Energy Audit Methodology
of
Electrical Systems

Programme on
Energy Conservation in Foundry Industry

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The Energy and Resources Institute
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## Contents

- Energy monitoring and auditing
- Introduction to electrical systems
- Electricity billing
- Power factor improvement
- Maximum demand control
- Electric motors
- Air compressors
- Pumps
- Lighting system
- Instruments for energy audit
Energy monitoring and auditing

Measure

Data

Result

Action

Analyze

Information
Energy monitoring and auditing

**Energy management (EM)**
- Judicious & effective use of energy to maximise profit
- Strategy of adjustment & optimising energy usage

**Energy audit (EA)**
- Systematic approach for decision making for EM
- Quantifies energy usage at user divisions
Need for energy audit

Three major expenses consist of energy, labour and material

The energy cost reduction

Identify energy conservation technologies and retrofits

It translates conservation ideas into realities
Classification of energy audit

Preliminary audit

- Establish energy consumption
- Estimate specific energy consumption of plant
- Identify in-depth study areas

Detailed audit

- Data collection
- Measurement and trials
- Post audit analysis
- Identification of Energy Conservation Measures (ECMs)
- Techno-economic evaluation of ECMS
- Implementation of selected ECMs
## Instruments used for detailed audit

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Application</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power analyser</td>
<td>Electrical Parameters, Harmonics analysis</td>
<td>Induction furnace, Air Compressor, Pumps, Motors, Lighting, Other electrical equipment</td>
</tr>
<tr>
<td>Ultrasonic flow meter</td>
<td>Water Velocity, Volume</td>
<td>Pumping system</td>
</tr>
<tr>
<td>Flue gas analyser</td>
<td>Flue gas O$_2$, CO, CO$_2$ and Temperature</td>
<td>Heat treatment furnace, Diesel fired melting furnace, Cupola</td>
</tr>
<tr>
<td>Hygrometer</td>
<td>Ambient Temperature &amp; RH</td>
<td></td>
</tr>
<tr>
<td>Digital temperature indicator</td>
<td>Temperature</td>
<td></td>
</tr>
<tr>
<td>Thermal imager</td>
<td>Surface temperature and image</td>
<td>Core shooter, Furnace temperature, Heat treatment</td>
</tr>
<tr>
<td>Lux meter</td>
<td>Lumen level</td>
<td>Below lighting fixture</td>
</tr>
<tr>
<td>Infrared thermometer</td>
<td>Surface temperature</td>
<td>Walls of furnace and heat treatment</td>
</tr>
<tr>
<td>Anemometer</td>
<td>Air velocity</td>
<td>Air compressor</td>
</tr>
<tr>
<td>Thermocouple</td>
<td>High temperature</td>
<td>Furnace</td>
</tr>
</tbody>
</table>
Introduction to electrical systems

Electrical systems
- Electricity Billing
- Maximum demand Control
- Power Factor Improvement

Equipment
- Electric motors
- Air compressors
- Lighting systems
## Electricity billing

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract demand</td>
<td>(kVA)</td>
</tr>
<tr>
<td>Recorded demand</td>
<td>(kVA)</td>
</tr>
<tr>
<td>Billed demand</td>
<td>(kVA)</td>
</tr>
<tr>
<td>Billed power factor</td>
<td>(pf)</td>
</tr>
<tr>
<td>Electrical units consumption</td>
<td>(kWh)</td>
</tr>
<tr>
<td>Time of day details</td>
<td>(TOD)</td>
</tr>
<tr>
<td>Rebate / Penalty</td>
<td>(+/-)</td>
</tr>
<tr>
<td>Fuel escalation charge</td>
<td>(Rs or %)</td>
</tr>
<tr>
<td>Electricity duty, tax, surcharge</td>
<td>(%)</td>
</tr>
<tr>
<td>Total monthly amount</td>
<td>(Rs./month)</td>
</tr>
<tr>
<td>CD= 580 kVA</td>
<td>BD= 451 kVA Previous hughest</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------</td>
</tr>
</tbody>
</table>

**Electricity consumption**

<table>
<thead>
<tr>
<th>Date</th>
<th>Current KWH</th>
<th>KVAH</th>
<th>RKVAH (LAG)</th>
<th>Amount in Rs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-04-2014</td>
<td>246598.00</td>
<td>247352.00</td>
<td>4042.00</td>
<td>443.690</td>
</tr>
<tr>
<td>09-05-2014</td>
<td>159310.00</td>
<td>159350.00</td>
<td>200.00</td>
<td>444.000</td>
</tr>
<tr>
<td>Billed Demand (KVA)</td>
<td>444 kVA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>--------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessed P.F. / Avg. P.F.</td>
<td>1.000 / L.F.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Billed P.F.</td>
<td>1.000 / L.F.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Billed pf 1.0 |

| TOD |

| pf penal/incentive |

| Last six months |

| Electricity charge |

| Bill amount |

| TOD Tariff EC | 90,131.00 |
| FAC @ Ps/U | 5,352.82 |
| Electricity Duty | 90,721.27 |
| Other Charges | 0.00 |
| Tax on Sale @ Ps/U | 12,744.80 |
| P.F. Penal Charges / P.F. Incentive | -70,560.99 |
| Charges For Excess Demand | 0.00 |

| TOTAL CURRENT BILL | 10,40,919.20 |
| Current Interest | 0.00 |
| Principle Arrears | -1,32,926.65 |
| Interest Arrears | 0.00 |
| Total Bill Amount (Rounded) Rs. | 9,08,290.00 |
| Delayed Payment Charges Rs. | 20,818.38 |

| Security Deposit Held Rs. | 16,38,000.00 |
| Addl. S.D. Demanded Rs. | 0.00 |
| S. D. Arrears Rs. | 0.00 |

<table>
<thead>
<tr>
<th>BILL MONTH</th>
<th>MAR-14</th>
<th>FEB-14</th>
<th>JAN-14</th>
<th>DEC-13</th>
<th>NOV-13</th>
<th>OCT-13</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNITS</td>
<td>1,67,330</td>
<td>2,63,650</td>
<td>1,85,280</td>
<td>1,13,220</td>
<td>1,22,630</td>
<td>1,39,970</td>
</tr>
<tr>
<td>BILL AMOUNT</td>
<td>10,68,994</td>
<td>17,18,034</td>
<td>14,69,423</td>
<td>9,74,829</td>
<td>10,10,729</td>
<td>12,79,361</td>
</tr>
</tbody>
</table>
The monthly MD will be the highest among the demand values recorded every half hour over the month.

The industry has to pay for the highest MD registered even if it occurred for just one recording cycle duration.

Figure 1.4 Demand Curve

Demand Curve
As example, in an industry, if the drawl over a recording cycle of 30 minutes is:
3500 kVA for 4 minutes;
4600 kVA for 12 minutes;
3100 kVA for 6 minutes;
3800 kVA for 8 minutes;

The MD recorder will be computing MD as:
\[
\frac{(3500 \times 4) + (4600 \times 12) + (3100 \times 6) + (3800 \times 8)}{30}
\]

= 3940 kVA (average is only 3750)
Maximum demand

![Graph showing maximum demand over time with categories for Contract demand (kVA), Billed demand (kVA), and Electricity Consumption (kWh).]
Methods of MD control

Manual type

Load scheduling

Demand monitoring activity

Even alarm can be set-up

Automatic demand controllers
- Large plant
- Load characteristics

Energy Management system
- Acts as per demand + programmable
- Monitoring Capability
What causes Low Power Factor?

Low power factors would occur when kVA is large.

What causes a large kVA in a system? The answer is…

“INDUCTIVE LOADS”.

Inductive loads include:

– Transformers, Induction motors
– Induction generators (wind mill generators)
– High intensity discharge (HID) lighting

These inductive loads constitute a major portion of the power consumed in industrial complexes.
Power factor improvement

1. Reactive component of the network is reduced and so also the total current in the system from the source end.

2. $I^2R$ power losses are reduced in the system because of reduction in current.

$$\% \text{ power loss reduction} = 100 \times \{1 - (\text{PF old}/\text{PF New})^2\}$$

3. Voltage level at the load end is increased.

$$\% \text{ voltage rise} = \frac{\text{kVAR of capacitor} \times \% \text{ imp. of transformer}}{\text{kVA of transformer}}$$
Location of capacitor

It could be

- At HT bus / transformer
- LT bus of transformer
- Main sub-plant buses
- Load points

Hence

- Identify the sources of low pf loads in plant
- Locate close to end equipment to reduce $I^2R$ loss
- Release of system capacity (kVA) happens if reactive current is reduced.
Location of capacitor

Incoming supply

Utilisation or distribution bus

$C_3$

$C_1$

$C_4$

$C_2$
## Losses in Electrical Distribution Equipment

<table>
<thead>
<tr>
<th>S.No</th>
<th>Equipment</th>
<th>% Energy Loss at Full Load Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
</tr>
<tr>
<td>1.</td>
<td>Outdoor circuit breaker (15 to 230 KV)</td>
<td>0.002</td>
</tr>
<tr>
<td>2.</td>
<td>Generators</td>
<td>0.019</td>
</tr>
<tr>
<td>3.</td>
<td>Medium voltage switchgears (5 - 15 KV)</td>
<td>0.005</td>
</tr>
<tr>
<td>4.</td>
<td>Current limiting reactors</td>
<td>0.09</td>
</tr>
<tr>
<td>5.</td>
<td>Transformers</td>
<td>0.40</td>
</tr>
<tr>
<td>6.</td>
<td>Load break switches</td>
<td>0.003</td>
</tr>
<tr>
<td>7.</td>
<td>Medium voltage starters</td>
<td>0.02</td>
</tr>
<tr>
<td>8.</td>
<td>Bus ways less than 430 V</td>
<td>0.05</td>
</tr>
<tr>
<td>9.</td>
<td>Low voltage switchgear</td>
<td>0.13</td>
</tr>
<tr>
<td>10.</td>
<td>Motor control centers</td>
<td>0.01</td>
</tr>
<tr>
<td>11.</td>
<td>Cables</td>
<td>1.00</td>
</tr>
<tr>
<td>12.</td>
<td>Large rectifiers</td>
<td>3.0</td>
</tr>
<tr>
<td>13.</td>
<td>Static variable speed drives</td>
<td>6.0</td>
</tr>
<tr>
<td>14.</td>
<td>Capacitors (Watts / kVAR)</td>
<td>0.50</td>
</tr>
</tbody>
</table>
Location of capacitor

It could be

- At HT bus / transformer
- LT bus of transformer
- Main sub-plant buses
- Load points

Hence

- Identify the sources of low pf loads in plant
- Locate close to end equipment to reduce $I^2R$ loss
- Release of system capacity (kVA) happens if reactive current is reduced.
MSME Foundry

- Induction furnace, 77.7%
- Cooling water circuit, 3.2%
- Air compressor, 6.3%
- Sand plant and finishing, 9.9%
- Lighting, 1.1%
- Misc, 1.7%
Pump and pumping system

Power consumption (kW)
- Usually lower than rated power
- Near to or higher than rated if re-winded

Flow rate (cu.m/hour)
- Most cases it was lower than design, few cases < 60% of design flow rate

Head (m)
- Most cases pressure gauges found not functioning

Optimizing piping design
- Water velocity ~ 1.8 – 2.0 m/s
Performance evaluation

Tank fill method

Empty receiver

Stop all usage of air, close receiver output valve

Start compressor, monitor time taken to fill the tank, in seconds

FAD (m3/min) = (Tank volume + Pipe volume)/ Time taken in minutes

Leakage test

No load i.e. no usage of compressed air

Switch on compressor

Say setting is 6.0 bar to 7.0 bar

Ton is time taken to compress air from 6.0 to 7.0 bar

Toff is time taken for pressure to drop back to 6.0 bar

Leakage % = \frac{\text{Ton}}{(\text{Ton} + \text{Toff})} \times 100
Air compressor

Air leakages
- Leakage of compressed air: 10 – 50 %
- Energy Saving Potential: 5 – 35 %

Variable Frequency Drive
- Loading of air compressor: 30 – 80 %
- Energy Saving up to 35 % possible

Optimum pressure setting
- One bar reduction
- Energy Saving 6 – 10 %

For example
- 300 cfm installed, generated FAD 264 cfm, leakages 23 %
- 60 cfm wasted
- Reducing leakages to 5 % = 14.0 % of electricity consumption by compressor
- Investment: 1.0 lakh INR
- Saving potential: 3.2 lakh INR
- Simple Payback: 4.0 months
Air compressor

Variable Frequency Drive

Without VFD

With VFD
Electric motors

**Power consumption (kW)**
- Usually lower than rated power
- Near to or higher than rated if rewinded

**Loading (%)**
- Once motor fails, it is replace by same/higher hp motor
- Leads to under loading

**Maintenance of motor**
- Keeping it dust free
- Periodic lubrication, gear-box alignment

**For example**
- Shot blast turbine motor
- Name plate efficiency = 84%
- Operating efficiency = 66%
- Replace it with higher efficiency motor
- Saving potential: 24%
- Investment : 0.26 lakh INR
- Saving potential: 0.54 lakh INR
- Simple Payback: 5.8 months
## Lighting

### Power consumption (W)

### Lux level (lm/m²)

### Luminous efficacy (lm/W)

### For example:
- T12 FTL to T5 FTL
  - Saving potential 22W/fixture
  - Higher luminous efficacy
- MVL to Metal Halide
  - Saving potential 100 – 200W/fixture
  - Higher luminous efficacy

### For Example

- **Existing lighting fixtures**
  - 15 T12 FTL of 40W
  - 12 MVL of 250W
- **Proposed lighting fixtures**
  - 15 T5 FTL of 28W
  - 12 MH of 150W
- **Investment**: 0.61 lakh INR
- **Saving potential**: 0.58 lakh INR
- **Simple Payback**: 3.2 months
Lighting

- Liminous Efficacy (lm/W)
- Life (hrs)

<table>
<thead>
<tr>
<th></th>
<th>T12</th>
<th>T5</th>
<th>MVL</th>
<th>MH</th>
</tr>
</thead>
<tbody>
<tr>
<td>20000</td>
<td>5000</td>
<td>5000</td>
<td>6000</td>
<td>20000</td>
</tr>
</tbody>
</table>
Be the change you want to see in the world