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Original Research Paper

Speed Regulation of Direct Current Motor Using AC-DC Buck Boost Converter by using Soft Starter Method

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Abstract: Regulating the speed of direct current motors is essential in a variety of industries. The speed of direct current can be controlled by adjusting armature resistance, voltage and field current. Voltage regulation can be achieved by utilizing an AC-DC buck-boost converter for increasing and decreasing voltage. Additionally, it is important to take into account the initiation of a DC motor. Initiating operation of a DC motor necessitates a significant current to prevent potential harm to the insulation. Due to this, it is important to keep the current low when starting a DC motor. One method to decrease the initial current is by using a soft starter, where the reference current is compared to the motor's armature current. This research resulted in the development of a circuit that efficiently adjusts voltage levels with a pulse generator, making it easy to regulate the speed of direct current motors. A PI controller can also regulate the velocity of a direct current motor. During the trial, it was discovered that the initial current in a direct current motor never went beyond 23.7 amperes, making this technique highly efficient for initiating a direct current motor.

Keywords: Current Low, Soft Starter, Voltage Regulation.

1. introduction

A motor is a device that changes electrical energy to mechanical energy. Direct current motors are comprised of both external and internal strengthening. Direct current motors are commonly utilized as drive motors in the automotive industry due to their simple speed control. Adjusting the current field, armature resistance, and armature terminal voltage can all be used to set the speed of a DC motor [1] [2] [3] [4]. A direct current motor needs careful monitoring as it requires a high starting current which can harm the insulation in the motor [5] [6]. Two methods of motor activation include utilizing starting resistance or implementing a starting current limiting circuit [3] [5] [7] [8] [9].

An electric motor transforms electrical power into mechanical power. It is believed that motors account for about half of the global energy consumption. Hence, improving the efficiency of motors is predicted to have a major influence on the worldwide energy crisis.

2. Literature Review

2.1. Direct Current Motor

DC motor, short for Direct Current Motor, is a device that transforms electrical energy from direct current into mechanical energy. In a DC motor, the electrical energy input is converted from direct current into rotational mechanical energy. A DC motor is a machine that changes electrical energy from direct current into mechanical energy. It relies on electromagnetic induction, in which a conductor with current flowing through it (typically a wire coil) positioned in a magnetic field is subject to a force that causes it to rotate [9] [10] [11]. This rotation is utilized for carrying out physical tasks [12].

DC motors have various uses such as in robotics, electric vehicles, industrial machinery, and household devices. DC motor is suitable for applications that necessitate speed regulation [13] [14]. This is the reason why DC motors are frequently utilized in applications such as trolleys, electric train manufacturing systems, elevators, and more.

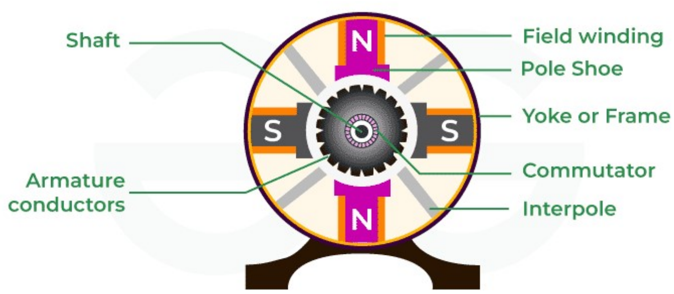

Figure 1. Diagram of Direct Current Motor

A DC motor consists of essential elements: a stator (permanent part creating a magnetic field) and a rotor that spins with winding or coil [15] [16] [17]. When a direct current voltage is applied to the coil, it causes electric current to pass through, creating an electromagnetic field [18]. When the rotor's magnetic field interacts with the stator's, it creates torque that makes the piece begin to rotate [19].

When a current carrying conductor is placed in a magnetic field, a mechanical force acts on it, which can be determined by Fleming’s left-hand rule. Due to this force the conductor becomes mobile in the direction of the force [20] [21].

Imagine that a conductor without any current flowing through it, placed in a magnetic field with no magnetic field passing through it. Imagine there is a space of air running from the North pole to the South pole. Electric current is passing through the conductor; however, the magnetic influence of the North and South poles has been eliminated. In this scenario, the conductor will sustain its magnetic field. Per the cork screw rule, the conductor's magnetic field lines of force will rotate in a clockwise direction [22].

There is a flow of current in the conductor while the main magnetic field is also in existence. The current in the conductor causes a magnetic field that aligns with the main field above it, but goes against the main field below it [23]. As a consequence, there is an accumulation of flux above the conductor while the flux density decreases below it.

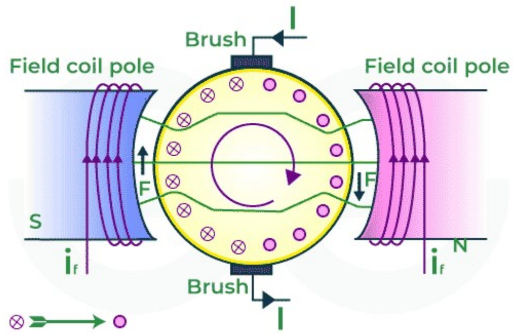

Figure 2. DC Motor Working Principle

It is evident that the force pushes the conductor downwards when it is acting on it. When the current flow in the conductor is reversed, the magnetic flux will increase in the downward direction and will attempt to lift the conductor upwards [24].

Therefore, there are three methods that can be used to control the speed of a direct current motor.

1. Voltage adjustment at the axle winding terminals, using the fact that a change in voltage at the shunt motor terminals will result in a proportional change in speed. Generally, the available power is constant voltage alternating current, so extra equipment such as rectifiers or motor-generator sets are needed to provide adjustable voltage to the motor [25] [26] [27].
2. Resistance tuning associated with the master winding circuit, This tuning is done by adding an outer series resistance into the master winding circuit to adjust the speed. This method can be used for series, shunt, and composite motors; for the latter two types, the series resistor must be placed between the shunt field and the winding shaft, not between the power grid and the motor [28] [29] [30].
3. Field current adjustment is a frequently used technique and is the main advantage of shunt motors. Regulating the field flow to control its flux and speed by adjusting the resistance of the shunt-field or neutralized field separately is a simple and economical method without affecting the motor losses much [31] [32].

2.3. Methods for Starting a Direct Current Motor

The starting of DC motor differs somewhat from the initiation of all other varieties of electrical motors. This variation is attributed to the fact that a DC motor, unlike other motor types, has a notably high initial current that could cause harm to the DC motor's internal circuit if not limited to a specific value [33]. The starter is the mechanism responsible for restricting the initial current of a DC motor. Therefore, the key point about how DC motors are started is that they require a starter to function [34]. Instead, a device with an adjustable resistance is linked in a series to the armature winding in order to control the initial current of a DC motor at a specific optimal level, while also ensuring the motor's safety [35].

The are two methods used for starting a direct current motor:

1) Starting Resistance
The most commonly used way to limit the large armature current at the time of starting is to make a prisoner installed in series with the armature resistance [36]. Slowly then the induced voltage is generated and the rotor begins to rotate. Along with this, the starting resistance must also be lowered. The lowering of the starting resistance can be done by hand (by humans) or automatically (by using electronic relays) [37]. The disadvantage of using this method is the loss of energy caused by the use of resistors and also current limitations can not be changed because it is predetermined. [38]
2) Starting Current Limiting Circuit
An alternative method for limiting armature current is to use a current limiting circuit [39].

This limiting circuit works by using a switch. The switch circuit used can be with MOSFET or GTO (gate turn on). This switch is controlled by hysteresis control. The control consists of a relay that compares the input signal with a threshold value called the hysteresis band (h band) [40]. This circuit works by comparing the reference current (the maximum current allowed at the armature) with the actual armature current.

3. Methodology

Modeling was performed using Matlab in this research. Using the toolbox within the MATLAB software, simulations were conducted. Experiments are conducted for a specific period of time using:

1. Simulating DC motor with soft starter sans speed controller for 1, 1.5 and 2 seconds.
2. Simulating a direct current motor with immediate starting within for 1, 1.5 and 2 seconds.
3. Simulating a DC motor with resistance, beginning with a 5 and 10-second delay.
4. Simulation of a DC motor with a soft starter incorporating a speed controller and a timed delay of for 1, 1.5 and 2 seconds.

The direct current motor parameters used in this research are shown in Table 1.

Tabel 1. DC Motor Parameter

Rating	Value
Speed	1750 rpm
Field voltage	300 V
Voltage rating	240 V
Rating current	21,1 Amp
L_a	0,028 H
L_f	156 H
L_{af}	0,9483 H
R_a	2,581 Ω
R_f	281,3 Ω
J	0,02215 N –rad/sec
Bm	0,002853 N.m.s
Tf	0,5161

4. Finding and Discussion

Based on the result, we found that it took half a second for the system to achieve stability with the current and voltage. The findings from the simulation reveal an inrush voltage of 64 amperes, which is thrice the nominal current of the machine at 21.1 amperes. The reason for this growth is the minimal resistance of the armature winding in the DC machine.

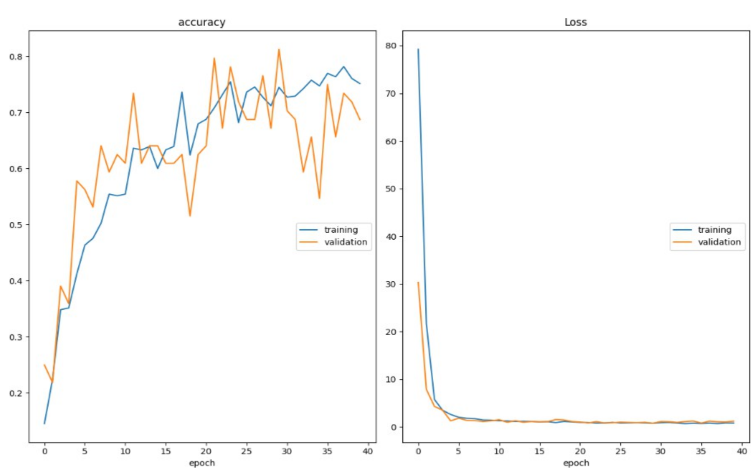

Figure 3. Achieve Stability with The Current and Voltage

The discovery demonstrates a steady rise in the voltage, initial current, and motor velocity up to the anticipated levels. This happens because the initial resistance slowly decreases until it reaches zero. This initial resistance serves to decrease the inrush current flowing into the motor's circuit upon startup. Once the resistance is removed, the machine will operate at its normal speed as the current flows directly to the machine without encountering resistance. The system will reach stability within 3.5 seconds once all initial resistance is removed.

Additionally, the findings also showed that the anchor current never surpassed the 25 Ampere maximum current limit. This occurs as the error current, comprised of the reference current and the machine current, reacts to the gate pulse at the GTO. If Ie (Ia-Iref) is greater than 2.5 amperes, the pulse will be set to zero (0); if it is less than -2.5 amperes, the pulse will be set to one (1). This comparison indicates that once the grid current hits 25 amperes, the current magnitude error Ie will be eliminated, causing the resulting pulse to be zero as well. If the grid current drops below 22.5 amperes, the pulse will stop the GTO gate and current flow; however, if the current is higher, the pulse will turn on the gate and draw the current away. You can adjust the initial current value by manually setting it equal to the reference current value. The system will reach a stable state in 1.3 seconds.

The Pulse GTO functions as the gate trigger for the GTO. When the pulse value is 1, the gate will open allowing current to flow; in contrast, when the pulse value is 0, the gate will close preventing current flow. The pulse value is determined by the reference current and the starting motor current values. If the motor's initial current exceeds the reference current, the pulse will be turned off (0); but if the motor's initial current is lower than the reference current, the pulse will be turned on (1).

This test is akin to the simulation test of a DC motor utilizing a soft starter without a PI controller as it depends on limiting the starting current. The variation is the inclusion of a speed controller circuit that serves as a limiter for the initial current. This device functions by evaluating the velocity of the DC motor against the set speed. The result of this comparison will later be inputted into the PI (Proportional- Integral) controller. The output of the PI controller will be evaluated against the initial current of the DC motor. This enables us to modify the motor's speed based on the input value given for the reference speed. The speed controller will enable the DC motor to achieve a speed close to 100 rad/s. The initial current will not go over a maximum current of 25 amperes.

A simulation for regulating the speed of a Direct Current Motor which is done by setting the Duty Cycle at a certain value. This simulation can be performed on a direct current motor simulation with a direct start, with a starter resistance, or with a soft starter without a speed controller. By changing the value of the duty cycle, the amount of voltage coming out of the buck-boost converter will change. Changes in the voltage that enters the motor network will make the motor speed vary along with the voltage. Simulation by changing the duty cycle is not effectively used in the simulation of direct current motor with soft starter and speed controller, this is because the speed of direct current motor is not really affected by the increase or decrease of voltage.

Table 2. Direct Current Motor Speed and Voltage generated with Change in Duty Cycle Value

D	Vout	Value
30	100	65
35	120	90
40	140	115
45	180	140
50	210	150
55	255	195
60	325	230
70	495	380
80	750	560

The speed of the direct current motor in this experiment only depends on the reference speed value