National Electrical Safety Campaign
kVAh Billing - Understanding Benefits
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By
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Agenda

- Back to Power Triangle Basics
- kVAh billing - The Why & What
- Load Types & their impacts on kVAh billing
- Getting familiar with the new Power Triangle
- kVAh Billing - Get on top to achieve maximum efficiency

Reactive Power Fundamentals

- Reactive power is used to develop the electrical environment to make the active power work, but isn't directly utilized for work, hence called useless power

Energy Input
kWh Conversion
Useful work Heating, Lighting, Motion etc (Active component)

Environment (EMF) will be created by kVAh (Reactive Component)

Ideally kU/kWh = Zero
So that kWh = kVAh and Power Factor = 1 (Unity)

Reactive Power Fundamentals

- Types and Characteristics of electrical power can be best explained with a Power Triangle

\[
P = S \cos \theta \\
Q = S \sin \theta \\
S = \sqrt{P^2 + Q^2}
\]
kWh and kVAh Billing

$\text{kWh} = \text{kW} \times \text{Time}$

$\text{kWh} = \text{Active Power} \times \text{Time}$

$k\text{Wh} = P \times \text{Time} = \text{No. of Units}$

$\text{kVAh} = \text{kVA} \times \text{Time}$

$k\text{VAh} = \text{Apparent Power} \times \text{Time}$

EARLIER:
1kW power X 1hr = 1kWh = 1 Unit of consumption

NOW:
1kVA power X 1hr = 1kVAh = 1 Unit of consumption

Power (kW or kVA)

Time

Energy is area under the power function

EARLIER:
1kW power X 1hr = 1kWh = 1 Unit of consumption

NOW:
1kVA power X 1hr = 1kVAh = 1 Unit of consumption

kVAh Billing - Overview

What Caused the shift from kWh to kVAh?

1. Substantial T&D losses to Distribution Companies
   - Due to poor Power Factor (Leading & Lagging) & Harmonics

2. Ambiguity of kWh Billing
   - PF penalties and incentives were ambiguous
   - Not in correlation with system losses & unfair

Provide control in hands of consumers to control their energy consumption

System Infra Maintenance & Upkeep
Extra system losses
Excessive KVA capacity
Blockage
Demand Side Management

Audit for a Discom's Consumers revealed
63% of consumers were overcompensating
Out of which 80% with resonance

Typical Billing Components

Fixed Charges
- Overheads
- Asset Depreciation
- Cost of Finance
- Proportional to Contract Demand

Statutory Charges
- Tax, Duties
- Late Payment Charges
- Early payment Discounts
- Proportional to energy consumption

Variable Charges
- Energy Charges
- Banking Charges
- APP, DUE, Incentives
- Proportional to energy consumption in kWh/kVAh

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kVAh Billing - Overview

kVAh Billing Details - Example - MSEDCL

- Demand Charges
- Energy Charges
- PF Incentives/Penalties (Not applicable for kVAh billing)
- Early Payment Discounts
- TOD charges
- Wheeling Charges
- Electricity Duty
- FAC - Fuel Charge Adjustment
- Bulk Discount
- Incremental Discount
- Duties and Taxes

Factors Affecting the kVAh

Effect of Load Variation

Time Cycle 1
Time Cycle 2
Time Cycle 3
Time Cycle 4
Time Cycle 5

kVAh_{SCYC} Meter recorded
kVAh_{SCYC} Calculated as:

\[ kVAh_{SCYC} = \sqrt{kWh^2 + kVARh^2} \]

One can see that kVAh-meter > kVAh-calc under continuously changing loading.

Factors Affecting the kVAh

Effect of Unbalanced Loading

kVAR-R
kVAR-Y
kVAR-B

kVAR-R
kVAR-Y
kVAR-B

Metered kVA = kVA-R + kVA-Y + kVA-B
Calculated kVA = \[ \sqrt{kW^2 + kVAR^2} \]

Highly inductive or Capacitive Loads = The loads that have poor Power Factor (Leading or Lagging)
Continuously Variable Load = The electrical loading that is continuously variable in nature. More abrupt the load changes, adverse is the effect on kVAh billing
Unbalanced Loading = The loads that are Unbalanced in nature. It even affects, if the unbalance phenomenon is continuously changing
Harmonics Prone Load = The loads with higher level of Harmonic currents and / or Harmonic voltages

Any of the above load types in your plant will necessitate action to optimise kVAh billing
Factors Affecting the kVAh

Effect of Harmonics
Current Vector Diagram with D-PF and PF concepts:

\[
\begin{align*}
\cos \phi_f &= \frac{I_{A-f}}{I_{R-f}} \\
\cos \phi_t &= \frac{I_{A-t}}{I_{R-t}} \\
\text{(Displacement PF)} \\
\text{Thus, } I_x > I_f & \quad \text{(Small approximation here)}
\end{align*}
\]

\[
I = \sqrt{I_{A-f}^2 + I_{R-f}^2 + I_{h}^2}
\]

\[
\cos \phi = \frac{I_{A-f}}{I_{R-f}} = PF = R-PF < D-PF \quad \text{(RMS PF)}
\]

IN PRESENCE OF HARMONICS

Harmonics (kw + kvar)

Image Courtesy: Mr. Tushar Mogre, APQI Partner

Summary kVAh Billing: Factors

Energy Billed (kVAh) is a combination of 6 factors:

1. Loads and their nature (Unbalancing, abrupt changes)
2. Reactive energy consumed and supplied
4. Severity of the harmonics/resonances
5. Varying load patterns & DERs (time of day/week/seasonal)
6. Unintentional billing errors due to metering issues

Image Courtesy: Mr. Tushar Mogre, APQI Partner

kVAh Billing - How to draw Benefits

1. Avoid Hasty actions Plan for long term based on assessment
2. In-depth Electricity Bill analysis
3. Analyse SCADA/BMS Energy/PQ Data
4. Comprehensive Monitoring of Energy + Reactive Power + Harmonics + PQ + RPC analysis
5. Accurate solutioning considering existing systems & vendor /technology neutral approach
6. Solution installation/upgradation and post installation performance monitoring

Image Courtesy: Mr. Tushar Mogre, APQI Partner
1. Avoid haste, avoid band-aids, Plan for long term
   - Variables affecting plant operations
   - Stock of existing systems affecting kVAh optimisation
   - Stock of existing processes for monitoring/controlling
   - Arrive at the impact that you currently foresee

2. Analysis of past 12 months of Electricity Bills
   - Goldmine of data exists in your bills
   - Energy consumption/PF/Actual Demand/Billed Demand patterns
   - Potential Losses and/or realistic savings estimates
   - Focus on other factors affecting billing
   - Estimate of investment vs. ROI

Electricity Bill Analysis - Case 1

<table>
<thead>
<tr>
<th>Months</th>
<th>Bill Cycle (No. of Days)</th>
<th>Actual Recorded Max Demand (kVA)</th>
<th>Recorded kWh</th>
<th>Recorded kVARh</th>
<th>Demand Charges</th>
<th>Energy (kVAh/kVARh)</th>
<th>Early Payment Discounts</th>
<th>Total Bill Amount</th>
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<tbody>
<tr>
<td>October</td>
<td>31</td>
<td>0.888</td>
<td>335</td>
<td>175</td>
<td>21375</td>
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<td>235471.06</td>
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<tr>
<td>November</td>
<td>30</td>
<td>0.866</td>
<td>325</td>
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<td>21130</td>
<td>21130</td>
<td>235405.08</td>
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<tr>
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<td>0.874</td>
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<td>170</td>
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<td>31</td>
<td>0.864</td>
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<td>170</td>
<td>21280</td>
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<tr>
<td>February</td>
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<td>21280</td>
<td>235940.98</td>
</tr>
</tbody>
</table>
Evaluate existing EMS/SCADA data

- Completeness of parameters
- Accuracy of the measurements being undertaken
- Historic data availability
- Locations of data being collected
- Decide on further study necessary or not
kVAh Billing - How to Draw Benefits

4 - Comprehensive Energy + Harmonics + Reactive Power + PQ + RPC monitoring

- Solve 5 problems with one action
- Number of Locations / Duration / Simultaneous measurements
- Type and configuration of analysers to be deployed (Inhouse/Remote??)
- Beware - Switching off RPC’s may do more harm
- Finalise right monitoring strategy - Short and Continual Basis

Remember this! (....before deciding on one quick solution....)

- The increase in your billing amount could be because of one or more factors.
- The solutions required could also be one or more.
- Most importantly, solution can be decided only after a thorough understanding of the factors that affect your system and increase the billing amount.
- A product/technology neutral approach will be valuable.

**Actual Case Study done with Product/Vendor Neutral Approach**

<table>
<thead>
<tr>
<th>Approach</th>
<th>Time of Study</th>
<th>Cost of the Study</th>
<th>Cost of Filters/Solution (suggested)</th>
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<tbody>
<tr>
<td>OEM Study &amp; Solution</td>
<td>1 Day</td>
<td>INR 10,000/-</td>
<td>INR 80 Lacs</td>
</tr>
<tr>
<td>Neutral Study &amp; Solution</td>
<td>5 Days</td>
<td>INR 100,000/-</td>
<td>INR 8 Lacs (90% savings)</td>
</tr>
</tbody>
</table>

kVAh Billing - How to Draw Benefits

**Advanced Harmonic cum PF cum Power Quality Study**

1. Harmonic and Power Factor Study decided
2. Monitoring the PCC with PQ Analysers
3. Data collected for 1 week
4. Data analysis using secqr®
5. Post Installation performance assessment

**Findings**

- I-Tdd% ~ 175% above threshold as per IEEE 519-2014
- 2.2 years

**Suggestion**

Install Detuned PF and Harmonic Filter which would individually cost Rs. 1,50,000 and Rs. 6,80,000 approx.

**Return on Investment**

Rs. 3,81,204 p.a. of consolidated savings
5 Optimum solution prioritising considering existing systems

- Solutions lie within your facility a lot of times
- Evaluate collective effectiveness of existing solution, problems and new if any to be considered
- Focus on overall solutions, specifications, best ROI & future service support
- Side-effects of using the solution – Buy to solve the problem, not perpetuate it
- Have a technology/vendor neutral mindset at this stage.

6 Solution installation & post performance verification

- Ensure complete ownership of the solution and performance
- Plan for minimal downtime for integration of the solution
- Integrate post installation, performance monitoring strategy
- Use power of technology - Ensure 24/7 compliance, don't settle for anything else

Some options available to choose from depending on end use application

- **For Inductive or Capacitive Reactive Load**
  - Usage of Fixed Inductors or Capacitors: For constant continuous Load without variation
  - Manually Switched Inductors or Capacitors: For Slow Load variation

- **For Reactive Power Load Variation**
  - Automatic Power Factor Correction (APFC) system: For slow variation in Load
  - Real Time Power Factor Correction (RTPPC) system: For fast variation in Load
  - Solid state Reactive Power compensator (STATCON): For abrupt variation in Load

- **For Harmonic Prone Loads**
  - Harmonic Filters, (Active or Passive – selected dependent on merits / demerits)
  - Usage of Detuned Reactors in APFC / RTPFC system if used for Load variation

- **For Unbalanced Loads**
  - Passive Unbalance Compensator: For Fixed Unbalanced condition
  - Solid state Unbalanced compensator (STATCOM): For Variable Unbalanced Loading

- **For Combination of Above type of Loads**
  - Hybrid systems: APFC / RTPFC / STATCOM combination.
Questions?

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