

Soft Starting Of DC Motor with IoT Application

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Abstract—This paper proposes a soft starting method of DC motor. The major drawback that occurs with conventional starting of a dc motor is the presence of high armature current. This initial current has dangerous effects on the dc motor such as damage of windings, high initial losses and creation of false operation of protective devices. It may also lead low efficiency and reduces the lifetime of the machine. Hence, there is a need to reduce the high initial starting current for better working of the dc motor through Soft Starting of DC motor. A soft starter can eliminate these problems by gradually increasing voltage to the motor terminals during startup, providing a controlled ramp-up to full speed. This lowers inrush current and controls starting torque, reducing mechanical shocks to the system and to the product and also with the use of IoT application it is easy to measure the accurate values of different parameters (Voltage, Current, Power etc.) by accessing it from cloud. The graphical representation of voltage, current, speed characteristics will be plotted automatically, which makes the starter to work with a smart technique.

Index Terms—Soft Starter, Buck Converter, IoT, Speed Control.

I. INTRODUCTION

The usual starting and speed control techniques of DC Shunt Motor makes use of some form of current limiting elements such as resistors. “At standstill, back EMF is zero and the only resistance opposing flow of current is the armature circuit resistance, which is quite small for all types of DC motor [1-4]. If a DC motor is started with full supply voltage across its terminal, a very high current will flow, which may damage motor and cause heating of winding. Therefore, it is necessary to limit the current to a safe value during starting”.

The rheostats are introduced to limiting the starting current and to control voltage across the windings. The above forms of control results in ohmic losses by the resistor and the loading of the machine is limited by the rating of current limiting resistors during speed control operations. Soft starters provides solution to this problem by taking advantage of minimal power dissipation of power converters relative to conventional methods and smooth starting along with speed

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control is possible. The proposed model uses a BUCK converter that provides soft starting of the DC motor. In this model Arduino is used to control the various sensors such as voltage sensor, current sensor, speed sensor. These sensors measures the voltage, current and speed of the DC motor and the measured values are displayed on the LCD display and the displayed values are extracted into XL-Spread sheet and the plots are automatically plotted in XL-Spread sheet by using an additional application called PLX-DAQ.

II. BLOCK DIAGRAM

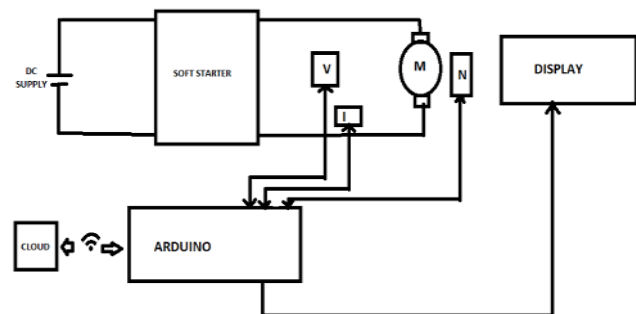


Fig. 1. Block diagram

The above figure shows the block diagram of soft starting of DC motor. This model is mainly proposed for 48V 2Amps DC shunt motor. In this proposed model the buck chopper is used as a soft starter by which the voltage is applied to the DC motor by using a variable knob though which the soft starting of DC motor is done smoothly. The major drawback that occurs while starting a dc motor is the presence of high armature current.

This initial current can have dangerous effects on the dc motor such as damage of windings, high initial losses and creation of false operation of protective devices. It may also lead to low efficiency and reduces the lifetime of the machine. “A soft starter can eliminate these problems by gradually increasing voltage to the motor terminals during startup, providing a controlled ramp-up to full speed. This lowers inrush current and controls starting torque, reducing mechanical shocks to the system and to the product [4-8]”.

With the use of sensors the values of voltage, current, and speed are measured and the measured values are displayed on LCD display and the same values are stored in XL spread sheet by using a controller called Arduino. And the characteristic graphs are plotted automatically.

III. BUCK CONVERTER

Initially the supply will be 230V AC supply and this model is proposed for 48V DC according to the motor ratings. So initially, the 230V supply will be reduced 50V DC supply by using a DC Adaptor and further this 50V DC supply is step down to controlled 48V by using a step down converter called Buck converter. The buck converter is a static power electronic device as shown in Fig. 2, “which converts fixed dc input voltage to a variable dc output voltage. It can be step up or step down. It is also considered as a dc equivalent of an AC transformer since they behave in an identical manner. Chopper systems offer smooth control, high efficiency, faster response and regeneration facility. The power semiconductor devices used for a chopper circuit can be force-commutated thyristor, BJT, MOSFET, IGBT and GTO”.

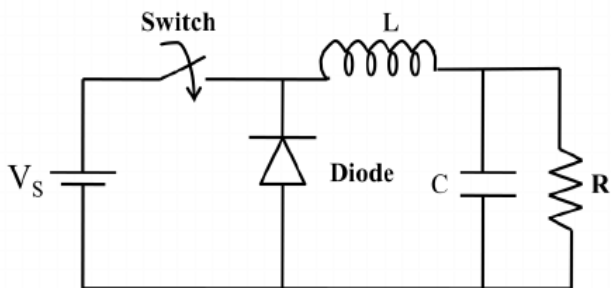


Fig. 2. Buck converter

For designing the buck converter for producing 48V dc output voltage initially, the buck converter is theoretically designed based on mathematical modeling of buck converter. the following calculations will gives the theoretical design of inductor and capacitor. For designing inductance and capacitance the following considerations will be followed,

- Input voltage $V_{in} = 50V$
- Output voltage $V_o = 48V$
- Frequency $F=1\text{ KHz}$
- Output current $I_o = 1.2A$
- Duty ratio $= V_o/V_{in} = 48/50 = 0.96$
- Load Resistance $R_L = V_o/I_o = 48/1.2 = 40\text{ ohms}$
- Voltage ripple $= 1\%$
- Inductance $= 1000\text{ micro H}$
- Capacitance $= 1-D/8*L*(dv/V)f^2$
- $C = (1-0.96)/8*1000*10^{-6} *(0.48/48)*1000^2$
- $C = 500\text{ micro F}$
- $C = 470\text{ micro F}$

By substituting the all the above values in Capacitance formula then the Range of capacitance will be 500 micro F, but according to market available ranges it is fixed to 470 micro F.

IV. MATLAB SIMULATION OF BUCK CONVERTER WITH DC MOTOR

For simulation of buck chopper, the following parameters are employed. The following parameters are decided based on the motor ratings. The parameters are as follows

Input voltage source (V_{in}) = 50 V DC

- Frequency = 1 kHz
- Duty ratio = 0.96
- Load Resistance = 40 ohms
- Inductance = 1000 micro H
- Capacitance = 470 micro F

“In MATLAB Simulink model, an IGBT switch is used for regulating the 50V dc to 48V dc. The switch is on or off through pulse generator, which gives the gate signal for switching, pulse of 1 KHz frequency at 96% duty ratio, which is gained by the duty ratio formula. The output of this converter is not pure dc it contains the high frequency harmonic content, which are removed through low pass filter. In this model 1000microH inductor and 470microF, capacitor has been used such as low pass filter. 40-ohm resistor has been used such as an output load. When this model as shown in Fig. 3 is simulated in MATLAB then we can observe the output voltage to be 47.89 V as shown in Fig. 4”.

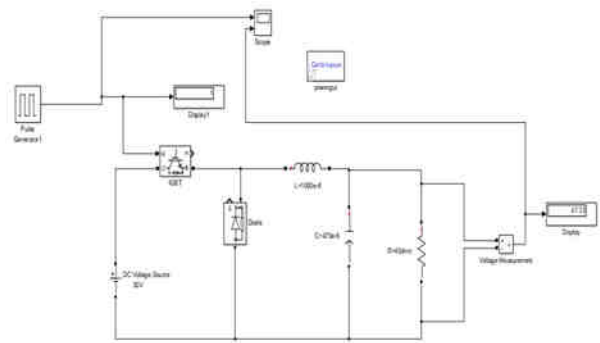


Fig. 3 Simulink Diagram of buck converter

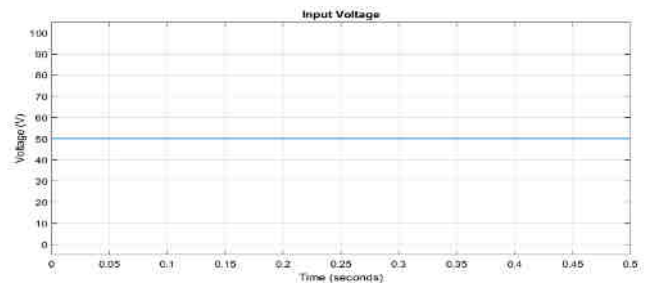


Fig. 4 Input voltage of buck converter

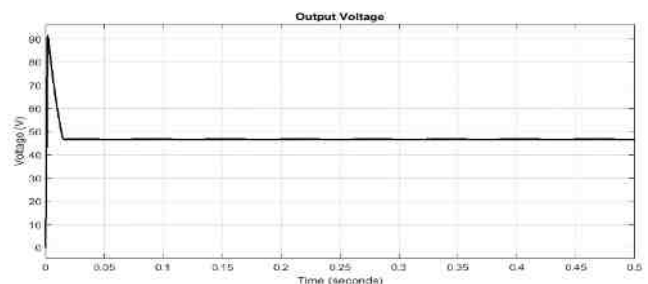


Fig. 5 Output voltage of buck converter

The MATLAB simulation results are showing that in Fig. 4 and Fig. 5. It can be comprehended that the input voltage is 50V and it is step down to 47.89V, which is approximately equal to 48V. This output voltage plot is showing in the Fig. 5.

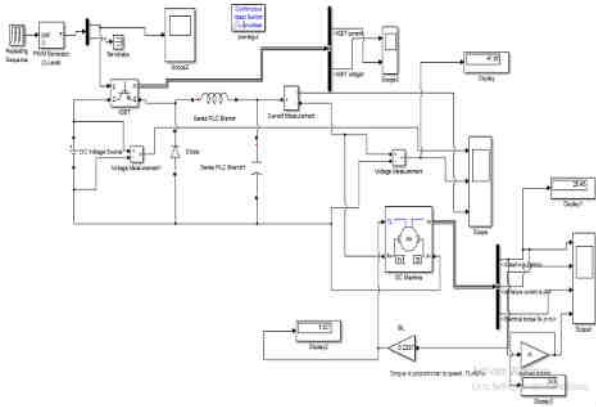


Fig. 6 Soft starter for DC Motor

“The proposed soft starter for DC motor is as shown in the Fig. 6 and is simulated using MATLAB/Simulink. The buck converter model having IGBT as switch. In order to have a varying duty cycle a repeating sequence is used and a PWM signal is generated to vary the duty cycle of the converter from 0 to 96%. The gate pulse generator generates the pulse and given to the IGBT. In this system buck converter is used as a smooth starter for a dc motor. The above diagram is the simulation circuit of this project. The dc source is given to through the switch. When the switch is closed, the inductor is charged and the capacitor provides supply to the load. When the switch is open the supply is obtained from the inductor. With the varying pulse width to the switch the output voltage of the soft starter increases from 0 to 48 V as shown in Fig. 7, which is applied to the DC, motor. The current of through the soft starter is shown in Fig. 8”.

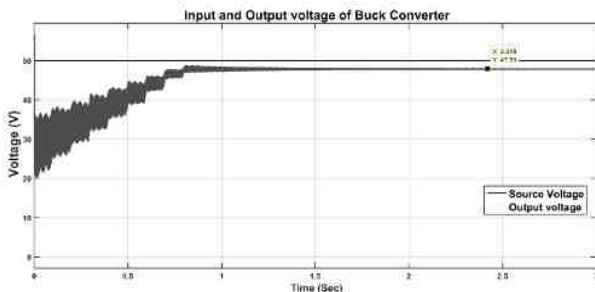


Fig. 7 Input and Output voltage of Soft Starter

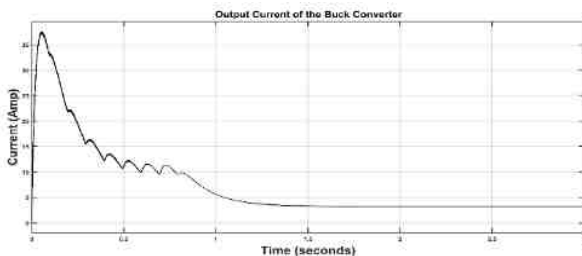


Fig. 8 Current through Soft Starter

With the varying output voltage of the soft starter as shown in Fig. 7 the motor starts slowly. The speed and torque of the dc motor is shown in Fig. 9 and Fig. 10. The speed of the dc motor is expressed in rad/sec and rpm as shown in Fig. 9.

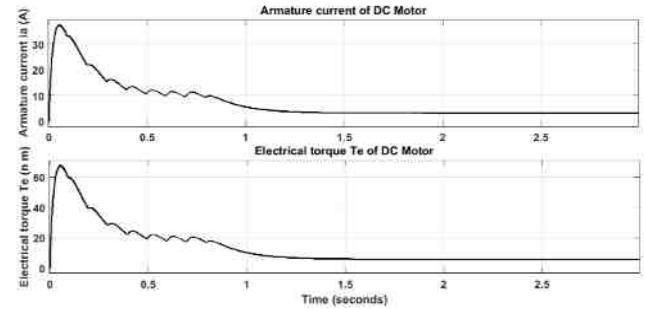
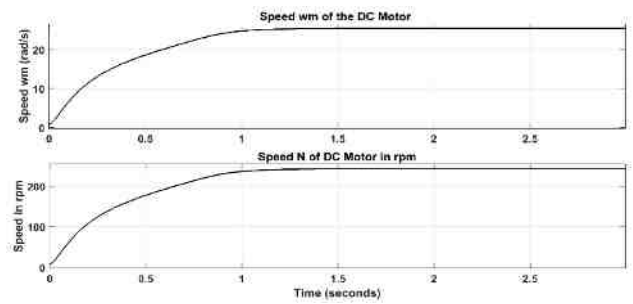


Fig. 9 Speed of the DC Motor

Fig. 10 Armature current and electric torque of the DC motor

The Hardware implementation of the same is described in the next section.

V. HARDWARE IMPLEMENTATION

The hardware implementation of this model mainly consists of Buck converter, Arduino uno, voltage sensor, current sensor, speed sensor and LCD display. The following circuit diagrams describes the connections of Arduino setup as shown in Fig. 11.

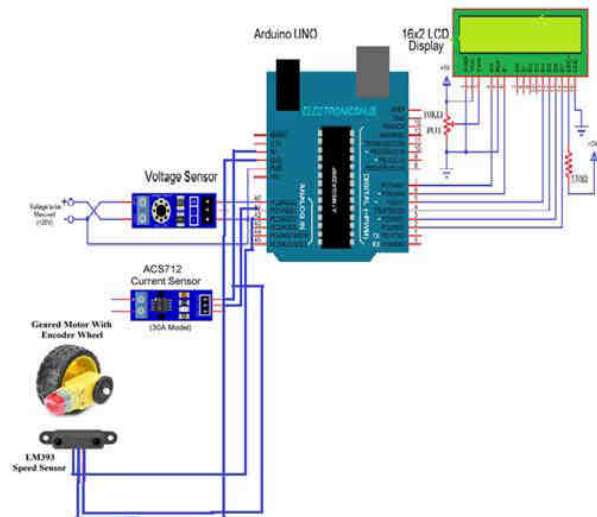


Fig. 11 Circuit diagram of the hardware model

“In the above Fig. 11 shows the circuit connections of voltage sensor, current sensor, speed sensor and LCD display to Arduino. First, connect the “S” and “-” pins of the Voltage Sensor to A₀ (Analog Input) and GND of Arduino respectively. Then connect the external voltage pins (voltage to be measured) to the screw terminal (check for polarity). Coming to the lcd, Digital I/O Pins 7 and 6 of Arduino UNO are connected to R_s and E while the Pins 5 through 2 of

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Arduino UNO are connected to D₄ through D₇ respectively. Then connect the VCC, GND and OUT of the ASC712 board to +5V, GND and A1 of Arduino. Connect the VCC and GND of the LM393 Sensor to +5V and GND of Arduino. The OUT pin of the sensor is connected to Pin A₂ of Arduino”.

Now coming to the working of this proposed model, it consists of smooth starting of dc motor. Now coming to the another part of the circuit is measuring the dc motor parameters. From the above Fig. 11 the voltage sensor will measures the voltage applied to the dc motor and passed the sensed value to the Arduino and the sensed value will displayed on the lcd display Fig. 12. “The voltage sensor will senses the voltage it is basically a voltage divider circuit, you can calculate input voltage using the formula $V_{in} = V_{out} * (R_2 / (R_1 + R_2))$. Here $R_1 = 30000 \Omega$, $R_2 = 7500 \Omega$ and V_{out} can be calculated from Analog Input of Arduino by using $V_{out} = (\text{analog value} * 5 / 1024)$ ”.

The current sensor will also works as voltage sensor that it senses the current passing through the dc motor and sends that data to the Arduino and the same thing will be displayed on the lcd display as shown in Fig. 13. “In order to calculate the current, divide this value with the sensitivity of the sensor (185mV/A for 5A Sensor, 100mV/A for 20A Sensor and 66 mV/A for 5A Sensor). The same is implemented in code as follows”

```
“adcvalue = analogRead(currentpin);”
“adcvalue = (adcvalue / 1024.0) * 5000;”
“currentvalue = ((adcvalue - offset voltage) /
sensitivity);”
```

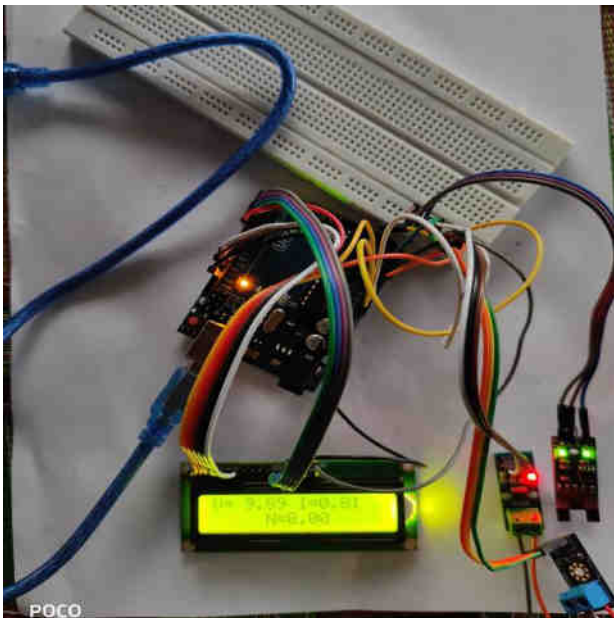


Fig. 12 Testing of Voltage, Current Sensor and LCD display

“In order to measure speed of a motor using Arduino, we used an LM393 Speed sensor with Arduino. The LM393 Speed Sensor Module is an Infrared Light Sensor integrated with LM393 Voltage Comparator IC. The shaft wheel (wheel with holes as shown in the image) is fixed to the geared motor and is placed in the slot of the sensor. Since the wheel is fixed to the motor, one rotation of the motor implies one rotation of

the wheel. Coming to the sensor, the Infrared LED and the NPN Photo Transistor are placed directly facing each other. When there is no object in the slot, the light from the Infrared LED always falls on the Photo Transistor. Now, it has mentioned that the wheel has 20 holes in it, so whenever the wheel makes one rotation, the infrared light from the IR LED is obstructed for 20 times from falling on the photo transistor. In the figure below it is showing the practical outputs of the model”.



Fig. 13 Voltage and Current measurement.

VI. PLX-DAQ

Another part of the proposed model is accessing the sensor values into XL-spread sheet. For assessing those values here in the hardware model, we used an additional application called PLX-DAQ for Data Acquisition. “PLX-DAQ is a simple add-on for Microsoft Excel that make it easy to simply create log in excel sheets for laboratory purpose or other DAQ purposes. It can be simply install it and open the sample excel file then you access the VBA code (Visual Basic for Applications) which is implementation of VB to be used inside Office Suite. if you simply want to gather the data of sensors and then use Excel to draw charts or diagrams for experiment you want, so PLX-DAQ and Arduino are super easy to use and start. For installing this First you need to download the ZIP file. After that un-Zip it and then enter the setup and follow along the installation process after that you’ll find that there’s a desktop folder called “PLX-DAQ”. Enter it and then open the Excel file as shown in Fig. 14”.

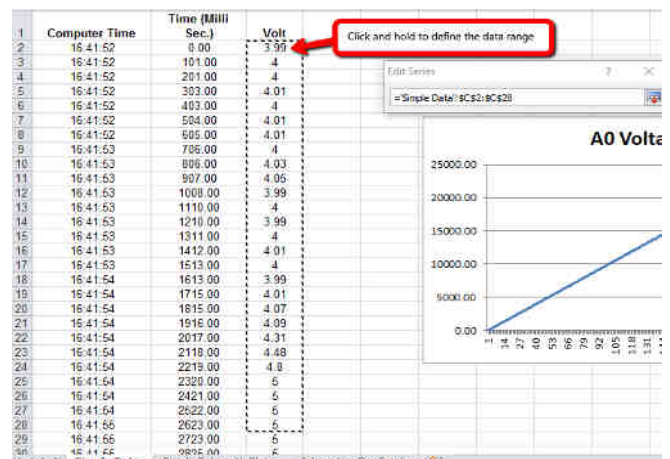


Fig. 14 storing of sensors values and making plots in PLX-DAQ

In the above Fig. 14 it is shown that how the sensor values will be stored in XL-spread sheet by using PLX-DAQ and the characteristic plots are plotted automatically. It is a simple useful application for accessing the sensor values into XL-spread sheet.

VII. CONCLUSION

High starting current of DC shunt motor is reduced, by starting motor with the help of Soft starter Module. If motor starts with 3-point starter it's starting current is around 12 Amperes. If motor starts with soft starter Module starting current is around 2 amperes. Using soft starter module machine life will improved and insulation of winding also less effected. Percentage current limiting factor is improved from 40% to 90%. By using this speed control also done smoothly. Soft starter reduces the power loss that caused in the 3 point starter while starting. The voltage, current and speed of dc motor are sensed and stored in XL-spread sheet and the characteristic plots are automatically plotted.

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