonics in the converter on the grid side are produced due to the non-linearity of the converter, and by the interaction with the voltage harmonics of the power supply. The results obtained in this work could be implemented in wind generation systems that use *back-to-back* converters with permanent magnet synchronous generators or double-fed induction generators. The scheme was implemented with a non-ideal resonant controller, capable of operating even when there are deviations in the frequency of the line. The purpose of this work is to inject currents into the power grid in a wind generation systems with very low harmonic distortion, which is achieved by implementing the proposed control and an appropriate design of the grid filter, which serves as an interface between the converter and the power supply.

Keywords:
Wind Generation, Grid Side Converter, Resonant Controller, Harmonic Reduction.

1. Introducción

La aplicación de los convertidores electrónicos de potencia operando como fuentes de tensión, en los sistemas de generación de energía eléctrica a partir de energías renovables, ha provocado la reducción de emisiones contaminantes y el correspondiente impacto ambiental. Como ejemplo de estos sistemas, la generación eólica utiliza diferentes tipos de generadores

*Autor para la correspondencia: jjrodriguezr@ipn.mx

To cite this article: Francisco E. Rodarte Gutiérrez, Jaime J, Rodríguez Rivas, Oscar Carranza Castillo, Rubén Ortega González, Edgar Peralta Sánchez. 2018. Harmonic Reduction in a Wind Power System with Resonant Controllers in a Rotating Reference Frame *DQ*. Revista Iberoamericana de Automática e Informática Industrial 00, 1–4. https://doi.org/10.4995/riai.2017.7133

Análisis del proceso de balanceo de voltaje en un arreglo de supercapacitores

Edgar Peralta Sánchez
Universidad Popular Autónoma del Estado de Puebla (UPAEP)
edgar.peralta@upaep.mx

Pedro Celestino Castellanos Morales
Universidad Popular Autónoma del Estado de Puebla (UPAEP)

Nayeli Itzel Hernández Zárate
Benemérita Universidad Autónoma de Puebla (BUAP)
nayitze@gmail.com

Gerardo Mino Aguilar
Benemérita Universidad Autónoma de Puebla (BUAP)

Beatriz E. Graniel García
Benemérita Universidad Autónoma de Puebla (BUAP)

Resumen

En este trabajo se presenta el análisis y validación experimental de una red de balanceo para supercapacitores. El problema de desbalanceo de voltaje cuando se conectan supercapacitores en serie es analizado, para lo anterior se introduce un modelo equivalente de supercapacitor y se estudian diferentes opciones de circuitos de balanceo. Mediante un modelo analítico se realiza el cálculo de la corriente de balanceo requerida para balancear una cadena de supercapacitores. Un estudio del impacto de condiciones iniciales de carga en los supercapacitores sobre el proceso de balanceo es presentado. Resultados de simulaciones y experimentales son mostrados para validar el análisis, modelado y simulación de la red de balanceo presentada.

Palabra(s) Clave(s): desbalanceo de voltaje en supercapacitores, redes de balanceo supercapacitor.

Direct Torque Control of a Permanent-Magnet Synchronous Motor with Neural Networks

[a,b]F.H. Ramírez-Leyva, [a]F. Trujillo-Romero, [a]S.O. Caballero-Morales, [b]E. Peralta-Sánchez

[a]Universidad Tecnológica de la Mixteca
División de Estudios de Posgrado
Carretera a Acatlima Km. 2.5
Huajuapan de León, Oaxaca, México.
{hugo, ftrujillo, scaballero}@mixteco.utm.mx

[b]Universidad Popular Autónoma del Estado de Puebla
Departamento de Ingenierías
21 sur 1103 Barrio
Santiago C.P. 72410, Puebla México
edgar.peralta@upaep.mx

Abstract— **Permanent-Magnet Synchronous Motors (PMSM), characterized by high power density and efficiency, domain most of the applications that require high performance in control of position, speed, and torque. Direct Torque Control (DTC) is one of the most used techniques to control these motors. In this work an intelligent approach is proposed for the realization of the DTC for a PMSM by means of Artificial Neural Networks (RN). In addition, a comparative between the response obtained with conventional DTC (DTCC) and the neural network based DTC (DTCRN) is presented. The training data for the neural networks consisted in the set of values obtained with the DTCC. Both systems were implemented and simulated with Matlab / Simulink.**

Keywords— Direct Torque Control, Permanent Magnet Synchronous Motors, Artificial Neural Networks.

I. Introduction

The use of Direct Current (DC) or Alternating Current (AC) Permanent-Magnet Motors (PMM) has been increased in diverse industrial applications, especially in those of low power. Their main characteristics are: high power density and efficiency. The brushless DC PMM is used in applications where low susceptibility of the commutator assembly to mechanical wear is required. The brushless CA PMM, known as Permanent-Magnet Synchronous Motor (PMSM) is mainly used in applications that require high control performance. Currently, the cost of this kind of motors, as the cost of high efficiency Digital Signal Processors (DSP), is competitive. This has encouraged their use, especially when high efficiency is required [1].

The most common control methods for the PMSM are the Field Oriented Control (FOC) and the Direct Torque Control (DTC). In FOC the equations of the motor are transformed into a coordinate system that rotates synchronously with the flux of the permanent magnets. This allows the separation of the equations of the motor, and to indirectly control the flux and torque by means of a current PI controller. This is very similar to the DC control of a machine [2].

The DTC was initially used for the control of induction motors, although it has shown very good results in the control of PMSMs. Its principle of operation is based in selecting the voltage vector which is applied to the stator in function of the differences between the actual and the reference torque, and the magnetizing flux [3]. When a speed control is required, a PI controller is included (where the input is the speed error and the output is the desired torque). In this kind of control is not required to know the parameters of the motor with the exception of the stator resistance. Also, the PWM modulator for the inverter is not needed.

Besides the classic control for the PMSM, another control methods that make use of flexible computing techniques have been developed. This is the case of the use of Fuzzy Logic and Neural Networks to realize the control of PMSMs. This kind of methods allow the modelling of the system based in the inputs of the system and the desired (required) outputs. This allows the consideration of all, or just a part of, the system as a black box, and to model de controller in an easier way. This is because there is no dependancy on the motor model equations. Instead, the dependancy is based on the behavior. Some examples of the use of flexible computing in motor control are: the work of Liu et al. [4] who replaced the conventional hysteresis controller by a two-input fuzzy controller. In [5] a neural network was used to emulate the state selector of the DTC. Also a control for the DTC has been developed using three neural networks to estimate the value of the stator flux, the sector zone, and the selection of the impulsion vector to improve the performance of the PMSM controller [6]. The use of hybrid approaches of independent flexible computing techniques has also been documented as in [7] where a neuro-fuzzy system was used to implement the torque controller of the DTC for a PMSM.

In this paper the DTC controller using two neural networks is presented: one to estimate the flux, the torque, and the selector's zone, and the other to select the impulsion vector. Matlab/Simulink was used to validate the functionality of the controller built with the classic approach and with the neural networks.

The paper is divided into the following sections: in Section 2 the model of the PMSM is described. The description of the modelling with Matlab is presented in Section 3. In Section 4, the simulations obtained with the respective implementations are presented. Finally, in Section 5 the conclusions and perspectives of this work are presented.

978-1-4799-3469-0/14/$31.00 ©2014 IEEE