high torque high power high acceleration servo system

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high torque high power high acceleration servo system:

Abstract

In this project a high torque high power high accelerated servo system will be designed.

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Chapter 1. Introduction

```
The requirements are given as follows:
@azimuth
the load is turned 90° in 100ms
@elevation
the load is turned 60° in 100ms
@azimuth & @elevation
the load is turned 60° in azimuth and the load is turned 30° in elevation
at the same time

servo system should be fit a phi 40cm x height 75cm cyclinder
servo system weight should be less than 135kg
servo motors should include safety brakes
stabilized pointing accuracy should be smaller than 0.5°

azimuth angle range is [-185° to +185°]
elevation angle range is [-30° to +60°]

operating temperature range should be -30° to +52°
```

```
%% input parameters
deltaposdeg = 90; %% [degree]
period = 0.2; %% [seconds] T   45° --> -45° 0.1s
inertiaazimuth = 1.6; %% [kg.m^2] motor inertia is not included
inertiaelevation = 0.5; %% [kg.m^2] motor inertia is not included
azimuthloadmass = 50; %% [kg]
elevationloadmass = 25; %% [kg]
```

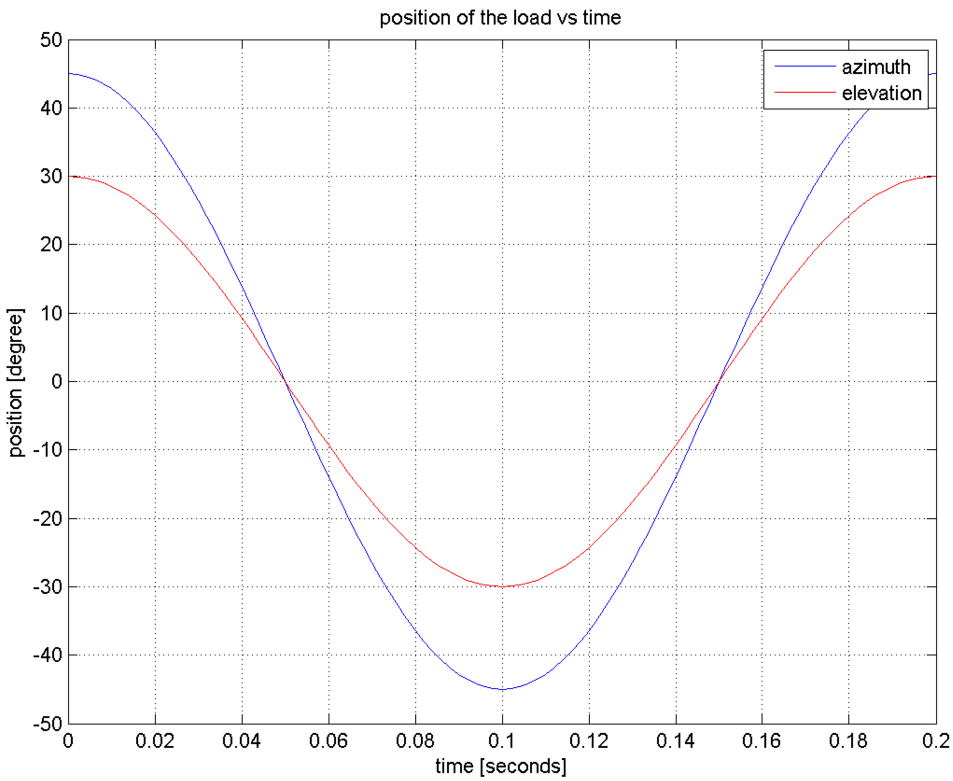
```
input parameters are given above.
```

Chapter 2. Basic Calculations

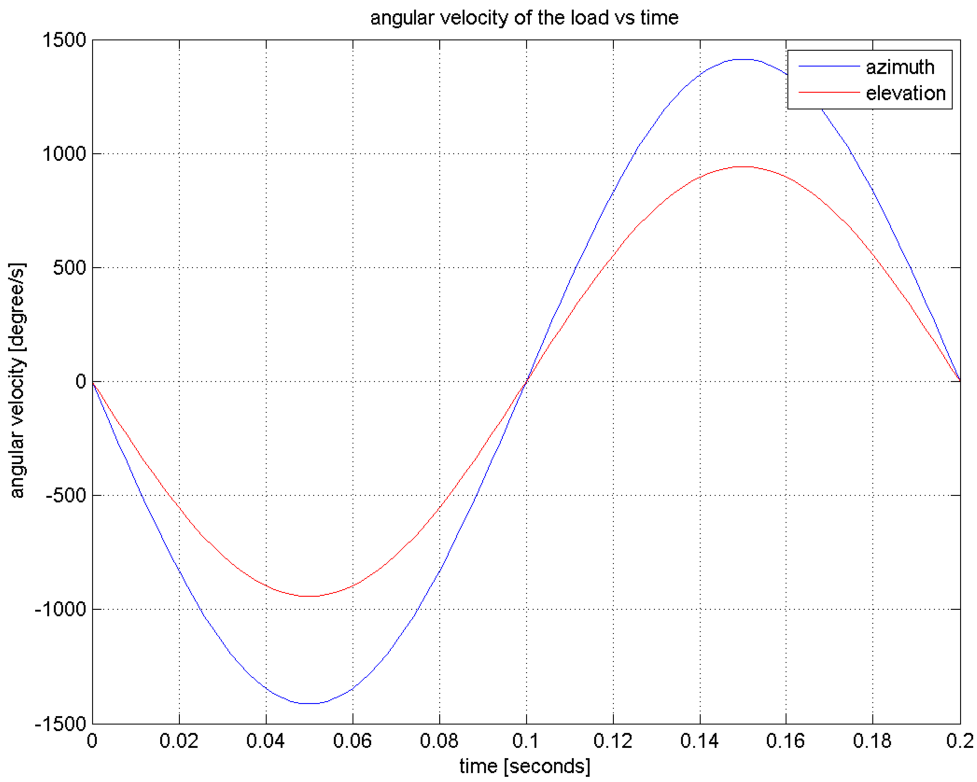
```
basic calculations are given below

%% velocity, acc, power, torque calculations
%% assume sinusoidal profiles
%% theta = A*cos(wt)   --> position
%% angvel = -A*w*sin(wt) --> angular velocity dtheta/dt
%% angacc = -A*w^2*cos(wt) --> angular acceleration dangvel/dt
%% desired requirement : 90° --> 100ms for azimuth
%% desired requirement : 60° --> 100ms for elevation
deltaposdegazmimuth = 90; %% [degree]
deltaposdegelevation = 60; %% [degree]
deltaposradazimuth = deltaposdegazmimuth*2*pi / 360; %% [rad]  2*A
deltaposradelevation = deltaposdegelevation*2*pi / 360; %% [rad]  2*A
period = 0.2; %% [seconds] T
angfreg = 2*pi/period; %% [rad/s]  w = 2pi/T
maxangvelazimuthrads = (deltaposradazimuth/2) * angfreg; %% [rad/s]
maxangvelelevationrads = (deltaposradelevation/2) * angfreg; %% [rad/s]
maxangvelazimuthdegs = maxangvelazimuthrads * 360 / (2*pi); %% [deg/s]
maxangvelelevationdegs = maxangvelelevationrads * 360 / (2*pi); %% [deg/s]
maxangvelazimuthrpm = maxangvelazimuthrads * 60 / (2*pi); %% [rpm]
maxangvelelevationrpm = maxangvelelevationrads * 60 / (2*pi); %% [rpm]
maxangaccazimuthrads2 = (deltaposradazimuth/2) * angfreg^2; %% [rad/s^2]
maxangaccelevationrads2 = (deltaposradelevation/2) * angfreg^2; %% [rad/s^2]
maxangaccazimuthdegs2 = maxangaccazimuthrads2 * 360 / (2*pi); %% [deg/s^2]
maxangaccelevationdegs2 = maxangaccelevationrads2 * 360 / (2*pi); %% [deg/s^2]
%% torque = inertia * acc
%% power = torque * angvel
maxtorqueazimuth = inertiaazimuth * maxangaccazimuthrads2; %% [Nm]
maxtorqueelevation = inertiaelevation * maxangaccelevationrads2; %% [Nm]
%% plot the assumed profiles
tres = period / 100; %% [seconds]
t = 0:tres:period;
posdegazimutharr = deltaposdegazmimuth/2 * cos(angfreg*t);
posdegelevationarr = deltaposdegelevation/2 * cos(angfreg*t);
figure;
plot(t,posdegazimutharr);
hold on;
plot(t,posdegelevationarr,'r');
grid;
legend ('azimuth','elevation');
title('position of the load vs time')
xlabel('time [seconds]');
ylabel('position [degree]');
saveas(gcf, 'snapshots\position_load', 'png')
angveldegazimuthsarr = -1*maxangvelazimuthdegs * sin(angfreg*t);
angveldegelevationsarr = -1*maxangvelelevationdegs * sin(angfreg*t);
figure;
plot(t,angveldegazimuthsarr);
hold on;
plot(t,angveldegelevationsarr,'r');
grid;
```

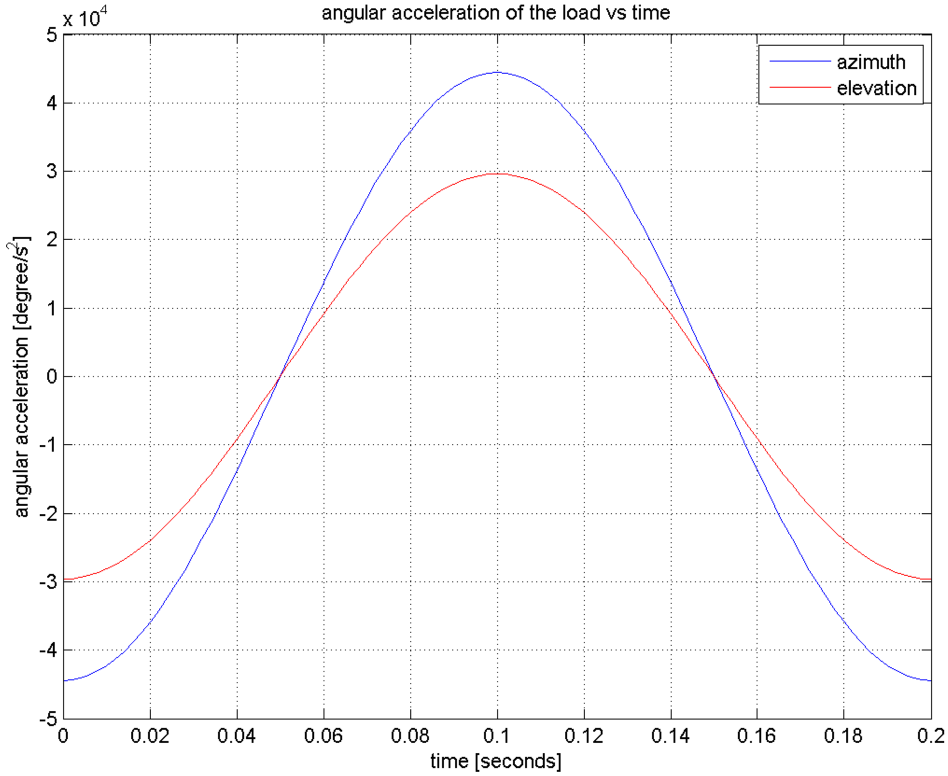
```
legend ('azimuth','elevation');
title('angular velocity of the load vs time')
xlabel('time [seconds]');
ylabel('angular velocity [degree/s]');
saveas(gcf, 'snapshots\velocity_load', 'png')
angaccdegs2azimutharr = -1*maxangaccazimuthdegs2 * cos(angfreg*t);
angaccdegs2elevationarr = -1*maxangaccelevationdegs2 * cos(angfreg*t);
figure;
plot(t,angaccdegs2azimutharr);
hold on;
plot(t,angaccdegs2elevationarr,'r');
grid;
legend ('azimuth','elevation');
title('angular acceleration of the load vs time')
xlabel('time [seconds]');
ylabel('angular acceleration [degree/s^2]');
saveas(gcf, 'snapshots\acceleration_load', 'png')
angaccrads2azimutharr = -1*maxangaccazimuthrads2 * cos(angfreg*t);
angaccrads2elevationarr = -1*maxangaccelevationrads2 * cos(angfreg*t);
torqueazimutharr = inertiaazimuth * angaccrads2azimutharr;
torqueelevationarr = inertiaelevation * angaccrads2elevationarr;
figure;
plot(t,torqueazimutharr);
hold on;
plot(t,torqueelevationarr,'r');
grid;
legend ('azimuth','elevation');
title('requirred torque of the load vs time')
xlabel('time [seconds]');
ylabel('torque [Nm]');
saveas(gcf, 'snapshots\torque_load', 'png')
angvelradsazimutharr = -1*maxangvelazimuthrads * sin(angfreg*t);
angvelradselevationarr = -1*maxangvelelevationrads * sin(angfreg*t);
powerazimutharr = torqueazimutharr .* angvelradsazimutharr;
powerelevationarr = torqueelevationarr .* angvelradselevationarr;
maxpowerazimuth = max(powerazimutharr); %% [watt]
maxpowerelevation = max(powerelevationarr); %% [watt]
figure;
plot(t,powerazimutharr);
hold on;
plot(t,powerelevationarr,'r');
grid;
legend ('azimuth','elevation');
title('requirred power of the load vs time')
xlabel('time [seconds]');
ylabel('power [Watt]');
saveas(gcf, 'snapshots\power_load', 'png')
```



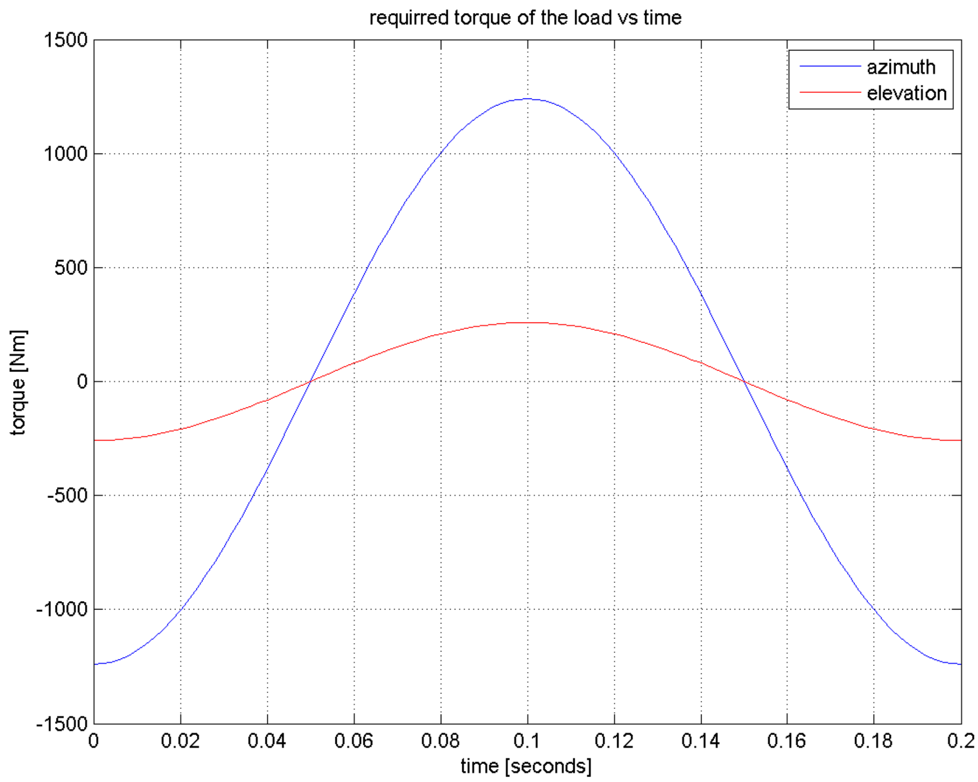

```
position of the load,
delta position is 90° for azimuth
delta position is 60° for elevation
period is 0.2000 second
```



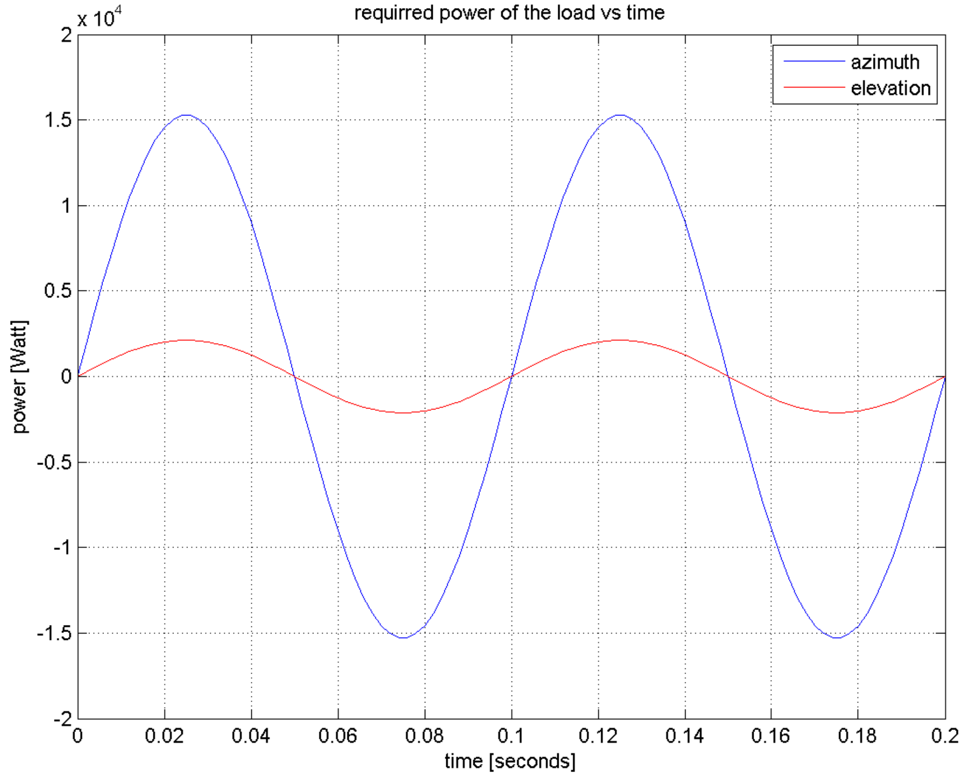

```
angular velocity of the load in degree/s
for azimuth
maximum angular velocity of the load is
1.4137e+03 deg/s
235.6194 rpm
for elevation
maximum angular velocity of the load is
942.4778 deg/s
157.0796 rpm
```




```
acceleration of the load in degree/s^2
for azimuth
maximum acceleration 4.4413e+04 deg/s^2
for elevation
maximum acceleration 2.9609e+04 deg/s^2
```




```
desired torque in Nm
for azimuth
maximum desired torque is 1.2403e+03 Nm
for elevation
maximum desired torque is 258.3856 Nm
```




```
desired power in Watt
for azimuth
maximum desired power 1.5271e+04 Watt
for elevation
maximum desired power 2.1209e+03 Watt
```

Chapter 3. Servo Motor & Driver alternatives

a servo motor from Kollmorgen KBM series is given below

KBM(S)-88XXX PERFORMANCE DATA & MOTOR PARAMETERS

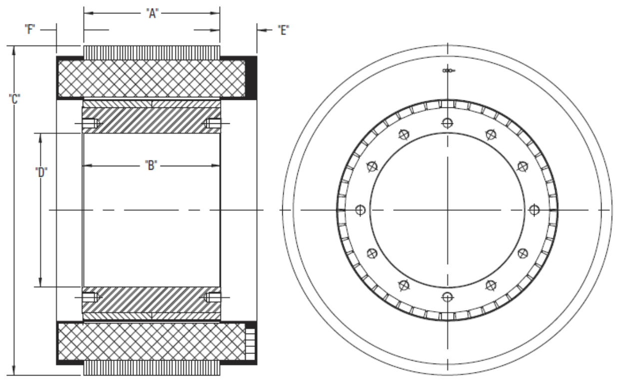
Motor Parameter	Symbol	Units	TOL	KBM(S)-88X03-X		
				A	B	C
Continuous Stall Torque at 25°C Amb. (1)	Tc	Nm	NOM	538	545	545
		lb-ft		397	402	402
Continuous Current	Ic	Arms	NOM	18.2	35.5	45.2
Peak Stall Torque (25°C winding temp)	Tp	Nm	NOM	1200	1200	1200
		lb-ft		885	885	885
Peak Current	Ip	Arms	NOM	53.1	106	134
Rated Continuous Output Power at 25°C Amb. (1)	P Rated	Watts		10450	16000	16000
	HP Rated	HP		14.0	21.4	21.4
Speed at Rated Power	N Rated	RPM		225	425	425
Torque Sensitivity (2)	Kt	Nm / Arms	+/-10%	30.0	15.5	12.8
		lb-ft / Arms		22.1	11.5	9.4
Back EMF Constant	Kb	Vrms/kRPM	+/- 10%	1812	940	772
Motor Constant	Km	Nm/√watt	+/-10%	20.6	20.9	20.9
		lb-ft /√watt		15.2	15.4	15.4
Resistance (line to line)	Rm	Ohms	+/- 10%	1.41	0.370	0.250
Inductance	Lm	mH		26	7.0	4.7
Inertia (KBM)	Jm	Kg-m²		0.298		
		lb-ft-s²		0.220		
Weight (KBM)	Wt	Kg		106		
		lb		234		
Inertia (KBMS)	Jm	Kg-m²		0.315		
		lb-ft-s²		0.232		
Weight (KBMS)	Wt	Kg		111		
		lb		245		
Max Static Friction	Tf	Nm		6.51		
		lb-ft		4.80		
Cogging Friction (Peak-to-Peak)	Tcog	Nm		4.88		
		lb-ft		3.60		
Viscous Damping	Fi	Nm/ kRPM		2.30		
		lb-ft / kRPM		1.70		
Thermal Resistance (3)	TPR	°C / watt		0.124		
Number of Poles	P	-		46		
Recommended Kollmorgen AKD Drive				02407	04807	04807
Voltage Req'd at Rated Output	Vac Input	Vac		480	480	400
Peak Stall Torque (4) (Motor with Drive)	Tp Drive	Nm	+/-10%	1153	1160	1050
		lb-ft		850	856	774
Cont. Stall Torque (4) (Motor with Drive)	Tc Drive	Nm	+/-10%	538	545	545
		lb-ft		397	402	402

Notes
1) Winding temperature = 155°C at continuous stall, at rated output, and for performance curves.
2) To calculate no-load Kt and Kb at 25°C, multiply by 1.064.
3) TPR assumes motor is housed and mounted to a 20" x 20" x 3/4" heat sink or equivalent.
4) Peak & Continuous Torques may be limited by drive current, see www.kollmorgen.com for complete drive ratings.

dimensions are as follows

KBM 88 Outline Drawings

KBM 88

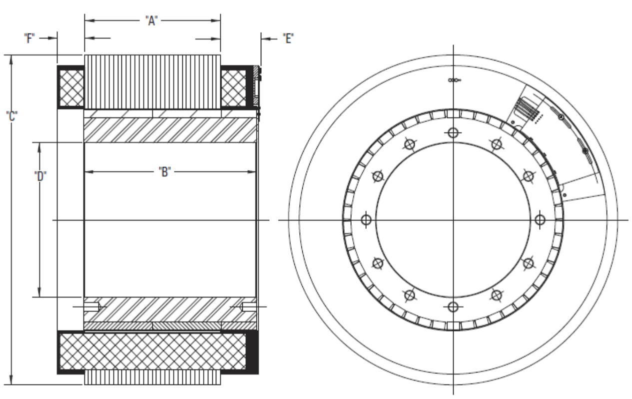


Model Number	"A" mm[inch]	"B" mm[inch]	∅ "C" mm[inch]	∅ "D" mm[inch]	"E" MAX mm[inch]	"F" MAX mm[inch]
KBM-88X00	33.66 [1.325]	36.37 [1.432]	331.46 [13.049]	155.01 [6.103]	37.59 [1.480]	27.43 [1.080]
KBM-88X01	67.56 [2.660]	70.36 [2.770]				
KBM-88X02	136.65 [5.380]	139.44 [5.490]				
KBM-88X03	205.74 [8.100]	208.53 [8.210]				

All dimensions are nominal. For more detailed and interactive 3D models with 2D product views, visit www.kollmorgen.com/kbm

dimensions cont.d

KBMS 88



Model Number	"A" mm[inch]	"B" mm[inch]	∅ "C" mm[inch]	∅ "D" mm[inch]	"E" MAX mm[inch]	"F" MAX mm[inch]
KBMS-88X00	33.66 [1.325]	71.37 [2.810]	331.46 [13.049]	155.01 [6.103]	40.64 [1.600]	27.43 [1.080]
KBMS-88X01	67.56 [2.660]	105.41 [4.150]				
KBMS-88X02	136.65 [5.380]	174.63 [6.875]				
KBMS-88X03	205.74 [8.100]	243.84 [9.600]				

All dimensions are nominal. For more detailed and interactive 3D models with 2D product views, visit www.kollmorgen.com/kbm

suggested driver from Kollmorgen AKD drive series is given below

240/480 Vac
3 Phase (187-528 V)

		Model				
Rated Data	**Units**	**AKD-x00307**	**AKD-x00607**	**AKD-x01207**	**AKD-x02407**	**AKD-x04807**
Drive Continuous Output Power	Watts	2000	4000	8000	16,000	32,000
Rated supply voltage	V	240/480				
Control logic, supply voltage	V	24				
Rated output current (RMS value ±3%)	A	3	6	12	24	48
Peak output current (±3%)	A	9	18	30	48	96
Peak time	s	5				
Current loop Bandwidth max.	kHz	2.5 to 4		2 to 3		
Velocity loop Bandwidth max.	Hz	0 to 800	0 to 600			
Position loop Bandwidth max.	Hz	1 to 250				
Update rate	MHz	1.5				
Weight (standard width)	kg	2.7			5.3	11.5
Weight (extended width)	kg	2.9			5.5	11.7
Height, without connectors	mm	256			306	385
Height, with connector	mm	290			340	526
Standard Width front/back	mm	65/70			99/105	185/185
Extended Width front/back	mm	95/100			99/105	-
Depth, without connectors	mm	185			228	225
Depth, with connectors	mm	< 225			< 265	< 265

Chapter 4. Conclusion

to choose suitable servo motor especially for azimuth seems to be a big problem.