

Separately-Excited DC Motors

Mathematical Dynamic Model

Prepared by: **Eng. Gabriel L. Julián (28/11/1997)**
for: **IMPSA Job A24700**
2 Main Hoist DC motors (Series Connected) for
Ship-to-Shore (STS) Container Gantry Crane
Customer: **NAVY Naval Ordnance Center-Port Hadlock, USA.**



1. Motor Data (General Electric (GE), USA):

Motor Type: General Electric, CD Kinamatic shunt wound DC Motor, Frame CD6063
Mechanical Power: 375 HP - 280 kW
Efficiency: 91 %
Voltage: 225 V (armature)
120 V (field)
Current: 1360 A (armature)
30/12.6 A (field)
Speed: 850/2070 rpm



Resistances (at 25°C: Cold windings)

- Armature = 0.0037 ohm
- Comm. (&Comp.) Fld. = 0.0016 ohm
=> **Ra = 0.0053 ohm** (arm. & Comm. field coils in series)
- Shunt Field = 11.1 ohm (two circuits in series) => 5.55 ohm (each circuit)
=> **Rf = 2.775 ohm** (field coils in parallel)

Resistances (at 128°C: Hot windings) = Resistances (at 25°C) x [1 + 4.3x10⁻³/°C x (128°C - 25°C)]

- Armature = 0.0053 ohm
- Comm (&Comp.) Fld. = 0.0023 ohm
=> **Ra = 0.0076 ohm** (arm. & Comm field coils in series)
- Shunt Field = 16 ohm (two circuits in series) => 8 ohm (each circuit)
=> **Rf = 4 ohm** (field coils in parallel)

Inductances (Unsaturated)

- Armature Circuit Total = 0.3494 mH
=> **La = 0.3494 mH**
- Shunt Field = 19.1 H (two circuits in series) => 9.55 H (each circuit)
=> **Lf = 4.775 H** (field coils in parallel)

Torque Constant, estimated linearized value (calculated at nominal conditions)

$T_{mnom} = P_{mnom} / \omega_{mnom} = 279.75 \times 10^3 \text{ W} / 89.0118 \text{ rad/s} = 3142.842 \text{ N.m}$

- $K_t = K_v = T_{mnom} / (I_{fnom} \times I_{anom}) = 3142.842 \text{ N.m} / (30 \text{ A} \times 1360 \text{ A}) = 0.07703 \text{ N.m/A}^2$
=> **Kt = Kv = 0.07703 N.m/A²**

Inertias (at high speed input shaft, motor side of gearbox)

- $J_m = 250 \text{ lb.ft}^2 = 10.54 \text{ kg.m}^2$ (WK2) (motor)
- $J_b = 112.5 \text{ lb.ft}^2 = 4.741 \text{ kg.m}^2$ (brake)

Inertias (at low speed motor shaft, load side of gearbox) → reflected to motor shaft

- $J_{mec} = 142 \text{ lb.ft}^2 = 5.984 \text{ kg.m}^2$ (drum, gearbox, etc.)
- $J_l = 8.2504 \text{ kg.m}^2$ (rated load (40LT) + spreader & headblock)
- $J_e = 2.132 \text{ kg.m}^2$ (empty spreader & headblock)

2. Model Parameters:

2 Separately Excited DC Motors - Series Connected

Armature parameters:

$$L_a = 2 \times 0.3494 \times 10^{-3} \text{ H} \quad \Rightarrow \quad \mathbf{L_a = 0.6988 \times 10^{-3} \text{ H}}$$

$$\text{Cold: } R_a = 2 \times (0.0037 + 0.0016) \text{ ohm} \Rightarrow \mathbf{R_a = 0.0106 \text{ ohm}}$$

$$\text{Armature Time Constant } \tau_a = L_a/R_a = 65.92 \text{ ms}$$

$$\text{Hot: } R_a = 2 \times (0.0053 + 0.0023) \text{ ohm} \Rightarrow \mathbf{R_a = 0.0152 \text{ ohm}}$$

$$\text{Armature Time Constant } \tau_a = L_a/R_a = 45.97 \text{ ms}$$

Field parameters:

$$L_f = 2 \times 4.775 \text{ H} \quad \Rightarrow \quad \mathbf{L_f = 9.55 \text{ H}}$$

$$\text{Cold: } R_f = 2 \times 2.775 \text{ ohm} \quad \Rightarrow \quad \mathbf{R_f = 5.55 \text{ ohm}}$$

$$\text{Field Time Constant } \tau_f = L_f/R_f = 1.72 \text{ s}$$

$$\text{Hot: } R_f = 2 \times 4 \text{ ohm} \quad \Rightarrow \quad \mathbf{R_f = 8.00 \text{ ohm}}$$

$$\text{Field Time Constant } \tau_f = L_f/R_f = 1.19 \text{ s}$$

Torque constant:

$$K_t = 2 \times 0.07703 \text{ N.m/A}^2 \quad \Rightarrow \quad \mathbf{K_t = 0.15406 \text{ N.m/A}^2}$$

Total Hoist Drive Inertia reflected to motor shaft :

$$\text{at Empty Spreader} \quad J_{\text{tote}} = 2 \times (J_m + J_b) + J_{\text{mec}} + J_e \Rightarrow \mathbf{J_{\text{tote}} = 38.678 \text{ kg.m}^2}$$

$$\text{at Rated load (40 LT) under Spreader} \quad J_{\text{totl}} = 2 \times (J_m + J_b) + J_{\text{mec}} + J_l \Rightarrow \mathbf{J_{\text{totl}} = 44.7964 \text{ kg.m}^2}$$

Reducer Gearbox ratio (motor shaft to drum shaft):

$$r = 24.45 : 1 \quad \Rightarrow \quad \mathbf{r = 24.45 : 1}$$

Load Gravitational Torque reflected to drum shaft:

$$M_l = 40 \text{ LT} = 40642 \text{ kg}, \quad M_s = 10.715 \text{ LT} = 10886.976 \text{ kg}, \quad M_h = 3.219 \text{ LT} = 3270.665 \text{ kg}$$

$$\text{Empty Spreader} \quad M_{\text{tot}} = M_h + M_s \quad \mathbf{M_{\text{tote}} = 14161 \text{ kg}}$$

$$\text{Rated load (40 LT) under Spreader} \quad M_{\text{tot}} = M_h + M_s + M_l \quad \mathbf{M_{\text{totl}} = 54801 \text{ kg}}$$

$$\text{Empty Spreader :} \quad T_{\text{le}} = (M_{\text{tote}} \cdot g) / 2 \times D_d / 2 \Rightarrow \mathbf{T_{\text{le}} = 41661.59 \text{ N.m}}$$

$$\text{Rated load (40LT) under Spreader :} \quad T_{\text{ll}} = (M_{\text{totl}} \cdot g) / 2 \times D_d / 2 \Rightarrow \mathbf{T_{\text{ll}} = 161224.27 \text{ N.m}}$$

$$\text{Friction coefficient reflected to motor shaft: } \mathbf{\text{neglected}} \quad \Rightarrow \quad \mathbf{f_m = 0 \text{ N.m/rad/s}}$$

3. Motor Block diagram:

