Computers and Electrical Engineering 000 (2017) 1–15

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

Design of intelligent controller for reduction of chattering phenomenon in robotic arm: A rapid prototyping[☆]

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ARTICLE INFO

Article history:
Received 8 May 2017
Revised 23 November 2017
Accepted 2 December 2017
Available online xxx

Keywords:
DC motor
DC-DC buck converter
Sliding Mode Control
Pulse-width modulator
Chattering and dynamic response
Cascade control
Electro magnetic interference

ABSTRACT

Robots functioning in the place of living beings is becoming more reliable as they can endure drastic physical conditions and can operate in airless conditions. Further, they can perform risky jobs and be not bothered by the job security and reputation. Sliding Mode controller (SMC) is a robust controller that has high stability, but it suffers from the problem of chattering. Power losses and severe electromagnetic interference (EMI) noises produced by the converter due to high switching frequency yields chattering. This paper puts forth the design of a hierarchal controller using differential flatness property to track the angular velocity trajectory of permanent magnet DC motor driven by a DC-DC buck converter. A cascaded control is used to regulate the DC-DC buck converter and it aids to reduce the chattering phenomenon to a minimum level. In addition, this control enhances the performance of the system by maintaining fixed switching frequency. Experimental observations show that the angular velocity is well traced under abrupt conditions.

1. Introduction

An Intelligent system is a collection of devices interconnected to one another, which is simple and compact in design. It is used in digital televisions, traffic lights, robotics, automobiles, gaming and airplane controls. Permanent magnet DC motors have various applications in the fields where speed ranges from small fractions to several horsepower. They can be widely used with high precision control strategies. They are best suitable for position control in robotics, coil winding, textile industry, welding, printing, pharmaceutical machinery, and in conveyor machine tool industry. Most of these applications demand velocity control or position control of the motor. Electromagnetic compatibility (EMC) is a property of power electronic devices that helps to coordinate various electromagnetic environments and enables them to work effectively and appropriately. The purpose of EMC is to allow a power electronic device to get habituated to a variety of external interferences and to assist the device to work in appropriate electromagnetic environment. Besides, EMC also ensures that the device is not affected by the electromagnetic interference with other electronic devices.

In literature, the adjustment of armature voltage is used to control the DC motor; several controllers are designed, which mainly focus on tracking of velocity trajectory of the DC motor. Linares- Flores et al. [1] proposed a smooth starter for angular velocity regulation of DC motor driven by DC-DC power converter. This method is designed based on the second-order model, where the parameters like converter-output-current and armature-inductance are neglected. Flores et al. [2] tracked

☆ Reviews processed and recommended for publication to the Editor-in-Chief by Guest Editor Dr. V. Suma.

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https://doi.org/10.1016/j.compeleceng.2017.12.010

Nomenclature

V_i	Applied voltage in the motor
i_{ar}	Armature current
K_e	Counter electromotive force constant
J	Moment of inertia of the rotor
ω/F_L	Angular velocity variable, Flat output
$\gamma_2,\gamma_1,\gamma_0,$	Controller gains of the motor
V_{out}	Capacitor output voltage of the converter
L	Input circuit inductance of the converter
R	Output Load resistance of the converter
E	Angular velocity tracking error
$\alpha_2,\alpha_1,\alpha_0,$	Controller gains of the converter
$S(X)$	Sliding surface
D	Duty ratio of the converter
k_m	Motor torque constant
L_{ar}	Armature inductance
R_{ar}	Resistance of the armature
b	Viscous friction coefficient of the motor
μ_m	Auxiliary control variable
i_L	Converter Inductor current
u	Logic state of the converter power switch
C	Capacitance of the output filter
F_1	Flat output variable of converter
e_V	Voltage tracking error
s	Instantaneous state trajectory
S_c	Slope of the triangular carrier
V_p,f_s	Triangular carrier amplitude and frequency
Φ	Trade off between tracking error and smoothing of control discontinuity

the trajectory of the velocity of a DC motor with DC buck converter via sigma-delta modulator through Sliding Mode Control, where the effectiveness is verified by numerical simulations. Fadil et al. [3] propounded the back stepping and fourth-order method which is used to regulate the velocity control of the DC-DC buck converter. He also proposed adaptive and non-adaptive versions, where the adaptive version gives better responses when torque changes when neither of the phenomenon of smooth reference nor parametric disturbances is considered. Ahmad et al. [4] compared the combined system of motor and converter, an evaluation of PI, fuzzy PI, and LQR controllers for velocity tracking task, without real-time implementation. Kumar et al. [5] proposed PI and back stepping controllers with numerical simulations which are used for the regulation of angular velocity. Bingol et al. [6] anticipated neural network controllers for a combinational system of DC motor and converter. This set allows the control parameters to be changed under operational conditions and are monitored by graphical user interface. Sira et al. [7] proposed a robust control for two combinations of converter-driven motors based on the disturbance rejections and flatness control. The effectiveness is observed based on numerical simulations. Chen et al. [8–11] proposed different control techniques such as closed-loop analysis, Sliding Mode Control and PI control for converters like Buck-Boost, Cuk and Boost, but a cascaded-control to regulate the converter of the motor is not carried. Tumari et al. [12] has modelled H infinity pole placement in linear matrix inequalities region for a buck converter. Silva Ortigoza et al. [13] designed a two-level controller in which one is associated with differential flatness and the other one is cascaded control that provides smooth starting for velocity tracking of DC motor driven by the converter. This controller is tested through experimentation using MATLAB-Simulink and the DS1104 board from dSPACE, but with the SMC controller which is often discontinuous. SMC provides high switching action, which results in chattering problem. Several authors [14–23] have designed converters for DC motors.

In the current research, a Sliding Mode Controller (SMC) is used and its principal function is to regulate the output voltage of DC-DC converter by varying the duty cycles in input voltage or by load variations. In this paper, SMC generates a control voltage rather than switching pulses and fed to the modulator to generate switching pulses at constant switching frequency. The constant switching frequency is maintained consistently, thus simplifying the design procedure and enhancing the regulation and the functioning of filter design. Also, this proposed control has good dynamic response and robustness. The proposed methodology (SMC-based PWM technique) is used for the optimal design of parameters to minimize the effect of predictable uncertainties of structural performance and to maximize the robustness. This SMC based PWM mainly addresses two distinct phenomenon i.e. Chattering and Dynamic performance under sudden load and parametric variations. The minimization of the above phenomenon gives the angular velocity trajectory, boosts performance in abrupt variations and in different uncertainties of system parameters.

Please cite this article as: K.V.R. Swathi, G.V.N. Kumar, Design of intelligent controller for reduction of chattering phenomenon in robotic arm: A rapid prototyping, Computers and Electrical Engineering (2017), https://doi.org/10.1016/j.compeleceng.2017.12.010