Best Practice Guide Book

Operation, Maintenance and Rewinding of Induction Motors in SME Industries
Best Practice # 1
Select Proper Size of Motor for Any Load

The motor for any application should not be oversized or undersized. Oversized motor runs on under-loading, hence low power factor and efficiency. Undersized motor runs on overloading, hence drawing more current than rated.

- The motor loading should be 80% to 95%
- Conduct motor load survey once in a year
- Measure line current by simple clamp-on meter and see that it is neither less than 60% nor more than 100% of the name plate rating current
- Always maintain a motor inventory list with the following information:
  - Capacity (HP or KW)
  - Date of installation
  - Supplier / Manufacturer
  - Voltage level (3-phase 415 volt or 1-phase 250 volt)

Example of Over-sized Motor:

<table>
<thead>
<tr>
<th>MOTOR NOMINAL LOAD (KW)</th>
<th>3.7</th>
<th>7.5</th>
<th>18.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTUAL LOAD (KW)</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
</tr>
<tr>
<td>PERCENTAGE LOAD (%)</td>
<td>100</td>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>EFFICIENCY (%)</td>
<td>83</td>
<td>83</td>
<td>77</td>
</tr>
<tr>
<td>POWER FACTOR</td>
<td>0.8</td>
<td>0.65</td>
<td>0.50</td>
</tr>
<tr>
<td>INPUT POWER (KW)</td>
<td>4.46</td>
<td>4.46</td>
<td>4.81</td>
</tr>
<tr>
<td>ABSOLUTE POWER (KVA)</td>
<td>5.573</td>
<td>6.858</td>
<td>9.61</td>
</tr>
</tbody>
</table>

A 15KW MOTOR USED IN PLACE OF A 7.5 KW MOTOR USES 3000 KWH MORE FOR 5000 HRS. OF OPERATION IN A YEAR
Best Practice #2
Always Keep and Maintain Simple Gadgets & Tools
Simple gadgets and tools are very helpful for performance monitoring and maintenance activities.

- Keep and maintain simple gadgets and tools at proper places
- Calibrate measuring instruments once in two years

Stroboscope to measure motor speed (Non-contact type)
Tachometer to measure motor speed (Contact type)

Clamp-on meter to measure current
Multimeter to measure multiple parameters
Infrared Pointer to measure surface temperature
Megger to measure earth resistance
**Best Practice # 3**

**Know the Name Plate Details of the Motor**

Important information are given on the name plate of the motor. It is good to know and understand those information.

- Ensure that there is a name plate on the motor
- The nameplate should be clean and clearly readable
- National Electric Manufacturers Association (NEMA) specifies that every motor must show:
  - Manufacturer Type
  - Rated Volts & Full Load Amps
  - Rated Frequency
  - No. of Phases
  - Rated Full Load Speed
  - Class of Insulation
  - Rated HP
  - Time Rating
  - Service Factor
  - Efficiency at Full Load
  - Power Factor at Full Load
  - Frame Size
  - Design Code
  - Class of Protection

- Important Information to Note
  - Rated Volts & Full Load Amps
  - Rated Full Load Speed
  - Class of Insulation
  - Rated HP
  - Efficiency at Full Load
  - Power Factor at Full Load
Best Practice # 4
Know Some Basics When Observing the Motor Name Plate
While observing the name plate, it is good to relate some basic fundamentals.

### Information from Speed

<table>
<thead>
<tr>
<th>Typical Speed (RPM)</th>
<th>No. of Poles</th>
</tr>
</thead>
<tbody>
<tr>
<td>920 to 960</td>
<td>6</td>
</tr>
<tr>
<td>1440 to 1480</td>
<td>4</td>
</tr>
<tr>
<td>2800 to 2950</td>
<td>2</td>
</tr>
</tbody>
</table>

### Information from HP or KW

- 1 HP = 0.75 KW
- 1 KW = 1.33 HP

### Information from Class of Insulation

<table>
<thead>
<tr>
<th>Insulation Class</th>
<th>Allowable Winding Temp (Deg C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>135</td>
</tr>
<tr>
<td>F</td>
<td>150</td>
</tr>
<tr>
<td>H</td>
<td>165</td>
</tr>
</tbody>
</table>

### Few Points to Remember

- Every 10 degree centigrade rise in winding temperature degrades the motor life by half.
- The starting current of motors rises by about 6 times of the full load current when switched on directly (popularly called as Direct-Online Starting)
- It is better to reduce the speed through gear or pulley from a higher speed motor than to use a lower speed motor.
Best Practice # 5
Lubricate the Bearing Properly
Using proper type of lubricant, with the right quantity and frequency is critical for optimum motor performance

▲ RIGHT LUBRICANT
For ball and cylindrical roller bearing: Upto 50 mm bore
When \( D \times N < 300,000 \) Use Grease
> 300,000 Use Oil
Where,
\( D \) is the shaft diameter in mm
\( N \) is the rated full load speed of the motor in RPM

▲ LUBRICATION STORAGE
▲ Storage area of lubricants should be clean to prevent ingress of dirt and moisture
▲ Grease drums should be kept in up-right position and should be covered.
▲ Ideally a grease gun should be used. Application of grease directly by hands should be avoided.

▲ REPLINESHMENT AMOUNT OF GREASE
Quantity to be replenished = 0.005 \( \times D \times B \) grams
Where \( D \) is shaft diameter in mm
\( B \) is width of bearing housing in mm

Points to Remember:
▲ Improper lubrication practice can cause bearing failure.
▲ Too much lubrication results in churning and higher heat loss.
▲ In-sufficient lubrication can increase the component failure due to excessive friction and heat.
Best Practice # 6
Maintain Bearing Surface Temperature Within Limits
Increase in bearing surface temperature may lead to premature failure of the electric motor

- Why does the bearing temperature Increases
  - Poor Lubrication: Under lubrication or Over Lubrication
  - Improper Fitting: Too tightly fit or misaligned or mechanical looseness
  - Damaged bearing: Damaged inner-race or balls

- On-Line Temperature Monitoring Techniques
  - Thermal tapes: Thermal tapes can be put on the bearing housing to know its temperature in running condition.
  - Infrared Sensor: An infrared temperature gun can be used to measure the bearing temperature.
  - Thermal Imaging: Thermal camera can also be deployed to know the temperature of bearing surface during motor operation.

- Temperature Limit on bearing Housing
  - The following thumb rule may be used to know the bearing housing temperature

<table>
<thead>
<tr>
<th>Shaft Diameter (in mm)</th>
<th>Speed (RPM)</th>
<th>DT in Deg C (Above Ambient)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upto 50 mm</td>
<td>Upto 1500</td>
<td>Ambient</td>
</tr>
<tr>
<td>50</td>
<td>2950</td>
<td>23</td>
</tr>
<tr>
<td>65</td>
<td>990</td>
<td>Ambient</td>
</tr>
<tr>
<td>1440</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>2950</td>
<td>35</td>
<td></td>
</tr>
</tbody>
</table>

\[ DT = \frac{D \times N}{2000} \text{ Deg F} \]

Where,

- D is the shaft diameter in mm;
- N is the speed in RPM
- DT is the resulting temperature above ambient in Deg F
Best Practice # 7
Provide Balanced Voltage to the Motor
Balanced/equal absolute voltage in all 3 phases increases motor performance

Few Points to Remember

- Motor operation beyond voltage variation of 5% is not recommended
- Even a small voltage unbalance gives rise to much greater current unbalance, resulting in temperature rise and failure of the motor.
- Motor operation at high voltage unbalance also results in derating the motor capacity.
- Phase to phase voltage to be checked at MCC terminals, motor junction box terminals periodically, once in every 6 months to ensure voltage unbalance within limits.
- Hand held devices such as voltage probes or crocodile clips in a multimeter can be used for measuring the magnitude of voltage unbalance. The digital voltmeter, if any on the MCC panel can also be used for this purpose.
- Poor quality of electrical connections like loose/corrosive contacts, improper lugs and broken cable strands in a particular phase also give rise to voltage unbalance.

Calculation of Voltage Unbalance

\[ \% \text{ Voltage Unbalance} = \frac{V_{\text{max}} - V_{\text{avg}}}{V_{\text{avg}}} \times 100 \]

Where,

- \( V_{\text{max}} \) is the maximum of the voltages in 3 phases
- \( V_{\text{avg}} \) is the average voltage in 3 phases

Field Observations During Energy Audit Studies

<table>
<thead>
<tr>
<th></th>
<th>RY (volt)</th>
<th>YB (volt)</th>
<th>BR (volt)</th>
<th>Unbalance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case1</td>
<td>380</td>
<td>390</td>
<td>418</td>
<td>5.56</td>
</tr>
<tr>
<td>Case2</td>
<td>375</td>
<td>409</td>
<td>380</td>
<td>5.41</td>
</tr>
<tr>
<td>Case3</td>
<td>411</td>
<td>380</td>
<td>395</td>
<td>3.96</td>
</tr>
</tbody>
</table>

Case Study of Relation Between Voltage and Current Unbalance in a 20 HP 3 phase induction motor for pump application

<table>
<thead>
<tr>
<th></th>
<th>% VOLTAGE UNBALANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.30</td>
</tr>
<tr>
<td>UNBALANCE IN CURRENT (%)</td>
<td>0.4</td>
</tr>
<tr>
<td>INCREASED TEMP. RISE (DEG. C)</td>
<td>0</td>
</tr>
</tbody>
</table>

Impact of Voltage Unbalance on Motor Capacity as per NEMA Specifications
Best Practice # 8

Install Capacitor Bank Near to the Drive

Improves power factor of the motor resulting in lesser current drawn and reduced cable losses

Key Points to Remember:

- Power factor of a motor at full load varies between 0.85 to 0.9
- Motor operation at part load, may reduce the power factor to even less than 0.5 which is not desirable at all.
- Motor operation at poor power factor results in draw of more current, higher kVA demand (higher energy bill in case of a two-part tariff system), higher cable losses and lesser voltage at motor terminal.
- Power factor correction is important to overcome these drawbacks through installation of capacitor banks. However, the sizing and location of these capacitor banks are critical for optimum operation.
- Power factor correction at the main incomming, only leads to some monetary saving, however does not impact in energy consumption.
- Capacitor banks installed at the motor end not only lead to loss reduction, but reduced KVA demand as well.
- Capacitor size should never be higher than the no load magnetizing current of the motor
- Capacitors consumer 0.2 to 0.6 W per KVAR, much less as compared to it’s potential benefits.
- Capacitors used for single phase motor starting, lighting circuits for voltage boost, don’t result in power factor correction.

Different Cases of Capacitor Installation
C1A- New Installation of LT Motor + Capacitor
C1B - Retro-fit Cases Wherein Capacitor Bank needs to be added to an existing motor
C1C – No separate switching is required as capacitor can be disconnected by the breaker before the stator
Best Practice # 9

Use Online Temperature Monitoring techniques to Observe Condition of Electrical Contacts

Loose/Corrosive contacts leads to rise in voltage and current unbalance, increase in operating temperature and failure of motor

- Loose/ corrosive contacts should be identified and attended to prevent any mishap/failure.
- Visual inspection may not reveal the problem at all.
- Temperature monitoring by using non contact type infrared cameras should be conducted to ascertain the quality of electrical connections, at least once in a year. More number of inspections will enhance the reliability.

**Criticality Criteria to Judge the Condition of Electrical Joints**

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Criteria (Differential Temperature Above Ambient)</th>
<th>Criticality Condition</th>
<th>Recommended Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Up to 10 deg C</td>
<td>Non-Critical</td>
<td>No action is needed</td>
</tr>
<tr>
<td>2.</td>
<td>Between 10 to 20 deg C</td>
<td>Less Critical</td>
<td>Regular Monitoring is needed</td>
</tr>
<tr>
<td>4.</td>
<td>Above 40 deg C</td>
<td>Critical</td>
<td>Should be attended immediately as per the severity.</td>
</tr>
</tbody>
</table>

**Visual Image – No Problem Detected**

**Image from Thermal Camera Indicating High Temperature in a Phase**

**Hot Spot Observed in a Particular Phase of MCC**

88 deg C
Best Practice # 10

Keep Maintenance Tools & Tackles at Proper Places
Designated places should be provided for all tools and tackles: A Place for Everything and Everything at its Place

- Properly arranged worktable, maintenance tools and gadgets helps in saving time during a repair/maintenance activity.
- Enhances safety during maintenance and prevents accidents.
Best Practice # 11
Use Personal Protective Equipments
Ensures safety of personnel during operation/maintenance

Mandatory Use

- Rubber gloves to be used for electrical works.
- Safety shoes to be worn to protect from chemicals, sharp particles, electrical wires etc.

Preferable Use

- Ear plugs should be worn when working in high noise area.
- Helmet to be used for general safety in an industry.
Best Practice # 12
Always maintain good condition of MCC panels
Ensures safety of operation

Connections without lugs
Outer insulation damaged in live electrical wires

Un safe method of drawing connections from joints without using proper lugs

Properly Maintained MCC Panel – Ideal Case

Display not Working – Whether the Panel is on current or off-line not possible to identify

Key Points to Focus –
- Indicators on the MCC panel should always be in operating condition.
- Connections should be made with proper lugs.
- Panel doors should always be kept in closed condition.
- Ensure proper ventilation around MCC panel.
Best Practice # 13
Maintain History Card of Motor Stoppage
Ensures proper record keeping of motor failure incidents for easy diagnosis of fault

**Important information to document**
- Type of problem/failure (whether mechanical or electrical)
- Downtime/stoppage duration
- Whether problem solved internally
- Major action takes (Preventive Maintenance, Replacement of Motor or motor parts, Rewound)

**Sample History Card of Motor Stoppage**

<table>
<thead>
<tr>
<th>Motor Id</th>
<th>Location</th>
<th>Motor Rating</th>
<th>Date</th>
<th>Observation</th>
<th>Type of Failure</th>
<th>Action Taken</th>
<th>Stoppage Time</th>
<th>Comments/ Additional Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>dd/mm/yyyy</td>
<td>Bearing Seizure</td>
<td>Mechanical</td>
<td>Bearing Replaced</td>
<td>4 hours</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>dd/mm/yyyy</td>
<td>Single-phasing</td>
<td>Electrical</td>
<td>MCC junction repaired</td>
<td>2 hours</td>
<td>Burn out of Y-phase contact</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>dd/mm/yyyy</td>
<td>Winding burn out</td>
<td>Electrical</td>
<td>Rewound</td>
<td>72 hours</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>dd/mm/yyyy</td>
<td>High Vibration</td>
<td>Mechanical</td>
<td>Loose foundation bolt tightened</td>
<td>15 mins</td>
<td></td>
</tr>
</tbody>
</table>
### Best Practice # 14

**Keep, Maintain and Practice Maintenance Schedule of Motors**

Proper Maintenance Schedule for motors is important to ensure reliability of operations and prevention of failure.

#### Maintenance Schedule of the motor should be developed from

- OEM specification or Experience of maintenance team, if OEM specification is not available

<table>
<thead>
<tr>
<th>Activity</th>
<th>What to Measure/Observed</th>
<th>How to Measure / Perform</th>
<th>By Whom</th>
<th>Frequency of Measurement</th>
</tr>
</thead>
</table>
| Visual Inspection of the Motor                | - Abnormal Noise  
- Unusual Smell  
- General Cleanliness | • Human sensor such as  
touch, ear, nose, eye | Shift operator | Every Shift             |
| General Cleaning                              | • Dirt, dust, unwanted material and improper ventilation     | • Using clean cloths, brushes and tiny blowers               | Maintenance Team | Daily                   |
| Check lubrication                             | • Grease quantity and colour in the cavity  
• Oil level indicator | • Visual observation                                      | Shift Operator | Every Shift             |
|                                               | • Bearing House Temperature                                 | • Infrared Gun                                               | Maintenance Team | Once in a week          |
| Check Power Supply Quality                    | • Phase to phase voltage and phase current                  | • Observation of voltmeter and ammeters in MCC Panel  
• Direct measurement at MCC and Motor junction boxes | Maintenance Team | Daily                   |
| Check Proper functioning of MCC panel display meters | • Glow of indicator lamps  
• Working condition of all meters | • Visual observation through selector switch | Maintenance team | Daily                   |
## Best Practice # 15

**Adopt Predictive Maintenance Techniques**  
On-line predictive maintenance techniques will improve reliability of motor system

<table>
<thead>
<tr>
<th>Technique</th>
<th>Instrument Used</th>
<th>Measurable Parameter</th>
<th>What is Diagnosed</th>
<th>Frequency of Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration Monitoring</td>
<td>Vibro Meter</td>
<td>Vibration at bearing houses</td>
<td>Compares with the acceptable vibration limit to identify if a problem exists</td>
<td>Once in 3 months</td>
</tr>
<tr>
<td>Vibration Analysis</td>
<td>Vibration Analyser</td>
<td>Frequency modulation of Vibration Amplitude</td>
<td>Identifies the root cause of the problem such as unbalance, mis-alignment, bad bearing etc.</td>
<td>Once in 6 months</td>
</tr>
<tr>
<td>Infrared Thermography</td>
<td>Thermal Imaging Camera</td>
<td>Temperature</td>
<td>Identifies temperature levels of electrical joints and connections, motor body surface and bearing housing, cable joints</td>
<td>Once in 12 months</td>
</tr>
<tr>
<td>Shock Pulse Monitoring</td>
<td>Shock Pulse Meter</td>
<td>Amplitude of shock generated at bearing housing</td>
<td>Bad or damaged bearing, inner or outer race damage</td>
<td>Once in 6 months</td>
</tr>
<tr>
<td>Motor Current Signature</td>
<td>MCSA Analyser</td>
<td>Stator current and voltage</td>
<td>Insulation degradation, rotor bar cracks, problem in end ring joints in rotor, eccentricity</td>
<td>Once in 12 months</td>
</tr>
</tbody>
</table>

Such techniques can be adopted without motor stoppage. Service providers give this service at reasonable cost.
Best Practice # 16

Adopt Best Practices in Rewinding

Best rewinding practices ensures efficiency level of motor close to its original value

---

**Step 1 : Preparation of Work table**
A clean work surface is important to ensure it’s free from dust and dirt.

**Step 2 : Remove Motor Housing to reveal armature, stator and windings**
Deployment of excessive force should be avoided while dismantling the motor housing as these may damage the insulation.

**Step 3 : Document present configuration and important parameters**
Important to document the important parameters such as rated current, capacity, type of winding to prevent deviation from design parameters post rewinding.
Best Practice # 16
Adopt Best Practices in Rewinding (Contd..)
Best rewinding practices ensures efficiency level of motor close to its original value

Step 4 : Removing Wire From Brush Tabs
Care should be taken to bend the tabs gently (and as little as possible) to prevent any damage. Also, the wires should be completely removed from the tabs before cutting the coils of the wind.

Step 5 : Cutting the coils
The easiest place to cut is at the top of the coils (top of armature and/or stator posts). The number of winds in each coil should be exactly counted to ensure replication.

Step 6 : Check for insulation damage
If the insulation lining the steel laminate areas is in good condition it should be put back. In case if it's damaged or burned it should be replaced with similar material as specified by the OEM.
Best Practice # 16

 Adopt Best Practices in Rewinding (Contd...)
Best rewinding practices ensures efficiency level of motor close to its original value

Step 7: Rewound the Motor
Rewind the armature using the same gauge and type of wire as it was as per the original design.

Step 8: Check for Wires
It should be ensured that none of the wires connecting to the tabs are touching.

Step 9: Re-assemble the motor housing
Post re-assembly the motor should be run for one to two hours in the rewinding facility to ensure safe operation before being dispatched.
Best Practice # 16

Adopt Best Practices in Rewinding (Contd...)

Best rewinding practices ensure efficiency level of motor close to its original value

Few Points to Remember

- Don’t go for rewinding again and again for the same motor: Efficiency typically decreases for every rewinding unless special care is taken during rewinding practice.
- Get the rewinding done through skilled persons.
- Make sure the work table is clean and free from dust, dirt, oil and any unwanted particles.
- While dismantling the winding from slots, care should be taken to prevent use of excessive force as this may damage the core. It is better to apply heat for easy removal of windings. This heating should be controlled and it should be ensured that the core is not exposed to excessive temperatures beyond specified by OEM.
- Important parameters such as rated power, current, type of winding design, number of turns, wire gauge etc should be documented carefully to ensure replication of past performance parameters post rewinding.
- Use wire of same gauge and material. Don’t use aluminum wire in place of copper wire.
- While removing wire from the brush tabs, care should be taken to bend the tabs gently and as little as possible to prevent any damage. Wires should be completely removed from the tabs before cutting the coils.
- Damaged insulation should be replaced with the same type and insulation rating as specified by the OEM.
- The winding design should be replicated with the exact number of turns and the same wire gauge and quality of wire. Any deviation may result in derating the capacity of the motor.
- The user should insist for efficiency test post rewinding.
Prepared By

WB-GEF Cell

Bureau of Energy Efficiency
Ministry of Power, Govt. of India
4th Floor, Sewa Bhawan, R.K.Puram
New Delhi – 110066
www.bee-india.nic.in