Lab 2. DC MOTOR DRIVE MODELLING

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Specialization: Automation

Objective

To get acquainted with modelling of speed/torque characteristic, of braking modes and of speed control of the DC motor in the Simulink software environment.

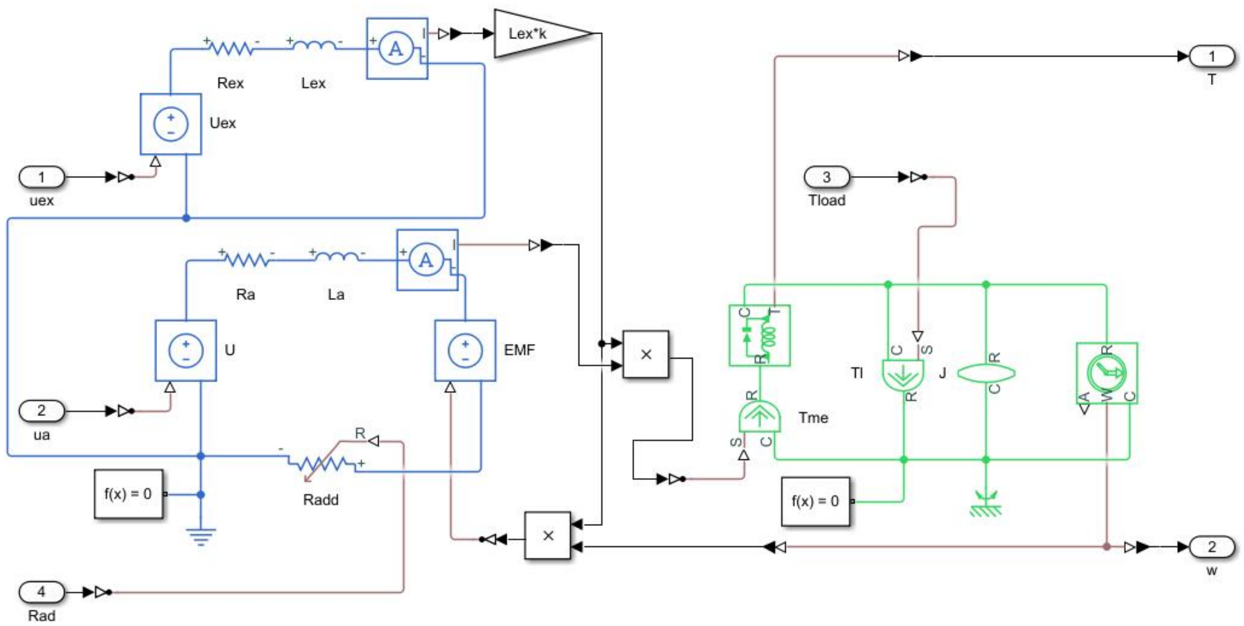

Figure 1. Simulation scheme of the electromechanical system DC motor – mechanical load.

Initial data

Parameter	R_a	L_a	R_{ex}	L_{ex}	I_{amax}	k	J	T_{load}
Value	9.9388 Ohm	41.4 mH	0.9674 Ohm	20.24 mH	9 A	0.0769	10.5886 $kg \cdot m^2$	2.1

1. Build a simulation circuit.

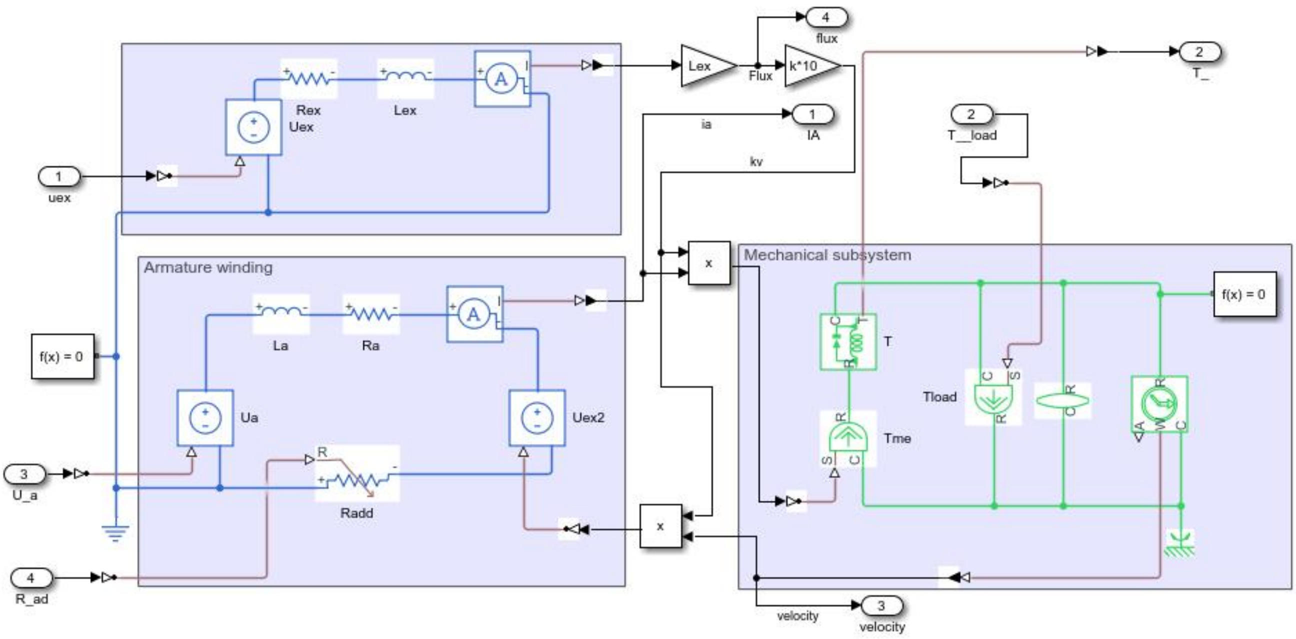

Figure 2. Simulation circuit.

2. Simulation of natural and artificial speed/torque characteristics of DC motor.

a. Speed control of the DC motor by changing armature voltage (U_{nom}, $0.8U_{nom}$, $0.6U_{nom}$, $0.4U_{nom}$, $0.2U_{nom}$).

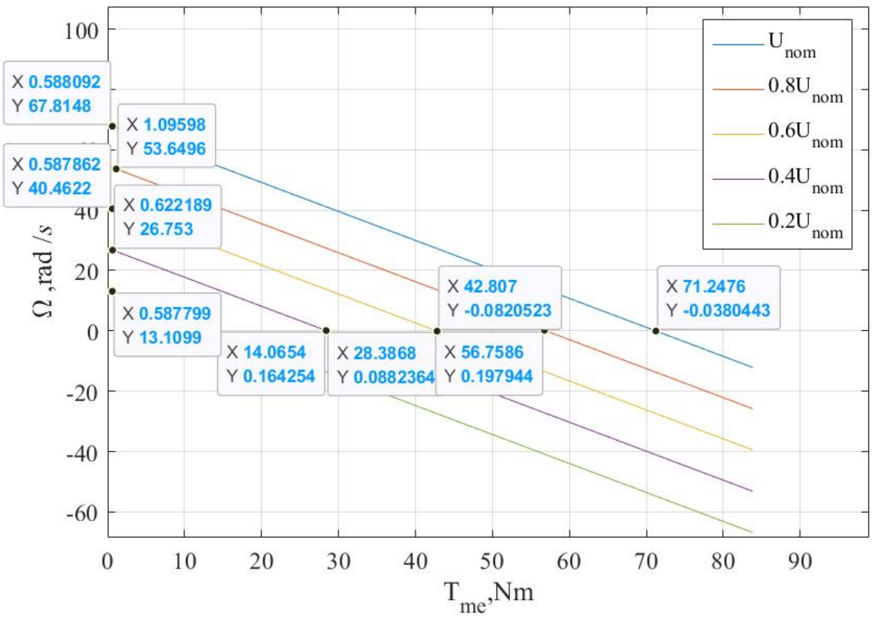

Figure 3. Speed control of the DC motor by changing armature voltage.

b. Speed control of the DC motor by changing the magnetic flux (Uex, 0.8Uex, 0.6Uex, 0.4Uex, 0.2Uex).

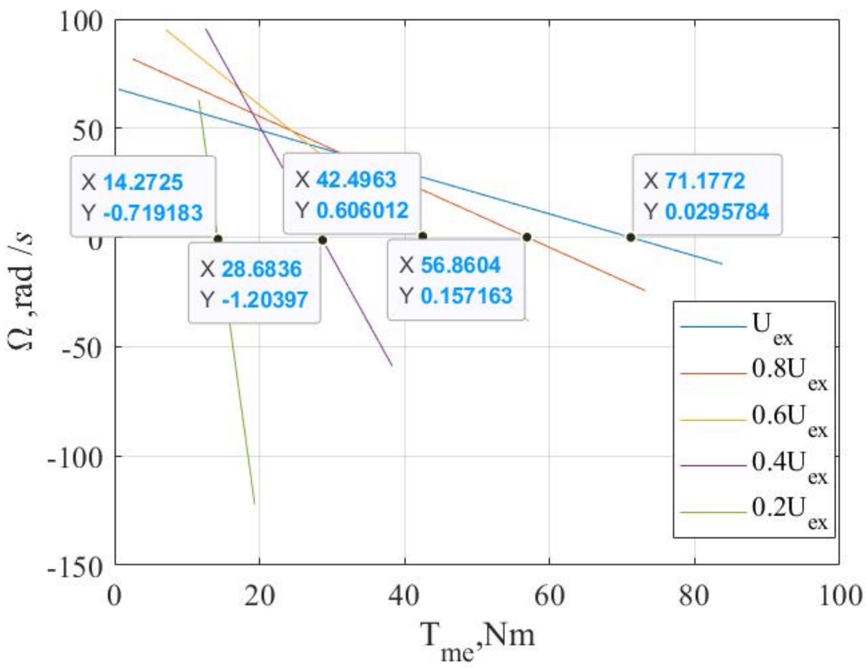

Figure 4. Speed control of the DC motor by changing the magnetic flux.

3. Simulation of braking modes.

a. Simulation of reverse braking by adding resistance R_{add}.

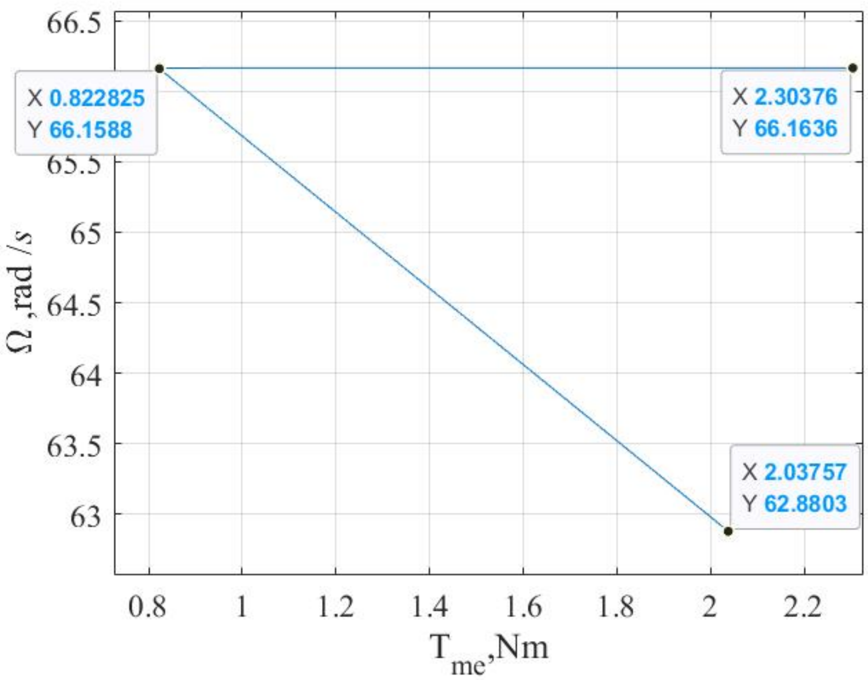

Figure 5. Reverse braking.

b. Simulation of dynamic braking by disconnecting converter and connecting resistance Radd.

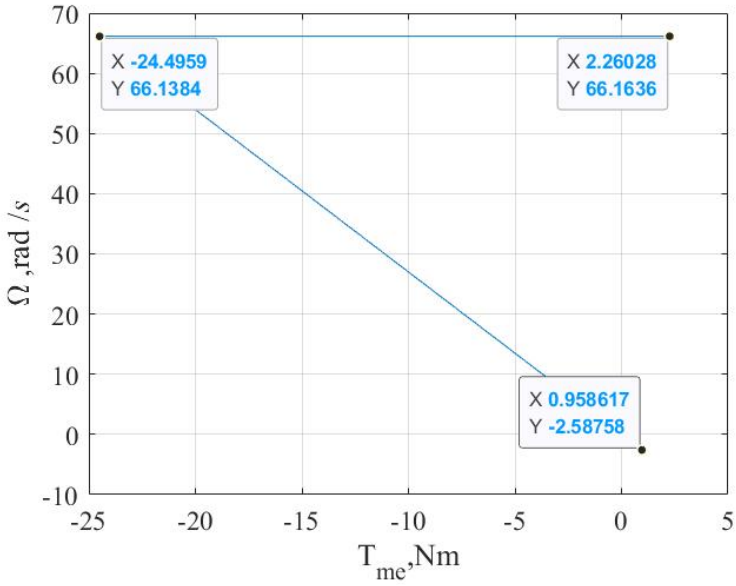

Figure 6. Dynamic braking.

c. Simulation of regenerative braking by changing armature voltage from Unom to 0.8Unom.

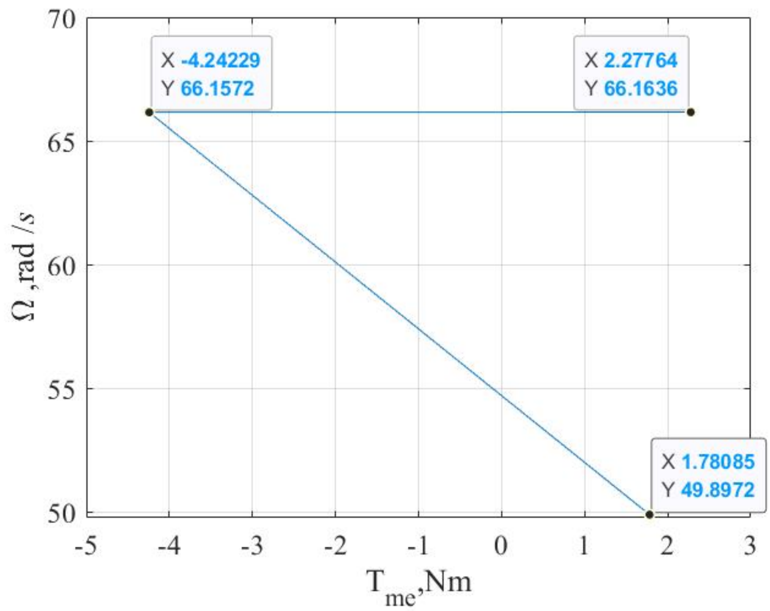

Figure 7. Regenerative braking.

4. Simulation of starting of the DC motor.

a. Simulation of direct starting of the DC motor.

$$I_{inr} = 22.0771\ A > I_{max} = 9\ A$$

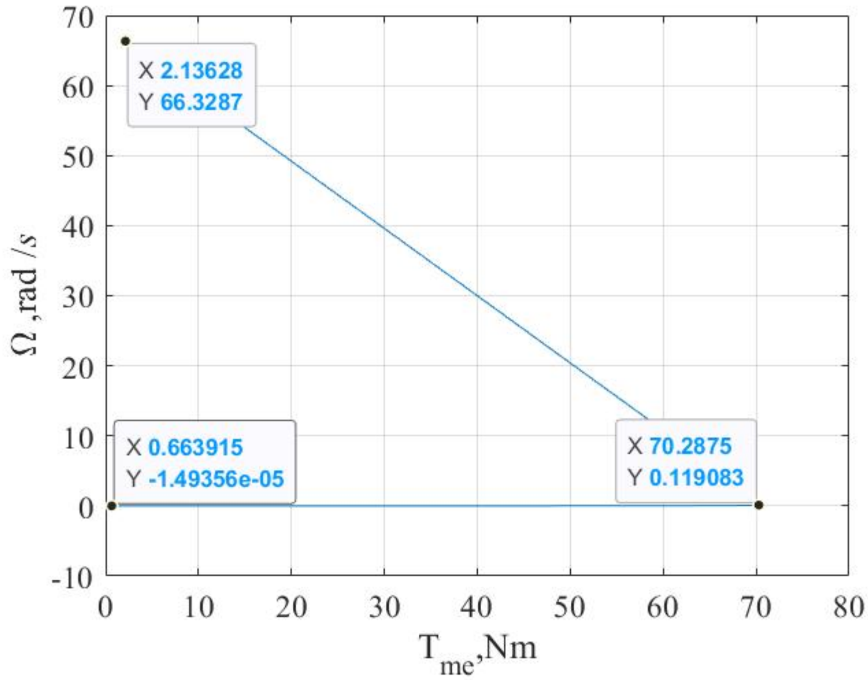

Figure 8. Direct starting of the DC motor.

b. Simulation of starting of the DC motor with additional resistances R_1, R_2, R_3. Armature current I_a must be lesser then maximum value I_{amax}.

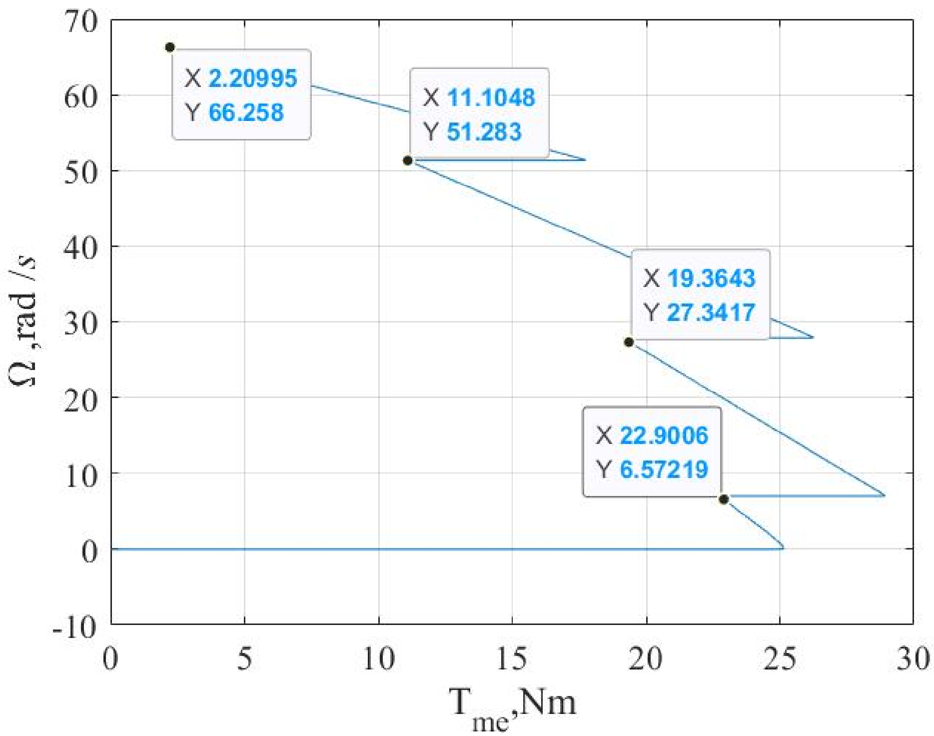

Figure 8. Starting of the DC motor with additional resistances.(speed)

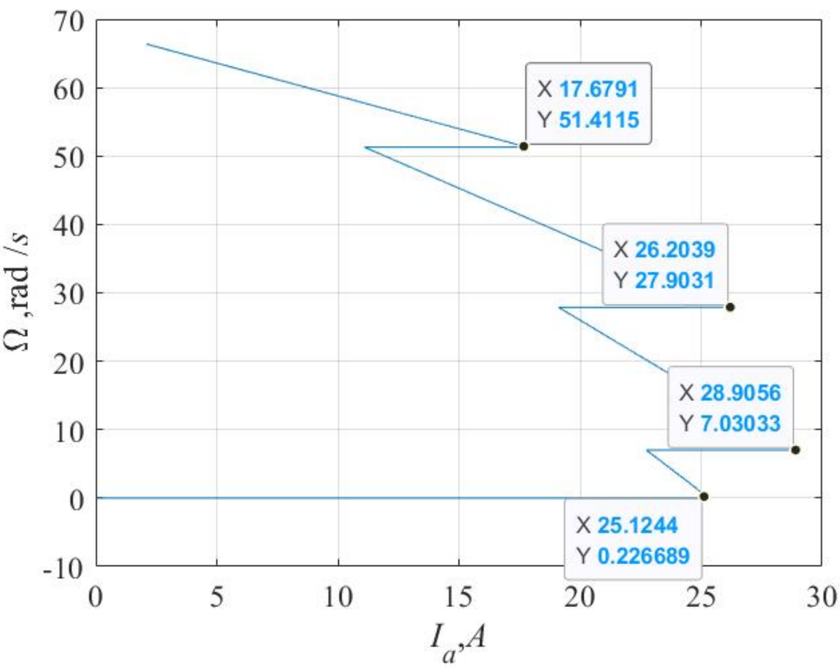

Figure 8. Starting of the DC motor with additional resistances.(current)

Each variant contains data about excitation winding parameters (L_{ex}, R_{ex}, U_{ex}), armature winding parameters (L_a, R_a, U_{anom}, I_{amax}), DC motor drive parameters (k, J, T_{load}).

5. Conclusion

1. Simulation of natural and artificial speed/torque characteristics of DC motor.

a) Speed control of the DC motor by changing armature voltage

Characteristics at different values of the armature voltage are **mutually parallel**.

In open-loop armature voltage control, the lower speed is limited by the speed drop from the load. In closed-loop systems, the speed drop can be reduced to sufficiently small values. As a result, it is possible to obtain a speed control range by changing the armature voltage. $D = \frac{\omega_{ex}}{\omega_{min}}$. speed control by changing the armature voltage is the main method of speed control in wide-range drives. It is suitable for constant load.

b) Speed control of the DC motor by changing the magnetic flux

We adjust the magnetic flux by adjusting the voltage of the excitation circuit. The motor torque decreases in proportion to the weakening of the magnetic flux. This method is suitable for constant power load.

2. Simulation of braking modes.

Braking modes are used to stop a mechanism quickly and precisely, for example when changing the direction of rotation, and modern drives make extensive use of the braking mode of the motor. Consider an electrical braking method for independently excited DC motors.

a) Simulation of **reverse braking** by adding resistance resistance R_{add}.

In this case, the load is lowered in the mode of braking by counter-wiring. To limit the armature current to an acceptable value in this mode, an additional resistance Radd must be introduced into the armature circuit. Thus, in the opposition mode, the direction of rotation the machine is opposite to the specified one, the machine operates in the generator mode and creates a braking torque. Energy is released on R_{add} therefore, this mode of braking is uneconomical. Reverse braking mode is often used in reversing drives to quickly reverse the motor or stop.

b) Simulation of **dynamic braking** by disconnecting converter and connecting resistance R_{add}.

The machine in this case operates in generator mode. The mechanical energy coming from the shaft side is converted into electrical energy and released as heat in the armature circuit resistances. Therefore, the mode is **uneconomical.** Dynamic braking is used in lifting mechanisms when lowering loads. In addition, dynamic braking is widely used to quickly stop the motor. To do this, using the control circuit, the motor armature is disconnected from the network and closed to additional resistance. The braking efficiency here is lower than in the reverse mode, since as the speed decreases, the braking torque also decreases.

c) Simulation of **regenerative braking** by changing armature voltage from U_{nom} to $0.8U_{nom}$.

If the motor speed is higher than the ideal idle speed, then the EMF of the machine becomes greater than the mains voltage. The armature current, as follows from the equation, becomes negative.

$$U_0 = k_v \omega_0 - \text{ nominal voltage}$$

$$i_a = \frac{0.8U_0 - k_v \omega_0}{R_a} < 0$$

Consequently, the sign of the torque also changes - it becomes braking. The machine operates in a generator mode: the mechanical energy coming from the machine shaft is converted into electrical energy and transferred to the power grid.

The characteristics of the generator mode with the return (recuperation) of energy are a continuation of the characteristics of the motor mode and are in the II quadrant. The regenerative braking mode is used, for example, in the drives of transport and lifting mechanisms when lowering loads. The method is very **economical,** since the **energy returns to the power grid.**

3. Simulation of starting of the DC motor.

Direct starting of a DC motor produces a large starting current, and the starting current usually exceeds the capacity limit. To avoid this, additional resistors are required to reduce the surge to the proper range.