TRAINING PACKAGES DEVELOPMENT

PACKAGE II: ELECTRICAL

Presenter: Dr Evan Murimi Wanjiru, PhD, CEM.
Presentation structure

- Target group
- Objectives
- Expected impact
- Sources of electrical energy
- Electricity consumption
- Components of utility bill
- Modules - 8 of them

"The age we live in is a busy age; in which knowledge is rapidly advancing to perfection."

- Jeremy Bentham
Target group

• Factory electricians

They deal with day-to-day running of factories.
They manage electrical equipment.
Objectives

Main objective
Train, equip and sensitize factory electricians with thorough information on electrical energy saving opportunities and related cost in a tea factory.

Specific objectives
- Provide thorough understanding of the tariff structure with its components
- Enlighten on various electrical energy consumers in a factory and their impact on cost.
- Quantify the impact of efficient operation of electrical equipment
- Sensitize the electricians on importance of proper maintenance.
Expected impact

At the end of the training, the electricians shall;

• Understand the **billing structure** and identify ways of saving cost.

• Be equipped with knowledge on **tracking and analyzing energy consumption** within the factory.

• Understand **efficient operation** of various electrical equipment in a factory.

• Ensure **proper maintenance** is carried out.

• Identify various **energy saving opportunities** in a factory and estimate energy and cost savings.

• Identify **measures** to take to stop energy wastage.
Modules

1. Power factor
2. Maximum kVA demand
3. Generator operation
4. Voltage balance
5. Lighting
6. Motors and fans
7. Energy monitoring & sub-metering
8. Maintenance
Sources of electrical energy

Most tea factories rely on
• Grid from Kenya power
• Hybrid (grid+hydro)
• Diesel generators as back up

• Oil generates just below coal.
• Most expensive to use
• Hydroelectric & wind emit the least
Electricity consumption

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Average Annual Units Consumed</th>
<th>Percent</th>
<th>Average Annual Cost</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>2,029,020 kWh</td>
<td>8%</td>
<td>23,841,171 kWh</td>
<td>58%</td>
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<tr>
<td>Thermal</td>
<td>22,917,592 kWh</td>
<td>92%</td>
<td>17,302,288 kWh</td>
<td>42%</td>
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<tr>
<td>Total</td>
<td>24,946,611 kWh</td>
<td>100%</td>
<td>41,143,459 kWh</td>
<td>100%</td>
</tr>
</tbody>
</table>

Electric energy accounts for less than **10%** total plant energy but accounts for **58%** of total plant energy cost.
Sectional consumption

Withering, CTC and Driers accounts for appr. 77-82% of total plant power demand/energy consumption

Several motors and fans

Highest energy saving potential
Components of previous utility bill-CI1 at 415V

- Fixed charge at **KSh 2500/period**
- Energy Consumption kWh (TOU)
  - peak @ **KSh 9.2/kWh**
  - Off-peak @ **KSh 4.6/kWh**
- Maximum demand kW (*Actual maximum consumed real power*)
- Power Factor kW/kVA (*Surcharge if below 0.9*)
- Maximum demand kVA (*maximum supplied power*) at **KSh 800/kVA**
- Other levies (WARMA, ERC, REP, FCC, FA, IA) and VAT

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*Must be at 100% production e.g. high crop season. Extra production can be shifted to off-peak*
Components of current utility bill-CI1 at 415V effective from 1st July 2018

- Fixed charge at KSh 0/period

- Energy Consumption kWh (TOU)
  - peak @ KSh 12/kWh
  - Off-peak @ KSh 6/kWh

- Maximum demand kW (Actual maximum consumed real power)

- Power Factor kW/kVA (Surcharge if below 0.9)

- Maximum demand kVA (maximum supplied power) at KSh 800/kVA

- Other levies (WARMA, ERC, REP, FCC, FA, IA) and VAT
Other tariffs:

<table>
<thead>
<tr>
<th>Code</th>
<th>Customer Type (Code Name)</th>
<th>Energy Limit kWh/month</th>
<th>Charge Method</th>
<th>Unit</th>
<th>2015/16 to date Approved</th>
<th>2018/19 KPLC Application</th>
<th>2018/19 ERC Approved</th>
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<tbody>
<tr>
<td>DC</td>
<td>Domestic</td>
<td>0-10</td>
<td>Fixed</td>
<td>KShs/month</td>
<td>150</td>
<td>200</td>
<td>0</td>
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<td>11-50</td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>2.50</td>
<td>13.01</td>
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<td>51-1500</td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>12.75</td>
<td>18.90</td>
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<td></td>
<td>&gt;1500</td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>20.57</td>
<td>25.56</td>
<td>15.80</td>
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<td>SC</td>
<td>Small Commercial</td>
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<td>Fixed</td>
<td>KShs/month</td>
<td>150</td>
<td>300</td>
<td>0</td>
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<td></td>
<td></td>
<td></td>
<td>Energy</td>
<td>KShs/kWh</td>
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<td>19.85</td>
<td>15.60</td>
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<tr>
<td>CI1</td>
<td>Comm./industrial</td>
<td>&gt;15,000</td>
<td>Fixed</td>
<td>KShs/month</td>
<td>2,500</td>
<td>3,100</td>
<td>0</td>
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<td></td>
<td></td>
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<td>Energy</td>
<td>KShs/kWh</td>
<td>9.20</td>
<td>13.77</td>
<td>12.00</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Demand</td>
<td>KShs/kVA</td>
<td>800</td>
<td>1,000</td>
<td>800</td>
</tr>
<tr>
<td>CI2</td>
<td>Comm./industrial</td>
<td>No Limit</td>
<td>Fixed</td>
<td>KShs/month</td>
<td>4,500</td>
<td>5,600</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>8.00</td>
<td>11.77</td>
<td>10.90</td>
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<tr>
<td></td>
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<td></td>
<td>Demand</td>
<td>KShs/kVA</td>
<td>520</td>
<td>650</td>
<td>520</td>
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<td>CI3</td>
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<td>Fixed</td>
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<td></td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>7.50</td>
<td>10.93</td>
<td>10.50</td>
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<tr>
<td></td>
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<td>Demand</td>
<td>KShs/kVA</td>
<td>270</td>
<td>350</td>
<td>270</td>
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<tr>
<td>CI4</td>
<td>Comm./industrial</td>
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<td>Fixed</td>
<td>KShs/month</td>
<td>6,500</td>
<td>8,000</td>
<td>0</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>7.30</td>
<td>10.63</td>
<td>10.30</td>
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<td></td>
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<td></td>
<td>Demand</td>
<td>KShs/kVA</td>
<td>220</td>
<td>280</td>
<td>220</td>
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<tr>
<td>CI5</td>
<td>Comm./industrial</td>
<td>No Limit</td>
<td>Fixed</td>
<td>KShs/month</td>
<td>17,000</td>
<td>21,000</td>
<td>0</td>
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<td></td>
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<td>Energy</td>
<td>KShs/kWh</td>
<td>7.10</td>
<td>10.32</td>
<td>10.10</td>
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<tr>
<td></td>
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<td>Demand</td>
<td>KShs/kVA</td>
<td>220</td>
<td>280</td>
<td>220</td>
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<tr>
<td>SL</td>
<td>Street Lighting</td>
<td>No Limit</td>
<td>Fixed</td>
<td>KShs/month</td>
<td>200</td>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>4.36</td>
<td>15.91</td>
<td>7.50</td>
</tr>
</tbody>
</table>
How can you reduce your electricity bill?

• **Reduce consumption kWh**
  • Lower rated motor/appliance
  • Reduce operation hours/idle operation

• **Improve Power Factor**
  • Install PF correction/Daily check of PF control system
  • Motor capacity vs duty

• **Reduce kVA**
  • Load scheduling

• **Reduce losses**
  • Voltage balancing
  • Motor loading
Module 1: Maximum kVA demand

- **Demand** is the rate at which energy is delivered to an electrical load.
- It is expressed in either kW or kilovoltamperes (kVA).
- **Maximum (peak) demand** - maximum rate at which electric energy is drawn through the meter during a period of time.

- **For example:**

For a house with, 4.5 kW water heater, 3.0 kW lighting, 15.0 kW cooking, 1 kW iron box and 1.3 kW microwave. If they all operate at the same time, the peak demand =24.8 kW.
• Electricity consumed after generation.
• Utilities must meet **highest demand**

- kWh (A) = kWh (B) i.e. shaded area.
- Peak = 2x average demand
- Capacity (A) = 2x Capacity (B)
- Peak only for short time

- Peak = average demand
- Utility can meet this demand efficiently.
Demand charges

- Are utility's costs for meeting a customer’s higher demand
- Based on the maximum kVA demand recorded in any half hour of billing period.

- Company “A” demand is 80 kW for 50 hours. \( \text{Energy} = 80 \times 50 = 4000 \text{ kWh} \).

- Company “B” demand is 20 kW for 200 hours. \( \text{Energy} = 20 \times 200 = 4000 \text{ kWh} \).

- Both use same amount of energy during the billing period.
- Should they pay the same?
- Required system capacity; 80 kW for Company A, 20 kW for B.
Load shifting and scheduling

• With **TOU tariff**, scheduling to process tea in cheaper off-peak periods (night) could save money.

<table>
<thead>
<tr>
<th>Day</th>
<th>Off-peak hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekdays</td>
<td>22:00 to 00:00 and 00:00 to 06:00</td>
</tr>
<tr>
<td>Saturdays and public holidays</td>
<td>14:00 to 00:00 and 00:00 to 08:00</td>
</tr>
<tr>
<td>Sundays</td>
<td>All day</td>
</tr>
</tbody>
</table>

• Extra tea (above 100%) would require **2000 kWh** to process.

• During peak, Energy cost
  
  \[9.45 \times 2000 = \text{Kshs 18,900}\]

• Shifting to off-peak, Energy cost
  
  \[7 \times 2000 = \text{Kshs 14,000}\]
Operational excellence

Do’s

• Operate withering when there is no processing
• Fully load processing lines
• Switch off unnecessary processing lines/loads
• Process extra crop during off-peak period if possible

Don’ts

• Run empty processing lines
• Minimize operating withering when processing is taking place
Peak demand reduced from 500 kVA to 400 kVA.
Demand cost= Kshs800/kVA
Cost savings= Kshs 80,000
Module 2: Power factor

Power factor (PF) = \frac{Working power}{Apparent power} = \frac{kW}{kVA} = \cos \theta

= \frac{Beer}{Beer + Foam}
How do I improve power factor

• **Consumers** of kVAR- transformers, induction motors, high intensity discharge (HID) lamps- **lower PF**.

• **Generators** of kVAR- capacitors, synchronous generators, synchronous motors- **increase PF**

• **To increase/improve PF:**

1. **Install capacitors (kVAR generators):** Capacitors store KVARs and release it opposing kVAR caused by the inductor load.

   \[ kVA = \frac{kW}{PF} = \sqrt{(kW)^2 + (kVAR)^2} \]
Energy/cost saving from capacitors

Assuming Max 600kVA recorded,

With **PF=0.78**,

\[ kW = 0.78 \times 600 = 468 \]

and

\[ kVAR = \sqrt{kVA^2 - kW^2} = \sqrt{600^2 - 468^2} = 375. \]

Correcting **PF to 0.99**, \( kVA = \frac{468}{0.99} = 473 \) \( kVA \) meaning

\[ kVAR = \sqrt{473^2 - 468^2} = 67. \]

Capacitors required to correct are \( 375 - 67 = 308 \) \( kVAR. \)

<table>
<thead>
<tr>
<th></th>
<th>Jan-16</th>
<th>Mar-16</th>
<th>Apr-16</th>
<th>May-16</th>
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<tbody>
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<td><strong>PF</strong></td>
<td><strong>KSh</strong></td>
<td><strong>PF</strong></td>
<td><strong>KSh</strong></td>
<td><strong>PF</strong></td>
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<td>Factory 1</td>
<td>0.88</td>
<td>129,478.00</td>
<td>0.84</td>
<td>370,143.00</td>
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<tr>
<td>Factory 2</td>
<td>0.85</td>
<td>412,547.00</td>
<td>0.85</td>
<td>302,163.00</td>
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<td>Factory 3</td>
<td>0.96</td>
<td>95,313.00</td>
<td>0.88</td>
<td>95,313.00</td>
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<td>Factory 4</td>
<td>0.87</td>
<td>0.93</td>
<td>0.82</td>
<td>714,807.00</td>
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<td>Factory 5</td>
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<td>0.87</td>
<td>173,526.00</td>
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<td>Factory 6</td>
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<td>1</td>
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<td>Factory 7</td>
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<td>223,387.00</td>
<td>0.82</td>
<td>247,832.00</td>
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<td>Factory 8</td>
<td>0.96</td>
<td>0.89</td>
<td>0.94</td>
<td></td>
</tr>
<tr>
<td>Factory 9</td>
<td>0.98</td>
<td>0.82</td>
<td>0.91</td>
<td></td>
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<tr>
<td>Factory 10</td>
<td>0.78</td>
<td>681,879.00</td>
<td>0.9</td>
<td>0.97</td>
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<tr>
<td><strong>Total</strong></td>
<td>1,447,291.00</td>
<td>1,335,998.00</td>
<td>1,485,018.00</td>
<td>970,217.25</td>
</tr>
</tbody>
</table>
Effect of switching off capacitor bank

• If the capacitor bank is switched off during processing, PF goes back to 0.78
• Demand is raised from 473 kVA to 600 kVA
• Financial losses (kVA demand)
  \[(600 - 473) \times 800 = Kshs. 101,600\]
• Additional losses due to PF surcharge
Impact of overcorrecting PF

- When PF=1, kW=kVA
- Overcorrecting increases kVA → higher cost
- Increased currents-losses!
- Increased voltage can damage equipment.

Both yield same kVA!!
More Capacitors cost more money!!
2. Proper loading of motors

- Do not operate under loaded motor (empty conveyors? OR idle running)
- Load motor at least 50% and above
- Purchase correct rated motor for duty
- Low LF leads to low PF
Benefits of improving power factor?

1. Lower cost of electricity by;
   a. Peak kVA billing demand- high PF → low KVAR → low KVA.
   b. Eliminating power factor penalty- Utility charges for low PF (<0.9).

2. Increased system capacity
   For example, a 1,000 KVA transformer with an 80% power factor provides 800 KW of power to the main bus. By increasing the power factor to 90%, the kW that can be supplied are:
   \[ 0.9 = \frac{kW}{1000}, \text{Hence kW} = 900 \text{ kW} \]

3. Improved voltage level: As power factor increases, total line current reduces, meaning more efficient, cooler motor performance and longer motor life.
Operational excellence

**Do’s**
- Do not oversize capacitor banks
- Always switch on capacitor banks when required
- Properly load motors and conveyors (at least 50%)

**Don’ts**
- Don’t run idle or empty conveyors
- Do not overload motors
Module 3: Generator

Cost considerations

• Cost of diesel
• Energy content of a liter of diesel: 32 MJ/l
• Energy conversion: 1 kWh = 3.6 MJ
• Generator electricity generation efficiency: 30%

\[ \eta_g = \frac{\text{output}}{\text{input}} \]

• 1 kWh of electricity requires how many kWh diesel?

\[ \text{input (kWh)} = \frac{\text{output (kWh)}}{\eta_g} = \frac{1}{0.3} = 3.33 \text{ kWh} \]

• How many MJ of diesel are these;

\[ 3.33 \text{ kWh} \times \frac{3.6 \text{ MJ}}{\text{kWh}} = 12 \text{ MJ} \]

• 1 liter of diesel has 32 MJ energy content and costs Kshs. 96.
• Cost of generating 1 kWh electricity is;

\[ \frac{12 \text{ MJ}}{32 \text{ MJ}} \times \text{Kshs. 96} = \text{Kshs. 36/kWh} \]
Specific Fuel Consumption (SFC)

- Quantity of diesel required to generate one unit of electricity.

\[
SFC = \frac{\text{Fuel consumption per unit time}}{\text{power produced}}
\]

- Lower SFC → higher efficiency
- Optimum SFC at 75-80% loading
- e.g. a 500 kVA set is observed to have 20% better SFC at 75% than at 25% loading
Generator efficiency

• Do not use a big generator to run small loads!!
• Factory can have 3 generators
  • Biggest generator- to use when at full load.
  • Medium generator- to use when at half load
  • Small generator- use when factory is not processing.

This saves on diesel cost and reduces CO$_2$ emissions
Generator maintenance

Use manufacturer’s recommended checklist

Service as recommended
Operational excellence

**Do’s**
- Where possible use the right generator for the load
- Regularly maintain generators per manufacturer’s recommendations

**Don’ts**
- Don’t use a very big generator for very small loads
Module 4: Motors & fans

- All induction motors have losses; constant (fixed) & variable losses.
- Full load motor efficiency varies from about 85% to 97%, due to losses;
Motor efficiency

IE1—Standard efficiency (EFF 2)
IE2—High efficiency (EFF 1). About 4 or 5% more efficient than IE1.
IE3—Premium efficiency. About 2 or 3% more efficient than IE2.
## Motor retrofitting/replacing

<table>
<thead>
<tr>
<th></th>
<th>22 kW</th>
<th>22 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>93%</td>
<td>86%</td>
</tr>
<tr>
<td>Process Hours</td>
<td>4200</td>
<td>4200</td>
</tr>
<tr>
<td>Load (70%)</td>
<td>15.4</td>
<td>15.4</td>
</tr>
<tr>
<td>Elec. Energy (kWh)</td>
<td>15.4/0.93 × 4200 = 69,548</td>
<td>15.4/0.86 × 4200 = 75,209</td>
</tr>
<tr>
<td>Energy Cost [KSh20/kWh]</td>
<td>KSh 1,390,960</td>
<td>KSh 1,504,180</td>
</tr>
</tbody>
</table>

### For retrofitting:
- **Energy Efficient Motor**: KSh 200,000
- **Savings**: KSh 113,220 per year
- **Pay Back**: 1.76 years

### In case of replace:
- **EE Motor Extra Cost over Std Motor Cost**: KSh 50,000
- **Savings**: KSh 113,220 per year
- **Pay Back**: 5.3 months
Motor rewinding

- Will repaired motor retain its efficiency?
- Repair decision making process involves:
  - Suitability for application (sizing, enclosure)
  - Condition of stator and rotor
  - Assess all damages: cost of repair vs replacement
  - Efficiency; lifecycle costing
  - Availability of funds & replacement motor
  - ROI for replacement acceptable when replacing with energy efficient motor?
Good rewinding practice

• To maintain or reduce winding copper ($i^2R$) losses;
  • Ensure overall length of turns in windings does not increase (more resistance increases losses)
  • Increase wire area if slot fit allows it (larger area reduces resistance, reducing losses)

• Maintain efficiency by
  • Copy-rewinding or improving winding pattern
  • Use same or shorter average length of turns
  • Using same parts as before e.g. bearings, fans etc.

• Why could efficiency drop?
  • Damage to the stator while removing damaged windings.
  • Reassembly can cause more acute problems
Methods of starting motors/fans

• Direct-on-line starting (D.O.L)- high starting current that may cause interference with supplies to other consumers.
  • Low power and torque.
  • Suitable for small fans (38 inches)

• Star-delta starting- stator phase winding are star-connected.
  • High energy consumption
  • Higher torque
  • Suitable for larger fans e.g. 48 inches.

• Auto transformer starting- auto transformer reduces stator starting current- torque seriously reduced.
  • When motor is up to speed, switch is moved to direct connection.
Fans: Dampers vs Variable frequency drives (VFDs)

• Dampers used to control volumetric air flow.
  • They are like pressing car’s throttle (accelerator) and brakes together!!
  • Cheap to buy & install
  • Energy inefficient
  • Require frequent maintenance

• VSDs/VFDs
  • operate like a car’s throttle.
  • Adjusts speed of motor based on demand.
  • Most energy efficient
  • More expensive to buy
  • Pay back within the lifetime.
  • Harmonic concerns
Operational excellence

Do’s
• Consider high efficiency motors while replacing std motors
• Follow due diligence while rewinding motors.
• Use suitable connection for motors and fans based on torque required.
• Consider VFDs in place of dampers

Don’ts
• Do not connect VFDs and then fix the speed.
• Do not use VFDs and dampers together.
Module 5: Voltage balance

- **Ideally:**
  - Load in each phase should be the same
  - No net current flows thro neutral

- **Not possible to achieve ideal situation**

- **Line voltage** - between phases.
- **Phase voltage** - between phase and neutral.

Three phase loads 415 V
Single phase loads 240 V
Causes of imbalance

• Unequal reactance in induction motors → varying current in three phases.
• Connecting single phase loads to only one phase.
• Unequal impedances in power transmission or distribution system.

Control Measures

• Distribute single phase loads equally among the three phases
• Replace or rewind motors with unbalanced three phase reactance
Quantifying the losses

\[ \% \text{imbalance} = \frac{\text{max. voltage deviation}}{\text{average voltage}} \times 100 \]

Example: average voltage = 420.8V.
\[ \% \text{imbalance} = \frac{422.7 - 420.8}{420.8} \times 100 \]
\[ = 0.45\% \]

- Up to 2% imbalance is acceptable.
- Operation of a motor with above a 5% imbalance condition can damage to the motor.
Effects of imbalance

- **Power losses:**
  - Low motor efficiency
  - Increased temperature $\rightarrow$ heat losses ($i^2R$).

- **Maintenance issues:**
  - Temperature rise: decomposes grease in bearings & de-rates motor winding
  - Fluctuating torque & speed – vibrations & noise damages the motor
  - De-rating of power cables: Imbalances cause higher current $\rightarrow$ heat losses ($i^2R$).

- **More power loss higher $\rightarrow$ more power bills.**

\[
\text{temperature rise} = 2 \times \%\text{imbalance}^2
\]

- 7% imbalance = double temp rise
- 10° C rise in temp. reduces motor life 50%
Operational excellence

**Do’s**

- Try to equally distribute single phase loads.
- Frequently monitor motors that could cause imbalances.
- Replace/rewind such motors.

**Don’ts**
Module 6: Lighting

Common sources of light

• Incandescent- has a wire element. 90% heat and 10% light (100W bulb produces 90W heat and 10W light)

• Fluorescent – linear, U-tubes, CFLs. 40% light and 60% heat

• LED – Light emitting diodes

• Natural (sunlight)

Skylight and LED at a tea factory
<table>
<thead>
<tr>
<th></th>
<th>LEDs</th>
<th>CFLs</th>
<th>Incandescent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifespan (hours)</td>
<td>50,000</td>
<td>10,000</td>
<td>1,200</td>
</tr>
<tr>
<td>Power (equiv. 60 watts)</td>
<td>6</td>
<td>15</td>
<td>60</td>
</tr>
<tr>
<td>Energy used over 50,000 hours (kWh)</td>
<td>300</td>
<td>750</td>
<td>3,000</td>
</tr>
<tr>
<td>Electricity cost (@Kes20/kWh)</td>
<td>6,000</td>
<td>15,000</td>
<td>60,000</td>
</tr>
<tr>
<td>Bulbs needed for 50,000 hours of use</td>
<td>1</td>
<td>5</td>
<td>42</td>
</tr>
<tr>
<td>Cost per bulb (Kes)</td>
<td>500</td>
<td>250</td>
<td>50</td>
</tr>
<tr>
<td>Cost of bulbs (Kes)</td>
<td>500</td>
<td>1,250</td>
<td>2,100</td>
</tr>
<tr>
<td>Cost of bulbs + energy after 50,000 hours (Kes)</td>
<td>6,500</td>
<td>16,250</td>
<td>62,100</td>
</tr>
</tbody>
</table>

For a house with 5 bulbs only, in 50,000 hours

<table>
<thead>
<tr>
<th></th>
<th>LEDs</th>
<th>CFLs</th>
<th>Incandescent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kWh)</td>
<td>1,500</td>
<td>3,750</td>
<td>15,000</td>
</tr>
<tr>
<td>Cost (Kes)</td>
<td>32,500</td>
<td>81,250</td>
<td>310,500</td>
</tr>
<tr>
<td><strong>Energy savings (kWh)</strong></td>
<td><strong>13,500</strong></td>
<td><strong>11,250</strong></td>
<td><strong>0</strong></td>
</tr>
<tr>
<td><strong>Cost savings (Kes)</strong></td>
<td><strong>278,000</strong></td>
<td><strong>229,250</strong></td>
<td><strong>0</strong></td>
</tr>
</tbody>
</table>
## Comparing the features of common bulbs

<table>
<thead>
<tr>
<th></th>
<th>LEDs</th>
<th>Fluorescent</th>
<th>Incandescent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequent On/Off Cycling</td>
<td>no effect</td>
<td>shortens lifespan</td>
<td>some effect</td>
</tr>
<tr>
<td>Turns on instantly</td>
<td>Yes</td>
<td>Slight delay</td>
<td>yes</td>
</tr>
<tr>
<td>Durability</td>
<td>Durable</td>
<td>Fragile</td>
<td>Fragile</td>
</tr>
<tr>
<td>Heat Emitted</td>
<td>Low (3.16 kJ/h)</td>
<td>Medium (15.83 kJ/h)</td>
<td>High (89.68 kJ/h)</td>
</tr>
<tr>
<td>Hazardous Materials</td>
<td>None</td>
<td>5 mg mercury/bulb</td>
<td>none</td>
</tr>
<tr>
<td>Replacement frequency</td>
<td>1</td>
<td>5</td>
<td>40+</td>
</tr>
<tr>
<td>(over 50,000 hours)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Evident that LEDs have the best qualities.
Retrofitting fluorescent lamps

- **Energy Efficient Lamp (LED):** KShs 3000
- **Assume 200 lamps replacement:** KShs 600,000
- **Savings:** \((4,180 - 1,300) \times 200 = \text{KShs 576,000/year}\)
- **Pay Back:** \(\frac{600,000}{576,000} \approx 1 \text{ year}\)

<table>
<thead>
<tr>
<th></th>
<th>Fluorescent</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (W)</td>
<td>58</td>
<td>18</td>
</tr>
<tr>
<td>Hours (in a year)</td>
<td>3,600</td>
<td>3,600</td>
</tr>
<tr>
<td>Energy (kWh/year)</td>
<td>(58 \times 3600/1000 = 209)</td>
<td>(18 \times 3600/1000 = 65)</td>
</tr>
<tr>
<td>Cost (Kshs/year)</td>
<td>(209 \times 20 = 4,180)</td>
<td>(65 \times 20 = 1,300)</td>
</tr>
</tbody>
</table>
Retrofitting security lights

- Replacing 10 Halogen lamps with LED Equivalent
- Cost of LED lights @2,500= KSh 250,000
- Energy Cost Savings: \((21,900 - 8,760) \times 10 = KSh 131,400/\text{year}\)
- Pay Back: \(\frac{250,000}{131,400} = 1.9\ years\)

<table>
<thead>
<tr>
<th></th>
<th>Metal Halide</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (W)</td>
<td>250</td>
<td>100</td>
</tr>
<tr>
<td>Hours (in a year)</td>
<td>4,380</td>
<td>4,380</td>
</tr>
<tr>
<td>Energy (kWh/year)</td>
<td>(250 \times 4380/1000 = 1,095)</td>
<td>(100 \times 4380/1000 = 438)</td>
</tr>
<tr>
<td>Cost (Kshs/year)</td>
<td>(1,095 \times 20 = 21,900)</td>
<td>(438 \times 20 = 8,760)</td>
</tr>
</tbody>
</table>
Proper lights operation

Sensitize

- Security lights should have photocells - night
- Photocells + motion sensors – night & motion

Consider solar security

Where possible, use natural light

Install occupancy sensors
Operational excellence

Do’s

• Pay attention to sensitizing materials on lights operation
• Occasionally clean the skylights.
• Automate lights operation where possible.

Don’ts

• Don’t leave lights switched on unnecessarily.
Module 7: Energy monitoring & sub-metering

• Install sub-meters in various sections of the factory.
• Periodically measure & record individual motors/fans
• Compare similar processes

You can’t manage what isn’t measured. If you don’t measure, you can’t improve it.
Why sub-meter?

• Verify utility bills
• Allocate energy costs and assign accountability
• Determine equipment/system efficiency
• Identify process problems
• Identifying future energy savings opportunities
• Compare similar processes
Potential energy savings from sub-meters

- **Increased awareness**- Employees *notice energy waste* e.g. lights left on when they know it is being metered.

- **Savings from increased accountability**- Measuring energy costs can show that *decisions* made by production staff & energy managers play a significant role in the overall cost of energy.

- **Savings from automation**- e.g. during peak electrical demand, non-critical load could be shut down.

**Instrumentation**

- In case there are no sub-meters, *use portable meters* such as power meters to record and monitor energy consumption.
What must you do?

By themselves, meters do not save money -- they only cost money to purchase and install. To maximize savings, complement a sub metering system with appropriate procedures.

• Keep records
  Develop & maintaining a database.

• Analyze the data
  Trends, peaks, and correlation with factors such as weather, season, operating shift, and production rate.
  Make sense of the data

• Take action
  For continuous improvement & preventive maintenance
  Actions could save the factory downtime, labour and money.
Operational excellence

Do’s
• Take energy consumption readings occasionally for various loads.
• Record and compare the consumption.
• Analyze the data
• Take appropriate actions.

Don’ts
• Don’t record data just because you are asked to!
Module 8: Maintenance

- Wiring should be neat! Ease of troubleshooting
- Use/ensure correct cable size, colour coding and termination
- Digitize records
- Properly label the distribution panel
- Never short circuit a fuse/circuit breaker. Prevent catastrophe!
Maintenance

• Power house should be kept clean
  • Close the door so as to only allow authorized personnel.
  • Ensure no water on the floor.
  • Should be well ventilated.

• Ensure all indicating devices are fully functional and properly set.

NO Shortcuts!!
Follow the procedure
Energy saved is energy generated.