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MULTIZONAL INTEGRAL PROPORTIONAL SPEED CONTROLLER FOR A DC MOTOR FED BY SEPIC CONVERTER

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ABSTRACT

This paper presents a multizonal integral proportional (IP) speed controller for a closed loop speed controller of a separately excited dc motor. The motor is fed from a dc power supply and sepic converter. This converter offers both step-up and step-down characteristics of the motor terminal voltage. A high performance is achieved with a simple control circuit having only one switch (MOSFET) for the proposed system. The output voltage and current are smooth and free of ripples. The converter operates in both open and closed loop speed control. A multizonal IP speed controller is used to overcome the possibility of change in the system parameters. The proposed modeling and simulation of the system are performed using differential equations which describe the system behaviour in the different operating conditions. The run up, transient and steady state are presented. Speed control using multizonal IP speed controller is given to satisfy the best required response for the load disturbances. Also, the motor speed can follow the desired reference speed smoothly in the different operating zones. The experimental results have ensured the proposed controller robustness, simple, and powerful control application capabilities. The experimental and simulation results of the converter for both open and closed loop speed control system are verified and a good correlation between them was found.

يقدم البحث محكم سرعة متعدد المناطق تكاملى تناسبى وذلك للتحكم في السرعة للمسار المغلق لمحرك تيار مستمر ذو إثارة منفصلة. تتم تغذية المحرك من منبع جهد مستمر ومحوال من نوع SEPIC يقدم هذا المحوال خواص الرفع والخفض على جهد أطراف المحرك. أمكن الحصول على خواص عالية لهذا النظام المقترح باستخدام دائرة تحكم بسيطة ذات مفتاح واحد للمحوال من نوع الموسفت، حيث تم الحصول على جهد وتيار الخرج ذو شكل منتظم وخالى من التذبذبات. يعمل المحوال في حالتى التحكم في السرعة للدائرتين المفتوحة والمغلقة. كما تم استخدام محكم للسرعة متعدد المناطق وذلك للتغلب على حالات التغير في ثوابت النظام. تم اقتراح نموذج للنظام وتمثيله باستخدام المعادلات التفاضلية التي تصف خواص النظام لحالات التشغيل المختلفة مثل الحالات العابرة وحالة الاستقرار. تم اقتراح نظاما للتحكم في السرعة باستخدام محكم سرعة تكاملى تناسبى متعدد المناطق وذلك للحصول على أفضل استجابة مطلوبة لحالات حدوث تغير في الأحمال وفى سرعة الاسناد. تم الحصول على النتائج المعملية للتأكد من أن المحكم المقترح قوى ومتميز وبسيط وذو قدرة كبيرة على تطبيقات التحكم المختلفة. تمت المقارنة بين النتائج المعملية والنظرية لنظامى التحكم في السرعة لحالتى الدائرة المفتوحة والمغلقة، وقد وجد أن هناك تطابقا كبيرا بين الحالتين.

Keywords: Sepic converter, Multizonal integral proportional controller, Separately excited DC motor, Speed control , DC to DC convereter.

1. INTRODUCTION

Direct current motor drives are used extensively in industries such as steel mill, paper mill, conveyors, and chemical industries. In many drive applications, the mechanical load varies considerably during operation. Such examples of this load are robots and machine tools. When a *fixed controller* setting is used for a dc drive system with wide load changes, unsatisfactory performance is often produced [1].

High performance dc motor *drives* are *important* for multitude of industrial applications [2]. Precise, fast, *effective* speed reference tracking with minimum overshoot/undershoot and small steady state error are essential control objectives. Conventional controllers are usually used for fixed structure, and fixed parameters *design [3-5]. Tuning and optimization* of these controllers are challenging and have difficult *task*, particularly under varying load conditions, and abnormal operation.

An artificial intelligent system based on fuzzy logic and neural network techniques was reported for a high performance dc drive [6]. A simulation study for an intelligent rule-based error driven gain scheduling controller for a chopper fed dc series motor was proposed in [7]. Alternatively, an intelligent self-adaptive rule based speed regulator for a permanent magnet dc motor drive is implemented in [8]. The dynamic and steady state performance of a symmetrical angle controlled dc motor is investigated, and the power factor of the system is improved using this technique. Also, the conventional analog proportional integral controller is used for speed control [9].

It is well known that power supplies can suffer considerably from current distortions and low power factor operations when a conventional diode bridge rectifier is operated with a dc filter capacitor at the output terminal. They result in large installation size and increased losses. To counteract these shortcomings, various passive and active input current wave shaping methods have been presented [10-13]. The supply currents can be passively waveshaped by connecting the series resonant circuit or parallel resonant circuit [10] with the supplies in series. However, it is difficult to obtain sinusoidal supply currents with a near unity power factor for a wide variety of operating conditions. On the other hand, when the cascade combinations of a diode bridge and boost dc-dc converter are used as the rectifiers, the sinusoidal supply currents can then be actively waveshaped with a near unity power factor operation by filtering the high order current harmonics if the rectifiers are operated in discontinuous current conduction mode [11-17]. They also have the advantage of simple pulse width modulation (PWM) with uniform duty factor and a single power switching device which provides the necessary control over the currents both in single phase [11-12] and three phase [13] configurations. Unfortunately, if both step-up and step-down output voltages, which have to be continuously regulated, are desired, they cannot satisfy the requirement. If, for example, the rectifier inverter system is considered, the rectifier with step-up and step-down characteristics will be useful because it enables the system to operate with pulse amplitude modulation at the inverter input terminal. Thus, PWM techniques for the inverter circuit may be merely focused on the decreasing in output ac voltage harmonics.

In the previous researches, they haven't paid an attention for the dynamic operation of a dc to dc sepic converter fed dc motor. Also, they haven't paid an attention for some different points of the operation with the load and speed reference changes. They have focused on one operating point only with IP speed controller.

In this paper, a speed control for a separately excited dc motor fed from dc supply through a sepic converter is presented. Step-up and step-down characteristics of the output voltage are obtained. A multizonal integral proportional speed controller is applied. The proposed modeling and numerical simulation of the investigated system is described in different modes of operation. An experimental system is built to verify the simulation results. The comparison between the experimental and simulation results has proved a good agreement with each other. Both results give a prediction with a high motor speed performance over a wide range of reference speed and load changes.

2. SYSTEM DESCRIPTION

Figure (1) shows the schematic diagram of the proposed system. The capacitor C_1 acts as a transfer element. The inductance L_2 and capacitance C_2 are used as a filter to obtain dc output load voltage with minimum ripples. The switching frequency (F_S) and the value of C_1 are determined according to L_1 value. The resonance frequency is calculated from the equation $f_r = \dfrac{1}{2\pi\sqrt{L_1 C_1}}$ and should be sufficiently higher than the switching frequency to prevent any resonance phenomenon in the ac circuit. The system parameters are given in the Appendix.

Step-up and down behaviour of the output voltage is obtained by regulating the control voltage (V_C) from zero to the maximum value of the carrier voltage (V_{car}). The Mosfet is derived on when the carrier voltage (V_{car}) is lesser than or equal to the control voltage, which is the speed control output. The duty ratio is given :

$$\text{Duty ratio} = \frac{T_{on}}{T_{on} + T_{off}} \qquad (1)$$

Where T_{on} = the Mosfet on time.

T_{off} = the Mosfet off time.

3. SYSTEM MODELING AND SIMULATION

To simulate the detailed operation, the voltage, current and motor equations have to be established for each operating mode.

Mode (1):

In this mode the Mosfet is on and the current i_1 will flow in the loop $(v - L_1 - r_1)$. The capacitor C_1 will discharge where the diode D is off. The equations describing this mode are: