PERFORMANCE ANALYSIS OF DC SERIES MOTOR USING BUCK BOOST CONVERTER

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Abstract - This paper presents a performance analysis of dc series motor using buck boost converter. A Buck-Boost converter using a MOSFET as a switch fed a dc series motor. The characteristics for step - up and step down of the output voltage are studied. It is found that this system poses a good operation performance with a minimum ripple in the output of the motor current and voltage. The mathematical models describing both the open and closed-loop systems are proposed using the differential equations describing the system in different modes of operation for open and closed loop systems. The steady-state, starting-up and transient operating' conditions are investigated for the open loop system. For the closed loop system, a positive step change in the load is investigated. Also, the effects of positive and negative step changes in the reference voltage are studied.

I. INTRODUCTION

This paper investigates an ac to dc buck boost converter feeding a dc series motor using a simple control method with a step up and down characteristics. In this system only one switch is used, and approximately a unity power factor is obtained. Added to these, the system has the advantage that the voltage and current of the dc series motor have minimum ripples. The modeling and digital simulation for the speed control system have been proposed. Starting-up, transient and steady-state operating conditions are given also. The proportional integral (PI) controller parameters are chosen to satisfy the required response. For both load and speed reference changes.

The buck-boost converters from ac to dc with only one switching device as a MOSFET can be used for small output power applications (1). Ac to dc cascade buck boost converter to achieve sinusoidal line current with two switching devices are given in references [2-4].

II. SYSTEM DESCRIPTION

Figure (1) shows the schematic diagram of the system. The system consists of a cascade combination of a diode bridge rectifier and a buck-boost converter connected to an AC single-phase supply. A step-up/down of the output voltage can be obtained by regulating the duty ratio, Where:

Duty ratio $\frac{T_{on}}{T}$ (1)

Where $T_{on}$ is the switch on time.

$T$ is the switch (on +off) time. The duty ratio can be controlled using the control voltage $V_c$ from zero to the maximum value (A) of the triangle voltage (carrier voltage signal) as shown in Figure (3). The motor speed is controlled by varying the control voltage $V_c$. The inductance $L_1$ is used as a transfer element. The capacitance $C$ is used as an output filter. The motor is a dc series motor. The load is a separately excited dc generator. The switching frequency is given by the following equation:

$F_s = \frac{1}{T}$ (2)

The dc series motor parameters and the buck-boost parameters are given in Appendix (1).
III. SYSTEM MODELING AND MODES OF OPERATION

Figure (2) shows the equivalent circuits for the operation modes. They are given as in the following form [5].

**Mode (1)** In this mode the MOSFET is on and the diode is off. The differential equations describing this mode are:

\[\frac{di_1}{dt}=\frac{1}{L_1}[-E-i_1R_1]\]  \hspace{1cm} (3)
\[i_s=0\]  \hspace{1cm} (4)
\[\frac{dV_m}{dt}=\frac{1}{C}[i_m]\]  \hspace{1cm} (5)
\[\frac{di_m}{dt}=\frac{1}{L_t}[V_m-i_mR_t-K_m\dot{i}_m]\]  \hspace{1cm} (6)
\[\frac{d\dot{i}_m}{dt}=\frac{1}{J}[K_m i_m^2-B\dot{i}_m-T_L]\]  \hspace{1cm} (7)

where \(L_t=L_m+L_f\), \(R_f=R_m+R_f\).

The magnetization characteristics of saturation can be taken as in the following form:

\[K_m=K_o/K_s\]

If \(i_m<i_{sat}\) then, \(K_s=1\).

If \(i_m>i_{sat}\) then, \(K_s=1+a(i_m-i_{sat})\)

where \(a=0.2694\), \(i_{sat}=0.8\) amp.

**Mode (2):** in this mode the MOSFET is off while the diode is on. The differential equations describing this mode are given as in the following form:

\[\frac{di_1}{dt}=\frac{1}{L_1}[-V_m-i_1R_1]\]  \hspace{1cm} (9)
\[i_s=0\]  \hspace{1cm} (10)
\[\frac{dV_m}{dt}=\frac{1}{C}[i_m]\]  \hspace{1cm} (11)
\[\frac{di_m}{dt}=\frac{1}{L_t}[V_m-i_mR_t-K_m\dot{i}_m]\]  \hspace{1cm} (12)
\[\frac{d\dot{i}_m}{dt}=\frac{1}{J}[K_m i_m^2-B\dot{i}_m-T_L]\]  \hspace{1cm} (13)

**Mode (3)** In this mode both the MOSFET and the diode are off. The differential equations describing this mode are given as follow:

\[i_s=0\]  \hspace{1cm} (14)
\[i_s=0\]  \hspace{1cm} (15)
\[\frac{di_1}{dt}=\frac{1}{L_1}[-i_m]\]  \hspace{1cm} (16)
\[\frac{di_m}{dt}=\frac{1}{L_t}[V_m-i_mR_t-K_m\dot{i}_m]\]  \hspace{1cm} (17)
\[\frac{d\dot{i}_m}{dt}=\frac{1}{J}[K_m i_m^2-B\dot{i}_m-T_L]\]  \hspace{1cm} (18)

**IV. SIMULATION RESULTS**

**V. i - Steady-State Condition**

Figures (4, 5) show the motor current and speed versus time. These results are computed under the case of a load torque equals to 0.4 N.m. It is clear that no ripples are shown in both the motor voltage and current, thus the motor speed is found to be smooth. The supply input voltages versus time are shown in Figures (6) for the same above condition. It is observed that the supply input power factor is approximately near to unity. Figure (7) shows the rectified voltage versus time while Figure (8) shows the coil current against time. The control voltage versus time at the steady-state is shown in Figure (9) for the same conditions mentioned previously.

**ii. starting up condition**

Figures (10-12) show the computed motor current, speed and voltage versus time during the starting-up.

**iii. Transient Condition**

Figures (13) show the computed motor speed versus time due to a step change in the load torque from 0.2 to 0.4 N.m. Figures (14) show the change in motor current versus time' due to the same above condition. It is observed that both the motor voltage and speed are decreased while the motor current and the supply input current are increased.

**iv. closed loop operation**

Figures (15,16) show the computed results for the response of motor current and speed due to a positive step change in the load torque from 0.1655 to 0.1855 N.m. A positive step change in the reference voltage (from 1.995 to 2.2) is made and the computed results for the response of the motor current, voltage and speed are shown in Figures (17,18).
Figure (4) motor current versus time

Figure (5) motor speed versus time

Figure (6) ac input voltage versus time

Figure (7) rectified voltage versus time

Figure (8) coil current versus time

Figure (9) control voltage versus time

Figure (10) motor current versus time during starting up

Figure (10) motor speed versus time during starting

Figure (10) motor voltage versus time during starting

Figure (13) motor speed versus time due to a step change in load torque.
CONCLUSIONS

The proposed modeling and simulation for a dc series motor fed from a single-phase bridge rectifier is presented in this paper. The suggested system is based on the cascade combination of a diode bridge and a buck-boost converter using only one switch (MOSFET). The presented control circuit for the proposed system has the advantage that it is simple and has a step-up and down smooth output voltage and current. The MOSFET is used to give an approximately sinusoidal supply current with approximately unity power factor. Also, the output voltage, current and speed have minimum ripples. The responses for starting-up and transient conditions are predicted in the proposed system. The controller parameters are selected for closed-loop speed control. The load and speed reference disturbances responses are given. It is concluded that in open-loop system, the speed is varied due to load change, while it is remained constant in the closed-loop system. The importance of the application for such a system is that it is used for traction purposes.

REFERENCES