

Simulation and Controlling the Speed of Electric Locomotive through PWM Technique

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Abstract: Motion control plays a very important role in traction purposes. Different type of motors AC & DC are used depending upon the type of traction. DC motors are used in many industrial and commercial applications require higher performance, reliability, variable speed and so on due to ease of controllability. DC motor are widely used because of easier controlling, whose speed is directly proportional to the supply voltage. Using this relationship between the speed and the supply voltage, in this paper mainly focused on the simulation of a pulse width controlled direct current motor using Simulink environment in MATLAB for Electric Locomotive Control.

Keywords: Traction, DC motor, PWM, Matlab, Simulink, Locomotive.

1. INTRODUCTION

Traction motor refers to an electric motor providing the primary rotational torque of a machine, usually for conversion into linear motion (traction). Electric locomotives generally have two or more AC or DC motors. In these locomotives, power is collected from an Electric trolley which is running on an overhead wire. The overhead wire can carry both types of supply AC as well as DC. Indian railway also used both types of supply systems:

- a) **AC System-** 25 KV single phase and three phase 50 Hz AC supply.
- b) **DC System-** 1500V DC supply (only western zone & central zone of railway).
- c) **Mixed type Locomotives**(AC traction with DC drives).

In this paper there is mainly focus on the mixed type locomotives. Where the 25 KV AC supply is used to drive the DC series motors through a converting applications. The first AC traction is introduced in 1959, namely (WAM series) uses DC locomotives of 2800 HP with a four water cooled ignitrons rectifiers, they were mostly developed by ER (Eastern Railway) in the Howrah-Asansol-Dhanbad-mughalsarai section of the Central Railway, but the ever best WAM series

Locomotive is WAM-4 introduced in 1970-72 the WAM-4 model was produced; the first indigenously designed and built electric loco (the first delivered by CLW). They were produced until about 1997. The locomotive is named as WCM 5 (built in 1962, by Chittaranjan locomotive works to RDSO's design specification) 3700 HP co-co. And WCM 6 (5000 HP were built in 1995 by CLW).

Then in the 80's the new era of electric locos were introduced with WAP-series locomotives by RDSO design specifications, the locos were at first used solely for the Howrah-Delhi Rajdhani, It was haul the 18-coach at a max. Speed of 120 km/h and an average speed of around 82km/h. Continuous power 3760 HP, the motor were

manufactured by Alstom/CLW (575 KW/770 HP, 750V, 1095 rpm each) Axle-hung, nose suspended, force ventilated motors. They were two silicon rectifiers are used. They have many more WAP-series traction motors namely WAP-2, WAP-3, WAP-4, WAP-5, WAP-6 and WAP-7. Now the days WAG and WAP series locomotives are much more efficient for the fright and passenger trains WAP-4 and WAP-6 D.C locos were much more used in Indian traction purposes with the use of Thyristor control techniques. The WAP-5 and WAP-7 is now converted from DC traction to AC traction because of the new control strategies were used to control the AC power. In this paper the main purpose of introduce about the DC traction series because the control methods of DC is made much more efficient and reliable at place of AC locomotives because the uses of GTO's and other electronic controllers are made the system more expensive.

2. D.C MOTOR

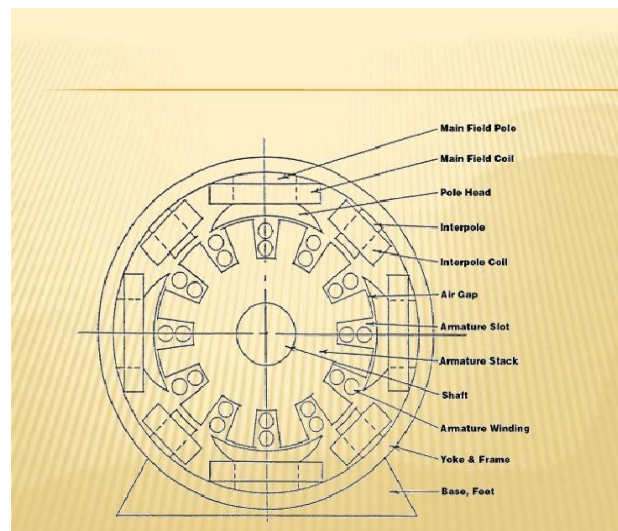


Fig 2 (a) Sketch review of dc series motor

The DC traction motors is a four pole DC series motor in which field winding is connected in series with the armature. It is a forced ventilated machine arranged for axle mounting on sleeve bearing. Transverse movement is limited by flanges of axle suspension bearings. The D.C series motor is high starting torque, vibration free machine.

3. THE DC TRACTION MOTOR: HOW IT DRIVES THE AXLE

Basically the shaft of locomotive of electric traction is fitted with the motor pinion (armature drive shaft) which is directly drive the gear of Axle. The hole arrangement of armature drive shaft is interlocked with traction motor case as shown in the fig 3 (a).

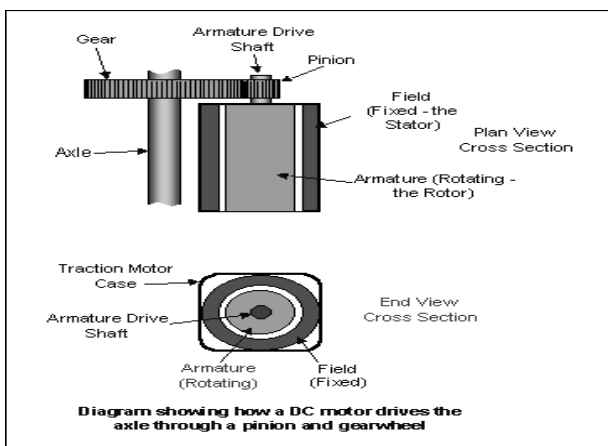


Fig 3 (a) DC Motor drive the axle through a Pinion and gearwheel

4. SPEED CONTROL OF DC MOTOR

The purpose of the motor speed controller is to take a single representing the required speed, and to drive a motor at that speed. Motor speed can be controlled by controlling-

- Armature voltage(V_a)
- Armature current(I_a)

It is obvious that the speed can be controlled by varying

- Flux/pole, Φ (flux control)
- Resistance of armature (R_a) circuit (Rheostatic control)
- Applied voltage V (voltage control)

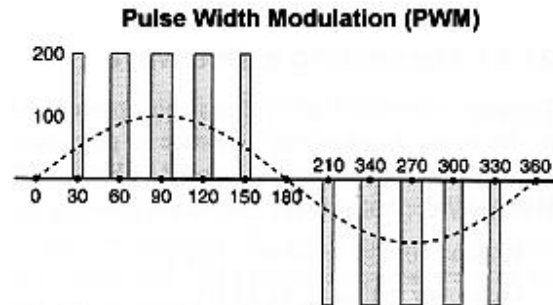
5. PWM TECHNIQUE

PWM (pulse width modulation) is a method for binary signals generation, which has two signal periods (high and low). The width (W) of each pulse varies between 0 and the period (T). The duty cycle (D) of a signal is the ratio of pulse width to period.

$$D = (t_1 + t_2) / T$$

AC voltages can be similarly controlled using bi-directional pulses to represent the sinusoidal. Wave Various PWM schemes are possible. Only one is shown here. By varying the pulse width, the amplitude of the sine

wave can be changed. Variable voltages can also be generated by using fixed pulse width but varying instead the pulse Amplitude (Pulse Amplitude Modulation-PAM) or the pulse repetition frequency (pulse frequency modulation-PFM).



5.1 Principle

The main principle is control of power by varying the duty cycle. Here the conduction time to the load is controlled by,

Let

For a time t_1 , the input voltage appears across the load i.e. ON state.

For t_2 time the voltage across the load is zero.

The average voltage at output is given by

$$V_a = 1/T \int V_o dt = t_1/T$$

$$V_s = ft_1 V_s = k V_s$$

The average load current

$$I_a = V_a/R = K V_s/R$$

Where T is the total time period = $t_1 + t_2$

$k = t_1/T$ is the duty cycle

The RMS value of output voltage is

$$V_o = (i/T \int V_o^2 dt)^{1/2} = K V_s$$

The output power is given by

$$P_i = 1/T \int V_o i dt = 1/T \int V_o^2/R dt = k V_s^2/R$$

The duty cycle can be varied from 0 to 1 by varying t_1 , T or f . Therefore, the output

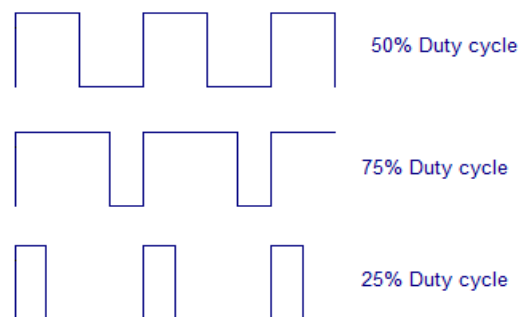


Fig 5.1 (a) Duty cycle Ratio

Voltage V_o can be varied from 0 to V_s by Controlling k , and the power flow can be Controlled.

6. BASIC CIRCUIT

The basic circuit consists of a 25 KV AC. Pantograph with a tap changer step down transformer, a set of rectifiers is used to convert the single phase AC supply to a ripple less DC to drive the DC locos.

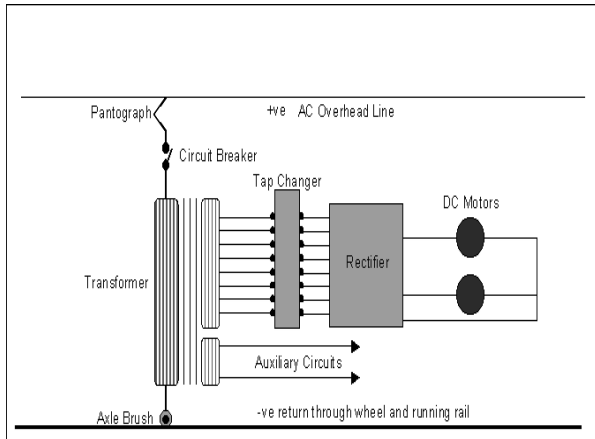


Fig 6 (a) Basic Electric traction outline diagram

7. MATLAB SIMULATION

Computer modeling and simulation tools have been extensively used to support and enhance electric machinery courses. MATLAB with its toolboxes such as Simulink and sim power system is one of the most popular software packages used by educators to enhance teaching the transient and steady-state characteristics of electric machines.

The simulation is done on the basis of the pulse width modulation technique in the drive circuit. The basic circuit of this simulation consist block of a subsystem, a buck converter, a DC motor block, a disturbance block & a scope (to see the simulation results).

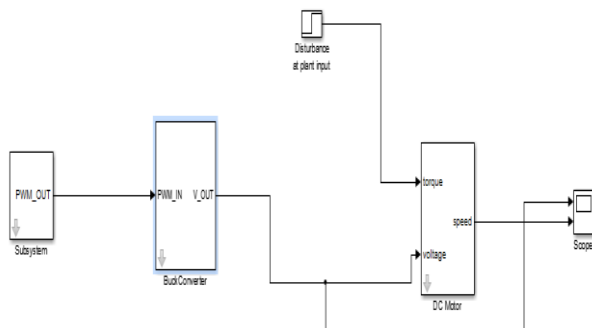


Fig 7 (a) Model created in SIMULINK Toolbox of MATLAB

7.1 The Sub System

The Sub System consists of a pulse generator input of the percentage duty cycle to be feed for buck converter.

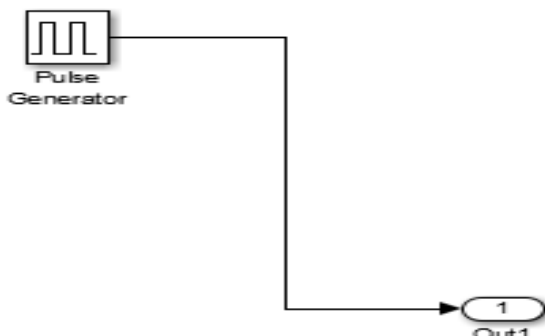


Fig 7(b) pulse generator of sub system

7.2 The Buck Converter

The Buck Converter is a form of DC to DC converter that can take an input directly from a DC source, such as battery. The input could also be DC derived from the AC mains (line) via a rectifier/reservoir capacitor circuit.

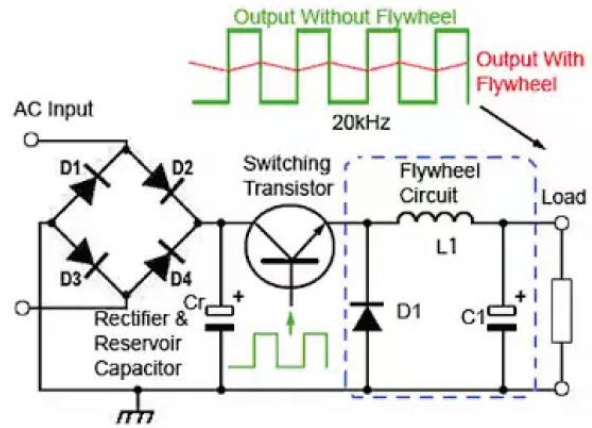


Fig 7 (c) DC to DC Buck Converter

As shown in the fig the buck converter consists of a the switching transistor, together with the flywheel circuit (D1, L1 and C1). While the transistor is on, current is flowing through the load via the inductor L1. The action of any inductor opposes changes in current flow and also acts as a store of energy. In this case the switching transistor output is prevented from increasing immediately to its peak value as the inductor stores energy taken from the increasing output; this stores energy is later released back into the circuit as a back e.m. fas current from the switching transistor is rapidly switched off. Here the use of continuous mode of operation to drive the locomotive continuously. It is made by if the current through the inductor (L) never falls to zero during the commutation cycle.

7.3 Disturbance at Plant Input

Step time, initial values, final values, sample time etc which are very useful and the system make reliable to operate but it generates some noise in the system, which are conclude as a disturbance but there are very small disturbances occurs by this parameters, So here we keep these parameters, constant or zero.

7. 4 DC Motor

This block is mainly consisting of the motors parameter like damping, inertia, back e.m.f, resistance and inductance of the motor. The output voltage of the buck converter is fed in this block to draw the graph of speed and input voltage waveform of the motor.

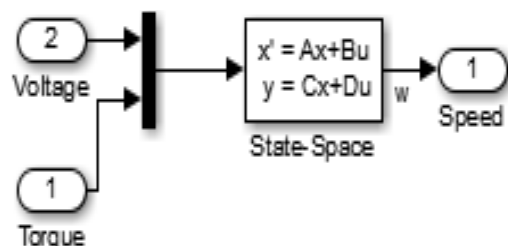


Fig 7 (d) State Space block of the DC Motor

This above (A,B,C,D) parameters is set by using double clicking on the D.C motor block to appear the dialog box of the system.

7.5 Scope

This is the display unit of the hole simulation and shows the graph of speed-torque and the output voltage of the buck converter circuit as later discussed, it has consist of two axis (x & y) for each measuring parameter the number of display units are extend by simply change in settings of scope.

8. SIMULATION RESULT& DISCUSSION

The basic simulation of DC locomotive is carried by updating the value of PWM duty cycle at proper extent, because the applied voltage can be varied by changing the duty cycle of PWM generator. The ratio of T_{on} to T_{off} is must to change with respect to time. Now first we observe the simulation result without setting the A, B, C, D parameters of DC Motor. This simulation is mainly shows the basic speed characteristic of WAP 6 (DC) locomotive.

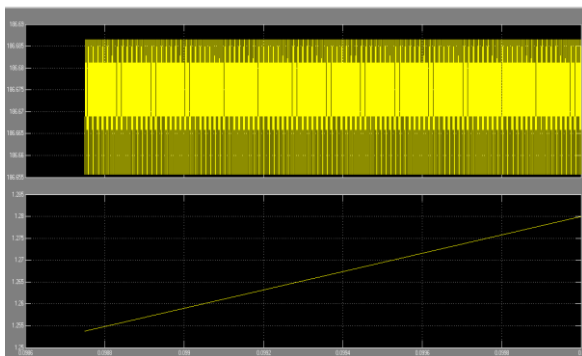


Fig 8 (a) Basic voltage and speed characteristics

Now again we conclude the parameters of drive to get some desirable values of speed, and applied voltage. The upper half of the graph shows the applied voltage waveform and lower is speed characteristics of the DC loco. The following graph is of the 20% duty cycle ratio, and mutual inductance (L) is set to 2.621. Where the resistance of the field and armature winding of the motor is set to 150 ohm, whereas the inertia of the drive is 15 $kg \cdot m^2$.

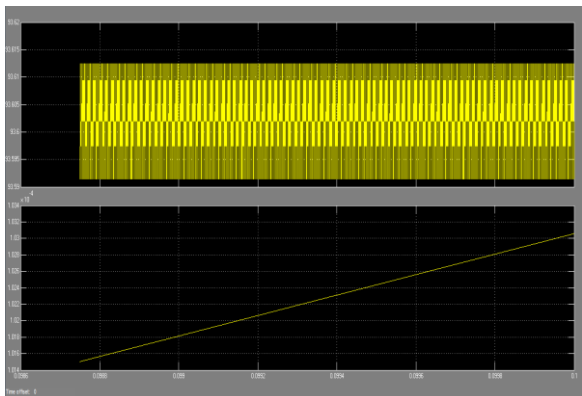


Fig 8 (b) voltage and speed characteristics after 20% PWM applied

Now again the simulation is done at the 40% duty cycle, and the damping ratio upto 0.272.

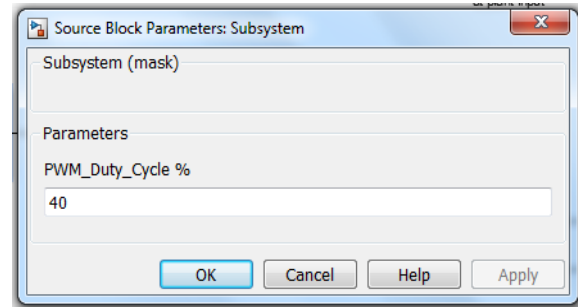


Fig 8 (c) 40% Duty cycle applied to drive

The above block shows the PWM duty cycle in percentage. This means the applied voltage is ON for 40%, and OFF for 60% out of 100% supply voltage, Means we can also say that the speed of DC motor behind the PWM control technique is below the maximum speed of the motor. At 40% the voltage is around 93.61 to 93.615V.

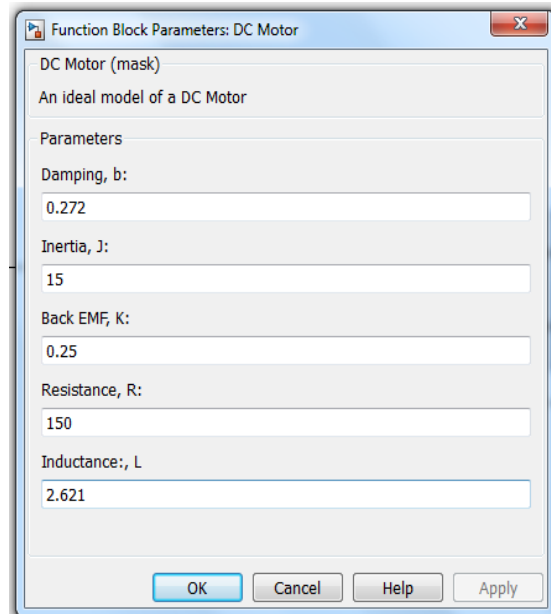


Fig 8 (d) Parameters block of D.C drive

The above block shows the parameter of the DC motor which is set to simulation at 90% PWM duty cycle, the 90% duty cycle take the voltage at 412.64V

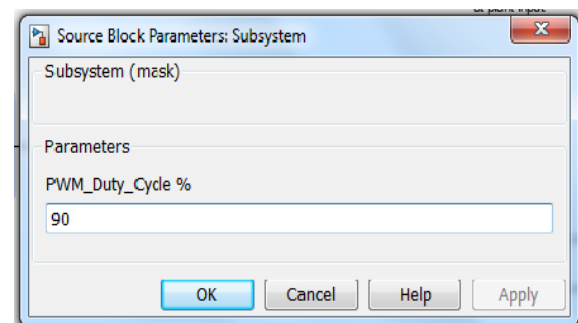


Fig 8 (e) 90% Duty cycle applied to system

The 90% duty cycle ratio gives the voltage around the maximum speed of the drive

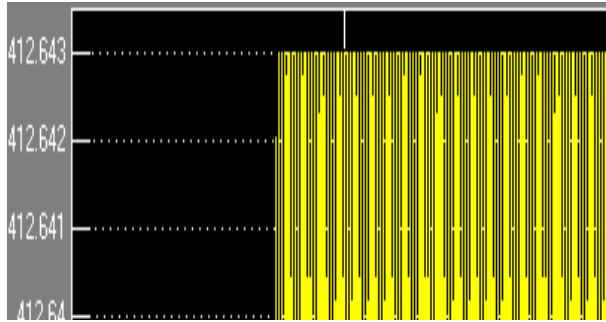


Fig 8 (f) Voltage at 90% Duty cycle

9. CONCLUSION

In this paper, the simulation of a PWM control techniques of a D.C Motor is developed using MATLAB/Simulink. The Simulation result shows that the applied voltage on the Motor is directly proportional to the speed of the motor. So the PWM technique is so reliable to control the D.C locomotives and gives variable speed as operator premises. It's have better future scope in upcoming high speed trains and also the operational cost is so much reduceable.

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BIOGRAPHY



Arvind Kumar Verma received the B.Tech Degree in Electrical Engineering from UPTU, Lucknow in 2014. Now he is pursuing his M.Tech in Electrical Engineering (Control & Instrumentation) from Department of Electrical Engineering, SHIATS, Allahabad (UP), India.