EPMN202 – Electric Drive System

Research Project

“Closed Loop Control of DC Motor Drives”

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I.Problem Statement:

Motor Data:

Dc separately excited motor

➢ Rated data 75KW, 1900 rpm

➢ Tacho-generator 60V/700 rpm

➢ Armature circuit (400V,207A dc continuously rated)

➢ Field circuit (220V ,6.18A)

➢ Torque rated 377 N.m

Load Data:

➢Type: Elevator

➢ Drum diameter: 90cm

➢ Empty cabinet: 200kg

➢ Counterweight: 280kg

➢ Max passenger weight: 150kg

Control:

➢ Rectifier for speed control will be used since AC supply is used

➢ Speed Profile: trapezoidal

➢ Max speed: 7 m/s

➢ Ramp up/down time: 0 seconds

II.Steady-state operating point for the fully loaded elevator (Calculations):

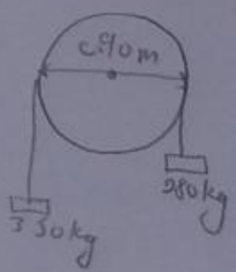
At rated conditions

$V_a = 400\,v \; ; \; I_a = 207\,A \; ; \; n = 1900\text{ rpm} \; ; \; T_{out} = 377\text{ N.m}$

Since no rotational losses is given

Assume $T_{out} = T_{dev} = 377\text{ N.m}$

$T_d = k\varphi I_a \rightsquigarrow 377 = k\varphi(207) \rightsquigarrow \boxed{k\varphi = 1.821}$



$T = mgr$ since $m = m_e - m_{counter} = (200+150) - (200 + 200 \times \frac{40}{100})$

$m = 70\text{ kg}$

$T_d = T_{mechanical} = 70 \times 9.8 \times (0.45)$

$T_d = 308.7\text{ N.m}$

Since $\underbrace{v}_{\text{velocity max}} = \omega r \Rightarrow 7 = \omega(0.45) \rightsquigarrow \omega = 15.56\text{ rad/s}$

$\rightsquigarrow n = 148.54$

since $E = k\varphi\omega$

$E = 1.821 \times 15.56 \simeq 28.3192\,v$

finally $T_L = k\varphi I_a$

$308.7 = 1.82\, I_a \rightsquigarrow I_a = 169.615\,A$

Since $V_a = E + I_a R_a$

$V_a = 28.3192 + 169.615\, R_a$

$\boxed{V_a = 59.19 \simeq 59\,v}$

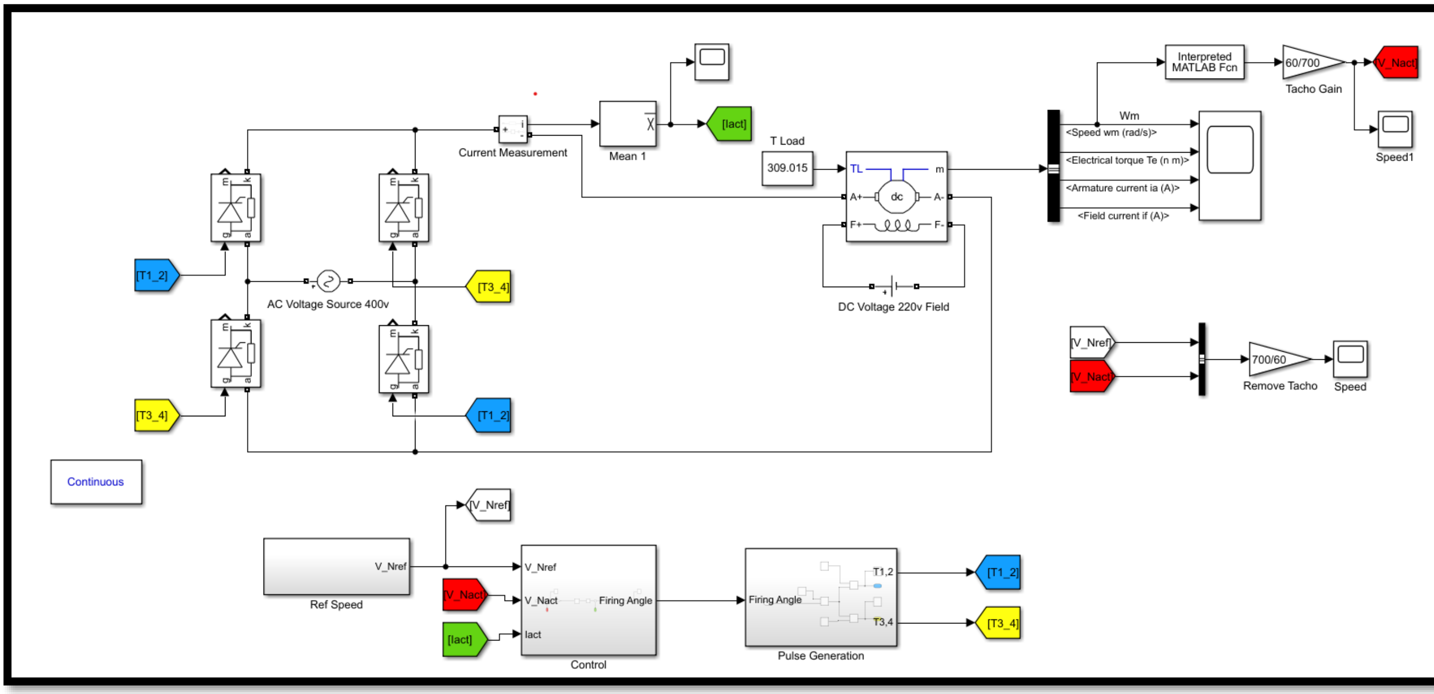
from Rated condition

$400 = E + 207\,(R_a)$

$E \rightsquigarrow k\varphi\omega \rightsquigarrow 1.821\left(1900 \times \frac{2\pi}{60}\right) = 362.32$

$R_a = 0.182\ \Omega$

III.Whole Simulink Model of the DC Machine:



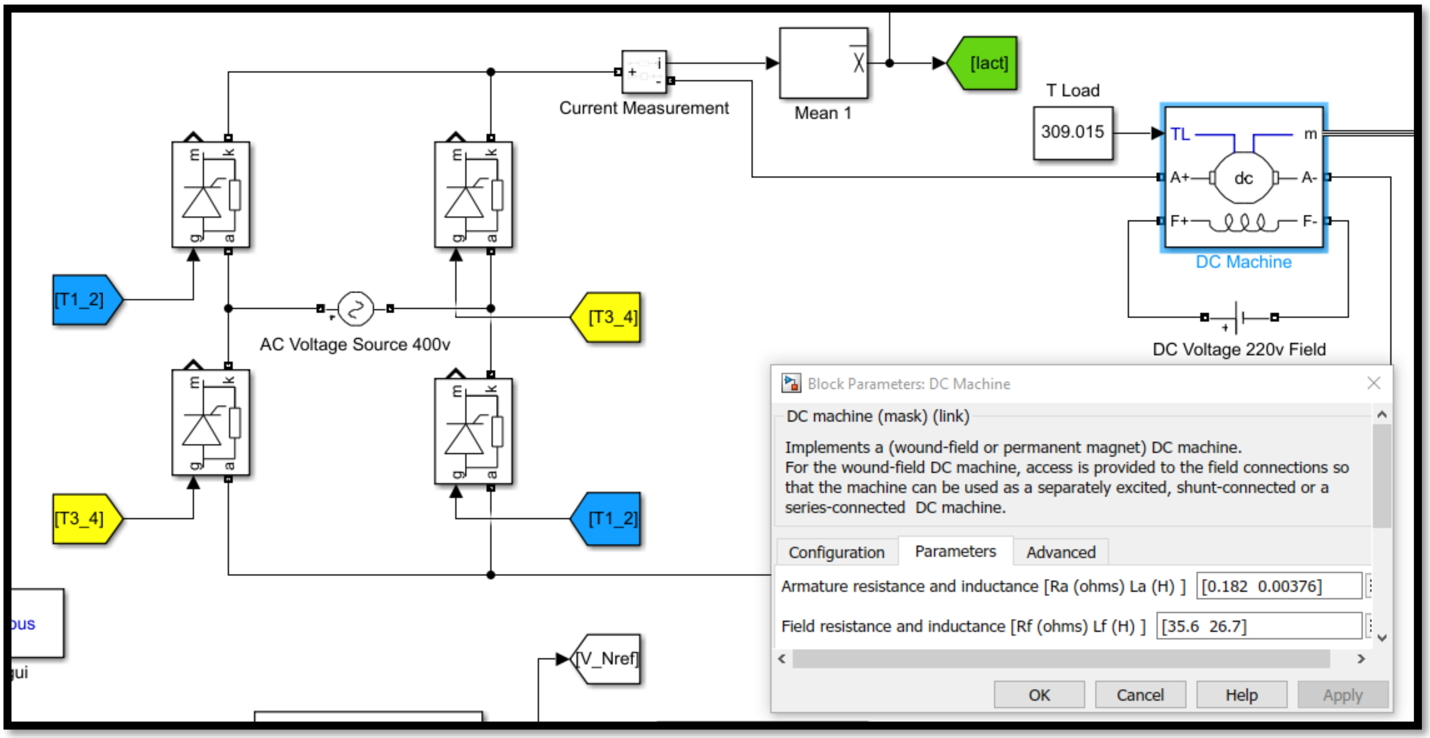
This figure illustrates each component of our model:

- ➢AC Voltage Source
- ➢Thyristors
- ➢Current Measurements
- ➢DC Machine
- ➢DC Voltage Source
- ➢Scopes
- ➢Reference Speed Subsystem
- ➢Control Subsystem
- ➢Pulse Generation Subsystem

IV.Close Look at the DC Machine:

Dc Machine Parameters:

- Armature Resistance Ra = 0.182 Ohms
- Armature Inductance La = 0.00376 H
- Field Resistance Rf = 35.6 Ohms
- Field Inductance Lf = 26.7 H



AC source is connected to a Rectifier Circuit (4 thyristors) that stabilizes the AC source to an approximately constant DC source.

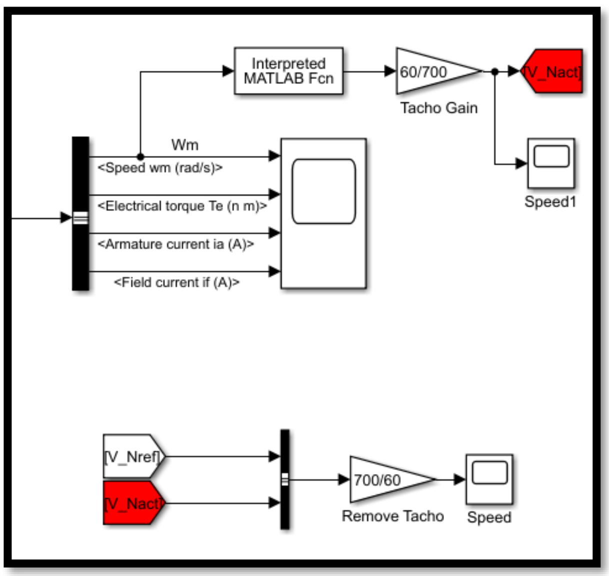
After calculating our Machine Parameters from the given target load and max speed, we concluded these resistances and inductances to be inserted in our model.

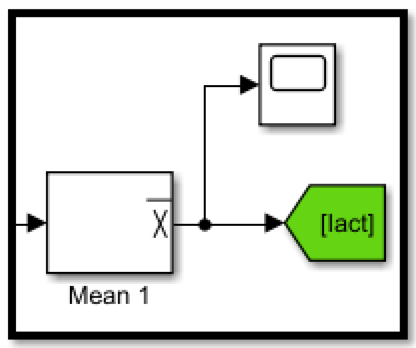
The Constant T Load block represents the net torque required to operate at after removing the counterweight plus 40% from the total passengers and cabinet weight, multiplying the weight by the radius to get the torque.

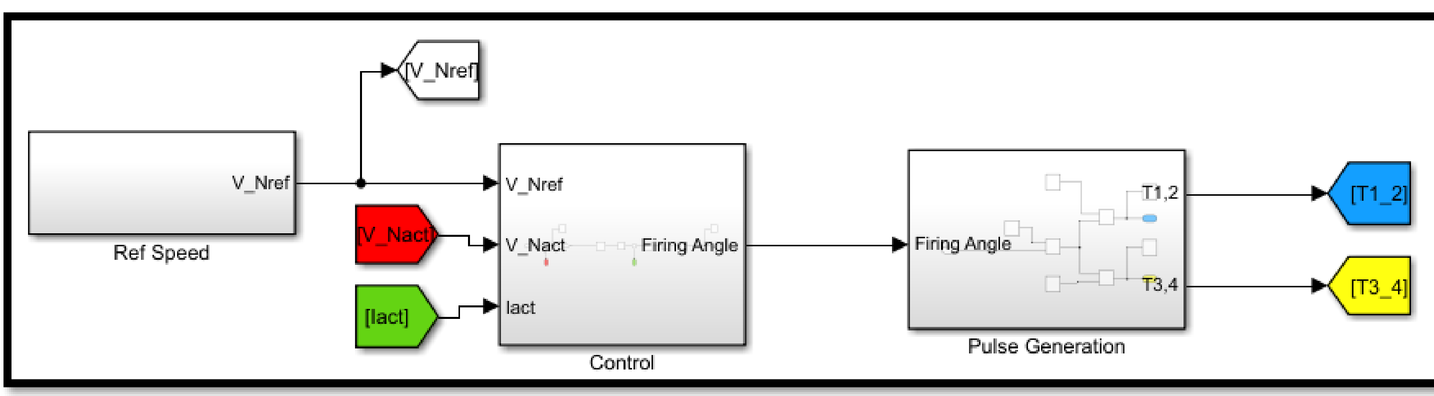
Using the Machine measurements on a bus selector to get our required readings to a scope and taking another connection of the Machine's speed (w rad/s) multiplying it by a function to be converted to speed (Nact rpm) and again to tacho-gain by **60/700** to be used in the control system with our reference speed.

V.General Construction:

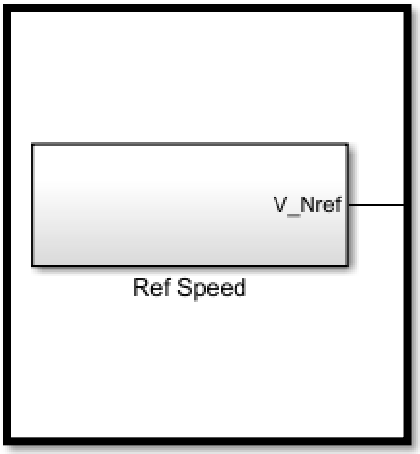
-Using MATLAB goto and from tags.
-Suitable Bus Selectors and Scope layout.
-Gain and Remove Blocks.
-Organizing and sub-forming subsystems.



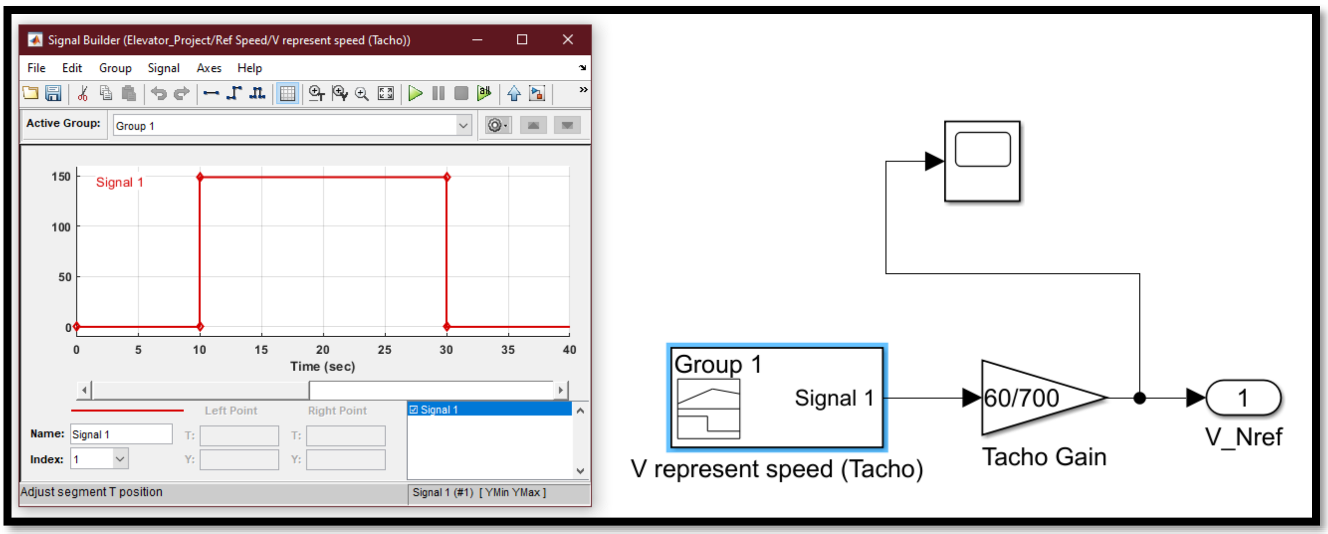




VI.Reference Speed Subsystem:

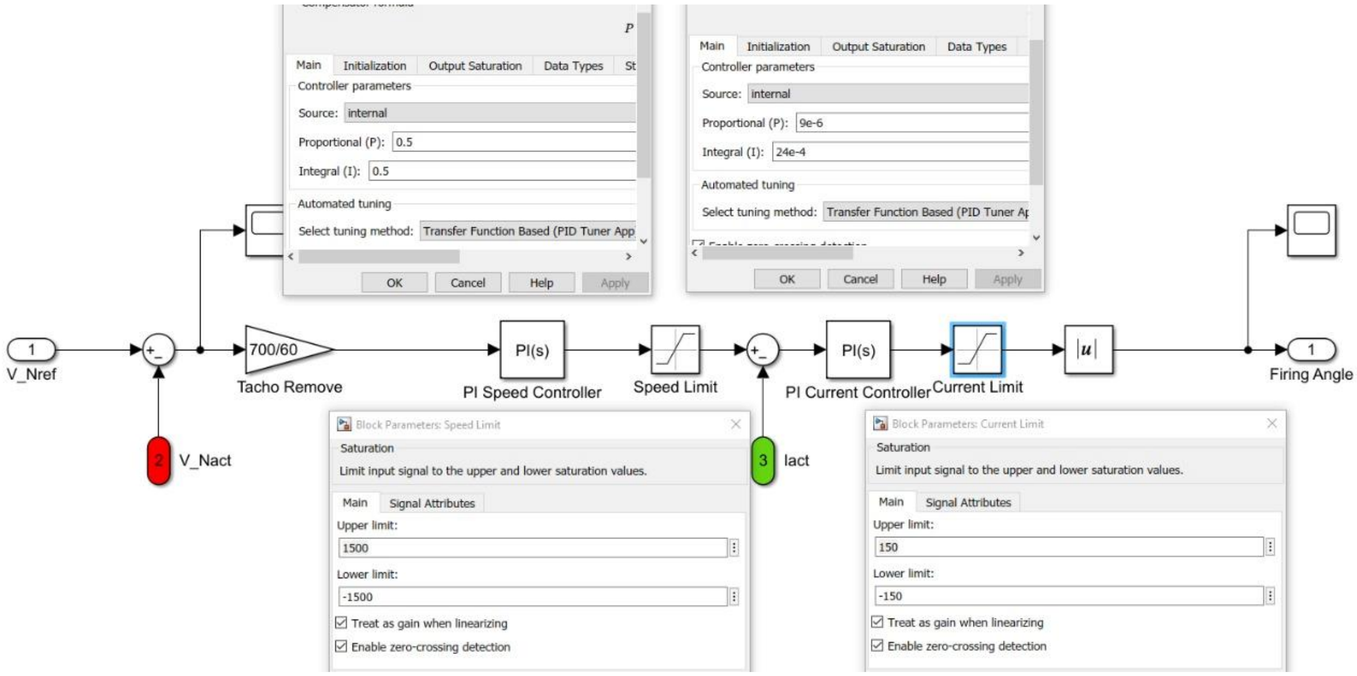


The V_Nref block represents the reference speed needed in terms of voltage and is used in controlling the voltage supplied to the motor by comparing this reference voltage to the actual speed coming from the motor.



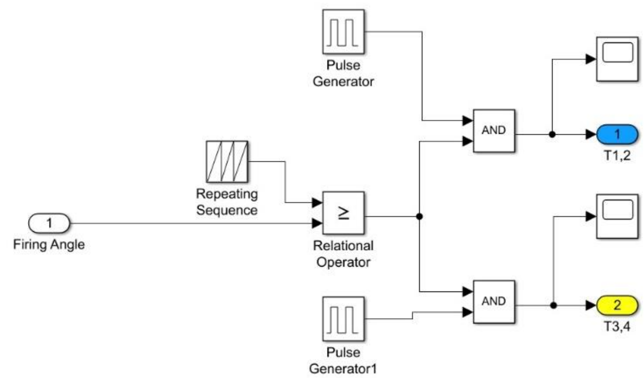
Inside the block, we enter the data or the speed we want to achieve, and the ramp up/down time required and then this speed entered in rpm is converted to a voltage of a ratio **60volt/700rpm** by a tacho gain in order to supply the required voltage to achieve required speed.

VII.Closed-loop speed control model incorporating current control in MATLAB Simulink:

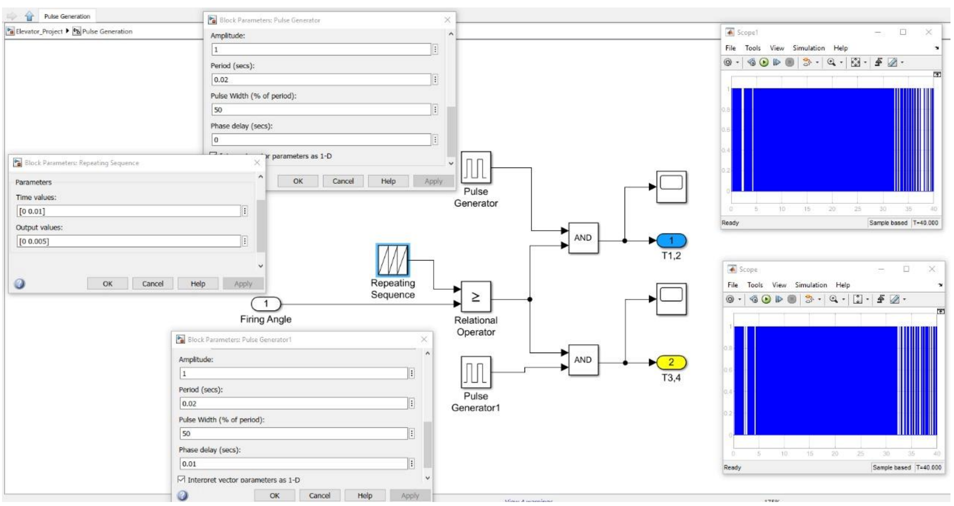


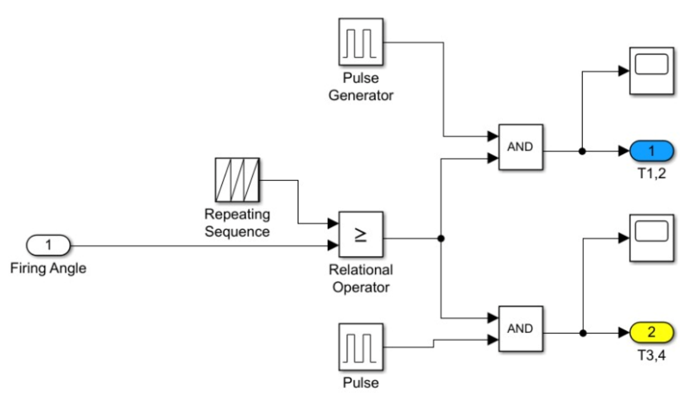
The control unit’s functionality is very brief, we give it the desired speed to be reached, and it gives us the required firing angle that we need to use in order to reach this speed. This can be easily maneuvered by using the V_Nref generated from the “Reference Speed Subsystem” mentioned above. VNref is given to the control unit which represents the desired speed to be reached and its unit is in (Voltage). We compare the difference between the V_Nref & V_Nact and generate V_error. The V_error is bypassed by a Tacho Removal which converts the Verror unit from (Voltage) to (rpm).
Now that V_error has been converted into speed in rpm, we input this value into a PI Speed Controller which gives out I_ref, we use saturation to protect the motor against overload current.
Then I_act is given to the system and compared with the I_ref. The difference between them generates Ierror. The error in current is given into PI Current Controller which gives out firing angle if we’re using thyristors or duty cycle if we’re using chopper. In this case we use thyristors, thus PI Current controller gives out firing angle. We then add another limitation using the Saturation. In addition to checking the validity of this firing angle we use the absolute function to make sure that this angle is always positive. This firing angle is then taken from the Control Unit and given into the Pulse Generation Subsystem

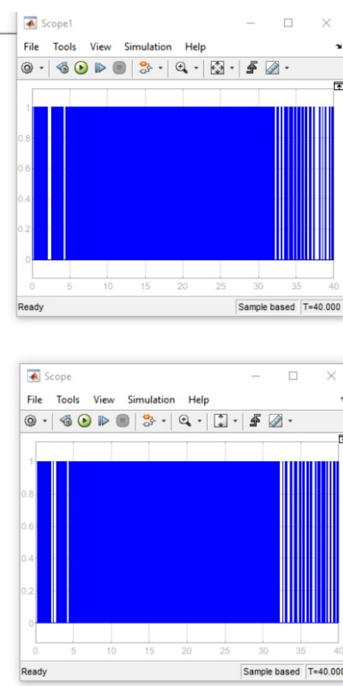
VIII.Pulse Genration Subsystem:



The repeating sequence block’s period is set to half the period of the pulse-generating block in order to compare the output of the repeating sequence block with the output of the second PI controller allowing us to control the motor’s speed by changing the firing angles of the full wave rectifier's thyristors. a pulse is sent to two thyristors in the first half cycle while the other pulse is sent to the other two thyristors in the second half cycle.

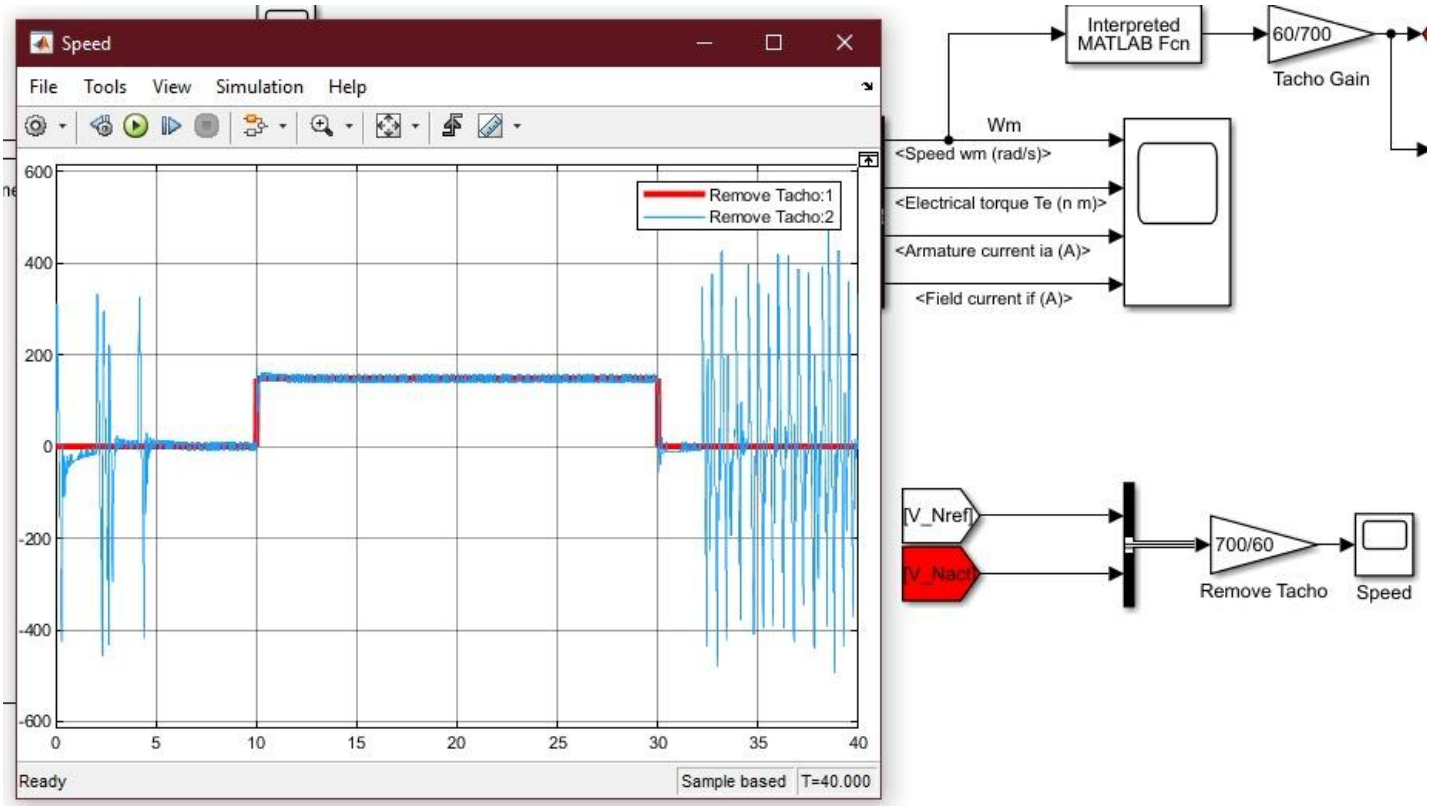






IX.Scope Output:

We used the Demux to identify all the outputs, so we could gain a trapezoidal curve representing the elevator's speed. It takes the V-nact and V-nref after removing tacho and generate the following curve



X.Conclusion:

At the beginning of the simulation, the motor was in a ripple (Transient state) until reaching a steady state then at the 10-second mark, an increase of the motor speed can be seen ramping up until reaching the maximum speed of 7m/s then the motor maintained that speed until reaching the point of ramp down where the motor will have to decrease its speed to zero at the 30-second mark to reach it's required destination.

Speed Control (Open Loop) Manually:

In simple words, a rectifier will be used to control the speed of the motor due to the AC supply used if it was DC a chopper would have been chosen. Moreover, a DC source will be used for the field then for the elevator motor the speed can be controlled by changing the firing angle (α) and controlling its armature voltage since it is controlled by a rectifier (based on AC Source). Finally we will obtain the torque of the load of the elevator on the motor using a Tacho-generator which measures the speed and converts it to volts which can later be manipulated for controlling purposes

Speed Control (Closed Loop) Automatic:

As for the Automatic, we will want to control the speed without having to change the firing angle (α) every time hence, we will use a PI controller which will measure the current speed output by the Tacho-Generator and compare it to the required speed (Nref) and an error will be calculated. Furthermore, a saturation value will be placed to limit/protect the motor against other currents and finally, the same done with Speed (Nact) will be done on current (Iact) by comparing it to the required and consequently have an error calculated using another PI controller and have it ready for the converter.