Appendix – I

APPENDIX-I

Output Equation of AC motor

Let Q = KVA rating of motor

E_{ph} = Output voltage per phase

I_{ph} = Current per phase

f = Supply Frequency

Φ = Flux per pole in Weber

T_{ph} = Turns per phase

K_w = Winding factor

p = No. of poles

n_s = Synchronous speed

D = Stator Diameter

L = Core length

B_{av} = Specific Magnetic loading

ac = Specific Electric loading

I_s = Current in each conductor

Z = Total armature conductors

Z_{ss} = Armature conductors per slot

m = No. of phases

C_0 = Output Coefficient

Consider an m phase motor having one circuit per phase.KVA rating of motor

Q = number of phases × output voltage per phase × current per phase × 10^{-3}

$$Q = m.E_{ph}I_{ph}.10^{-3} \qquad [1.1]$$

Terminal voltage of each phase may be taken equal to the induced emf per phase,

We have, Induced emf per phase [58]

$$E_{ph} = 4.44\, f\, \Phi\, T_{ph}\, K_w \qquad [1.2]$$

$$\therefore \mathbf{Q = m} \times 4.44\, f\, \Phi\, T_{ph}\, K_w\, I_{ph} \times 10^{-3} \qquad [1.3]$$

$$\text{But } f = pn_s / 2 \qquad [1.4]$$

Therefore we can write,

$$Q = \mathbf{m} \times 4.44\, (pn_s / 2)\, \Phi\, T_{ph}\, K_w\, I_{ph} \times 10^{-3} \qquad [1.5]$$

$$Q = 1.11\, K_w\, (p\Phi)\, (2m\, I_{ph}\, T_{ph})\, n_s \times 10^{-3} \qquad [1.6]$$

Now current in each conductor

$I_s = I_{ph}$ (As there is only one circuit per phase).

Total number of armature conductors

Z = number of phases × (2 × turns per phase) = $2m\, T_{ph}$

$\therefore$ **Total electric loading** $I_s Z = 2m\, I_{ph}\, T_{ph}$

$$\text{Hence, } Q = 1.11\, K_w\, (p\Phi)\, (I_s Z)\, n_s \times 10^{-3} \qquad [1.7]$$

$= 1.11\ K_w$ (total magnetic loading) (total electric loading) (synchronous speed $\times 10^{-3}$)

But $p\Phi = \pi\ DL\ \mathbf{B_{av}}$ **and** $I_s Z = \pi\ D\ \mathbf{ac}$

Substituting these values in equation [1.7],

$$\mathbf{Q = 1.11}\ K_w (\pi\ DL\ \mathbf{B_{av}})\ (\pi\ D\ \mathbf{ac})\ n_s \times 10^{-3}$$

$$\mathbf{Q = (1.11\pi^2\ B_{av}\ ac\ K_w} \times 10^{-3})\ D^2 L\ n_s$$

$$= (11\ \mathbf{B_{av}\ ac\ K_w} \times 10^{-3})\ D^2 L\ n_s \qquad [1.8]$$

$$Q = C_0 D^2 L\ n_s \qquad [1.9]$$

$$C_0 = 11\ \mathbf{B_{av}\ ac\ K_w} \times 10^{-3} \qquad [1.10]$$

Equation [1.10] is known as the output equation of an a.c. machine. Quantity C_0 is called the output coefficient.

Motor Specifications at "Jyoti Switchgear Ltd".

KW= 2.2 POLE= 4.0 VOLT= 320.0 FRAME= CTF-112 FRAME NO.= 112.0

DATE OF RUN: 08/01/2009 TIME OF RUN: 13:47:35.33

INPUT DATA PROJECT NEW ROTOR TYPE = SINGLE CAGE

STATOR DATA		ROTOR DATA	
O.D.=	165.000	O.D.=	105.000
I.D.=	105.000	I.D.=	33.500
STACKLENGTH=	110.000	STACKLENGTH=	110.000
STACKING FACTOR=	.950	STACKING FACTOR=	.950
NO. OF DUCTS=	.000	NO. OF DUCTS=	.000
WIDTH OF DUCT=	12.700	WIDTH OF DUCT=	12.700
NO. OF SLOTS=	36.000	NO. OF SLOTS=	33.000
SLOT DIMENSIONS		SLOT DIMENSIONS	
SLOT OPENING=	2.500	SLOT OPENING=	.800
WIDTH AT TOP=	7.000	WIDTH AT TOP=	5.300
WIDTH AT BOTTOM=	4.600	WIDTH AT BOTTOM=	1.900
LIP HEIGHT=	.500	LIP HEIGHT=	.750
WEDGE HEIGHT=	.500	NECK HEIGHT=	.750
HEIGHT ABOVE WEDGE=	13.800	HEIGHT BELOW NECK=	16.200
CONDUCTOR PER SLOT=	96.000	BAR LENGTH=	140.000
CONDUCTOR SIZE= 1/ .60 0/ .00 0/ .00			
CONDUCTOR AREA=	.283	AREA OF BAR	60.608
ENAMEL AREA=	.454	AREA OF RING	150.000
COIL PITCH=	9.000	WIDTH OF S.C.RING=	15.000
NO. OF PARALLEL PATH=	3.000	DEPTH OF S.C.RING=	10.000
STATOR CONNECTION=	STAR	ROTOR SKEW =	1.000
AIR GAP=	.300	DENSITY OF IRON=	7.650
RHO OF COPPER(75C)=	.022	DENSITY OF COPPER=	8.900
RHO OF BAR=	.044	DENSITY OF BAR=	8.900
RHO FOR RING=	.044	DENSITY OF RING=	8.900
CLASS OF INSULATION=	B	IRON LOSS PER KG=	5.300
SUPPLY FREQUENCY(Hz)=	50.000	STAMPING GRADE=	500C

PERFORMANCE ANALYSIS AT 100% VOLTAGE

WINDING FACTOR=	.960	SLOT FILL FACTOR(%)=	53.330
CK1=	1.271	OVERHANG PROJECTION=	28.051
CK2=	1.035	MEAN LENGTH OF CONDUCTOR=	208.343
CK3=	1.000	ST. RESISTANCE AT 75 C=	2.351
EFFECTIVE CARTER FACTOR=	1.316	ST. RESIST AT 50 C=	2.010

MAGNETIC CIRCUIT CALCULATION

FLUX PER POLE IN WEBERS=	.0045	ALPHA=	1.469

STATOR TOOTH	WIDTH	AVERAGE DENSITY	MAXIMUM DENSITY	ROTOR TOOTH	WIDTH	AVERAGE DENSITY	MAXIMUM DENSITY
BTS1=	4.738	1.013	1.488	BTR1=	4.410	1.139	1.674
BTS2=	4.742	1.012	1.487	BTR2=	4.568	1.100	1.616
BTS3=	4.746	1.011	1.485	BTR3=	4.726	1.063	1.562
STATOR CORE HEIGHT =			15.200	ROTOR CORE HEIGHT =			18.050
STATOR CORE DENSITY=			1.421	ROTOR CORE DENSITY=			1.104
AIR GAP DENSITY=		.497	.731				
STATOR TOOTH AT=			12.496	ROTOR TOOTH AT=			68.815
STATOR CORE AT=			11.651	ROTOR CORE AT=			1.966
AIR GAP AT			229.560	TOTAL AT=			294.488
SATURATION FACTOR=			1.283				

LEAKAGE REACTANCE

XSL1=	.555	PSI1=	.000
XZZ1=	.565	XZZ2=	.953
XHANG=	.935	XER=	.135
XM=	68.894	XSKL=	.672
KP=	.960	MAG. CURRENT=	2.367
R2=	1.437	XSL2=	.949
X1=	2.728	X2=	2.036
CORR FACTOR FOR RESIST(KR)=	1.139	LOCKED ROTOR RESISTANCE=	1.574
CORR.FACTOR FOR REACT(KI)=	.960	LOCKED ROTOR REACTANCE=	4.592

IRON LOSSES

IRON LOSS IN TEETH=	.063	IRON LOSS IN CORE=	.047
TOTAL IRON LOSS=	.109		

NO LOAD-LOCKED ROTOR-PULL OUT PERFORMANCE

	NO LOAD	LOCKED ROTOR	PULL-OUT
SLIP(%)	.050	100.000	27.049
STATOR CURRENT	2.584	30.460	20.714
ROTOR CURRENT	.062	29.543	19.947
INPUT POWER	.190	10.828	9.571
POWER FACTOR	.163	.641	.834
TORQUE RATIO	-.001	187.323	289.273
CURRENT RATIO	.465	5.488	3.732

LOAD PERFORMANCE

% LOAD	125(%)	100(%)	75(%)	50(%)	25(%)
OUTPUT-KW=	2.747	2.200	1.650	1.100	.550
SLIP=	5.378	4.060	2.903	1.867	.923
STATOR CURRENT=	6.827	5.551	4.443	3.529	2.873
ROTOR CURRENT=	6.050	4.679	3.414	2.255	1.122
STATOR COPPER LOSS=	.329	.217	.139	.088	.058
ROTOR COPPER LOSS=	.156	.094	.050	.022	.005
STRAY LOAD LOSS=	.017	.013	.010	.007	.004
FRICTION-WINDAGE LOSS=	.030	.030	.031	.032	.032
IRON LOSS=	.109	.109	.109	.109	.109
TOTAL LOSSES=	.642	.465	.340	.257	.209
EFFICIENCY-%=	81.051	82.559	82.914	81.040	72.443
POWER FACTOR=	.896	.866	.808	.694	.477
CURRENT DENSITY=	8.044	6.540	5.235	4.158	3.385
AMP-CON PER CM=	238.404	193.850	155.174	123.247	100.336
QUE-ALPHA=	1917.607	1267.833	812.398	512.490	339.661

ROTOR BAR CURRENT DENSITY 2.587 ROTOR RING DENSITY= 2.745