ASTA EPSILON ENGINEERING

Medium-High Voltage High Power 3 phase Induction Motors from AEG

Power rating: 200 kW to 10000 kW
Voltage: 3 kV to 13.8 kV
Cooling: IS 6362:1995 (IS8A1W7)

Detailed Description and Analysis of 1 MW Machine

Voltage: 3.3 kV
Poles: 4
Synchronous Speed: 1500 rpm
Operational Speed: 1490 rpm

Stator Design

1.1 Stator Core

- **Material**: Use silicon steel laminations (e.g., M35 or M42 grade) to reduce core losses (hysteresis and eddy currents).
- **Lamination Thickness**: Typically, 0.35 mm for 50 Hz motors to minimize eddy current losses.
- **Stacking Factor**: Around 0.95, accounting for insulation layers between laminations.
- **Core Diameter**: Optimize based on flux density (ideal range: 1.2–1.5 T) to prevent saturation.

1.2 Stator Windings

- **Configuration**: Star-connected for phase-to-neutral voltage distribution.
- **Conductor Material**: Copper with a high conductivity (IACS rating > 100%).
- **Conductor Size**: Sized to handle the current without excessive heat (ampacity and thermal limits).
- **Winding Type**:
  - Use distributed windings for smoother torque and reduced harmonics.
  - Slot pitch and winding pitch should be optimized to reduce leakage reactance.
- **Number of Slots**:
  - Choose a slot count to minimize slot harmonics. For a 4-pole motor, typical slot count per phase: 36.

1.3 Insulation

- **Voltage Withstand**: Insulation class F or H (155–180°C).
- **Insulation Layers**: Mica-based or epoxy-coated insulation for medium voltage.
- **Creepage Distance**: Ensure adequate creepage and clearance distances to prevent breakdown.

For the AE1000I354 motors, the stator will be CRNO steel, 0.35 mm thick laminations with 36 slots.
For AE1000I354 Standard motors, Steel grade M35
For AE1000I354 Premium and Premium+ motors, Steel grade M42

Steel Required for Stator and Rotor: 2395 kg
Steels Costs:
M35: 39,51,750 INR
M42: 51,49,250 INR

Rotor Design

2.1 Rotor Core

- **Material**: Laminated silicon steel, similar to the stator core.
- **Air Gap**: Maintain a uniform and optimized air gap (0.5–1 mm depending on motor size) for efficient flux transfer.

2.2 Rotor Bars

- **Material**: High-conductivity copper or aluminium (copper preferred for efficiency).
- **Shape**: Skewed bars to reduce cogging torque and noise.
- **Design**: Double-cage rotors can be used to improve starting torque without affecting efficiency.

2.3 End Rings

- Ensure high mechanical strength and conductivity to handle rotor currents and minimize losses.

Conductor Analysis

For a **1 MW, 3.3 kV motor**, **rectangular wires** are strongly recommended. Here's why:

- The motor's high power and voltage demand a **high conductor cross-sectional area** to handle the current without excessive losses.
- Rectangular wires will enable you to optimize the slot fill, improving both electrical efficiency and thermal management.
- For a conductor cross-sectional area of ~**87.5 mm²**
- 8mm×11mm, or similar dimensions depending on manufacturing constraints.

- Insulation thickness: 0.1−0.2 mm, depending on voltage requirements.

Copper conductor price: 775/ kg * 422 kg = 327050 INR

Copper cage for bar price: 800/kg * 34kg = 27200 INR

Total copper cost: 327050 + 27200 = 354250 INR

Magnetic Circuit

3.1 Magnetic Flux Density

- Target range: 1.2–1.5 T in the core.
- Ensure saturation does not occur, especially at the air gap and teeth.

3.2 Leakage Flux

- Minimize leakage reactance through:
  - Optimal slot fill factor (~0.6–0.7).
  - Proper winding distribution and slot design.

3.3 Magnetizing Reactance

- Ensure sufficient magnetizing reactance to maintain flux without excessive no-load current.

Thermal Design

- **Heat Sources**:
  - Copper losses (I^2R) in windings.
  - Core losses in the stator and rotor.
  - Stray load losses and mechanical losses.
- **Thermal Management**:
  - Incorporate cooling ducts in the core.
  - Optimize the placement of the fan and liquid cooling channels.

Performance Parameters

Synchronous Speed	1500 rpm
Operational Speed	1490 rpm
Slip	0.67%
Torque	6410 Nm
Power (kW)	1000
Power (hp)	1341
Voltage	3300 V

Simulation and Optimization

- Use finite element analysis (FEA) to:
  - Verify flux density distribution in the core and teeth.
  - Optimize the air gap field for uniformity.
- Simulate rotor dynamics to validate torque ripple and thermal performance.

Detailed Analysis of AEE1000I354 series motors

Specifications	Unit	AEE1000I354 -Tier 0	AEE1000I354 -Tier 1	AEE1000I354 -Tier 2	AEE1000I354 -Tier 3
Power	kW	1000	1000	1000	1000
Power	hp	1341	1341	1341	1341
Torque	Nm	6410	6410	6410	6410
Synchronous Speed	rpm	1500	1500	1500	1500
Operational Speed	rpm	1490	1490	1490	1490
Frequency	Hz	50	50	50	50
Pole	-	4	4	4	4
Slip	%	0.67	0.67	0.67	0.67
Voltage	V	3300	3300	3300	3300
Current (full load)	A	219.8	219.8	206.9	206.9
Starter Type	-	Star-Delta	Star-Delta	Soft	Soft
Starting Current*	A	439.6	439.6	519.25	519.25
Ramp Up Time*	sec	10	10	8	8
Power Factor	-	0.85	0.85	0.85	0.85
Efficiency*	-	0.93	0.93	0.95	0.95
Overheating Protection	-	Motor Shutdown	Motor Shutdown	Motor Shutdown + Fault Detection	Motor Shutdown + Fault Detection
Overcurrent Protection	-	-	MCCB	MCCB	MCCB + Fault Detection (HCR[1])
Overvoltage Protection	-	-	-	MOV Surge Arrestors + OVR[2]	MOV Surge Arrestors + OVR + Fault Detection
Ground Protection	-	-	-	-	ELCB + Fault Detection

Processor Unit	-	-	-	ABB UMC100.3 Motor Controller	ABB AC500 PLC
Cooling	-	Cooling Fin + Forced Air Cooling (FAC)	FAC + Unidirectional Liquid Flow (ULF) Cooling	FAC + ULF Cooling	FAC + Bidirectional Liquid Flow (BLF) Cooling
Communication	-	-	-	CAT6	CAT6
Insulation Class	-	H	H	H	H
Cooling Class	IS	IC0A1	IS8A1W7	IS8A1W7	IS8A1W7

*values can vary with operating conditions

[1]High Current Relay
[2]Over Voltage Relay

Cost Analysis

AE1000I354 (Tier-0)

Particulars	**Quantity**	**Cost (INR)**
M35 CRNGO Steel Laminations 0.35mm	2395 kg	39,51,750
Copper Conductor Windings 8x11 mm Rectangular	422 kg	3,27,050
Copper Double Cage Bars	34 kg	27,200
Elmotherm H71-A Class H Insulation Varnish	370 kg	3,18,200
DuPont Nomex Insulation Paper Class H	2 kg	8,500
SA 516-Gr 70 steel water jacketed motor casing	2950 kg	1,77,000
SAE 4340 Steel Motor Shaft 100 mm Diameter	71 kg	5,325
Therm-O-Disc Overheating Relay	1	950
SKF 22228 CCK/W33 Spherical Roller Bearings	2	81,400
Manufacturing Labour Costs	-	75,000
Other Misc. Costs (Extra Conductor, Wires, Bolts etc)	-	25,000
Manufacturing Grand Total		**49,97,375**

AE1000I354 (Tier 1) Standard

Particulars	Quantity	Cost (INR)
Standard Motor Manufacturing Costs	-	49,97,375
Chint 450A Moulded Case Circuit Breaker	1	16,000
AE Motor Integrated Water Pump System	1	15,000
AE Motor Mounted Heat Exchanger Mechanism for ULF	1	3,000
Manufacturing Grand Total		**50,31,375**

AE1000I354 (Tier 2) Premium

Particulars	Quantity	Cost (INR)
Standard Motor Manufacturing Costs	-	50,31,375
M42 CRNGO Steel Laminations 0.35mm	2395 kg	51,49,250
[Subtract M35 CRNGO Steel Laminations 0.35mm price]	-	-39,51,750
ABB PSTX MV Soft Starter	1	5,50,000
ABB UMC100.3 Motor Controller	1	25,000
ABB REF615 Numerical Relay	1	80,000
ABB POLIM-H 3.3kV Surge Arrestors	5	10,000
Manufacturing Grand Total		**68,93,875**

AE1000I354 (Tier 3) Premium+

Particulars	Quantity	Cost (INR)
Standard Motor Manufacturing Costs	-	68,93,875
ABB AC500 PLC Motor Controller	1	1,05,000
[Subtract ABB UMC100.3 Motor Controller]	-	-25,000
AE Motor Integrated Water Pump System	1	15,000
AE Motor Mounted Heat Exchanger Mechanism for BLF	1	5,000

[Subtract AE Motor Mounted Heat Exchanger Mechanism for ULF price]	-	-3,000
ABB REJ 601 Ground Fault Relay with ELCB	1	22,800
Manufacturing Grand Total		**70,13,675**

All costs are subjected to change without prior notice.

Costs of aftermarket parts depend on the market price.
Costs of AE parts depend on supplier availability and parts market price.