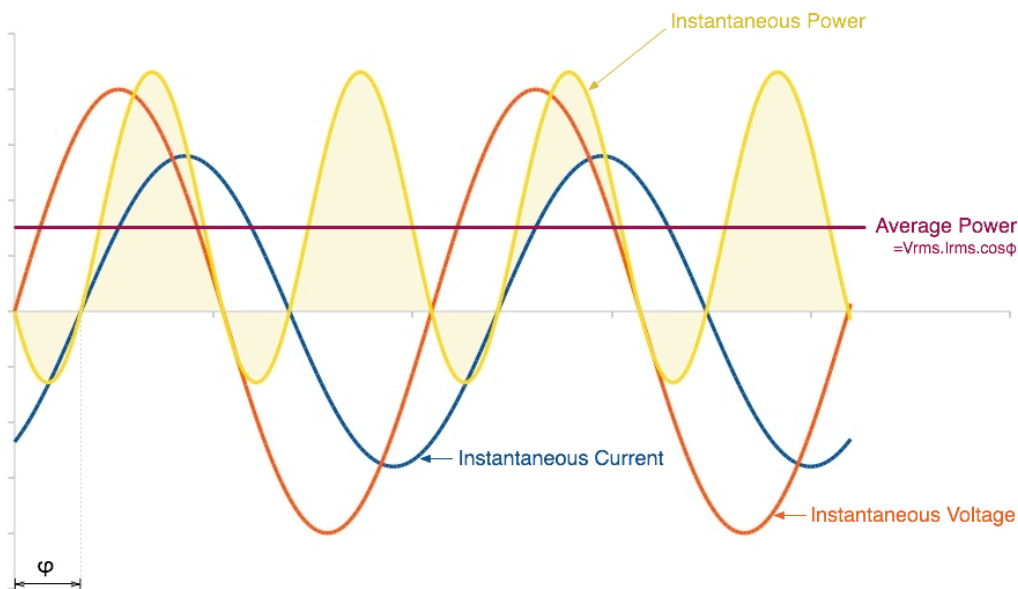


Reducing energy costs starts by understanding what's driving your energy use and how efficient your electrical installation is. You may be familiar with monitoring your kWh consumption from electricity bills and from more granular dashboard reports, but it's now time to get started with what's really happening with your electrical loads (appliances, machines, etc).

The theory part

In AC circuit analysis, both voltage and current vary sinusoidally with time. The presence of reactive elements like inductors and capacitors directly impact the current wave by shifting it with respect to voltage wave (ϕ), see below.



Power is the rate at which energy is consumed by an electrical load or produced by a generator, and the value of instantaneous power is obtained by multiplying instantaneous voltage with instantaneous current.

Instantaneous power varies with time sinusoidally, so we generally look at the average power within a given time frame, for example the period of the sinusoidal wave. The average power is calculated as:

$$P = V_{rms} \times I_{rms} \times \cos\phi \text{ (W)}$$

$$V_{rms} = \text{RMS Voltage} = V_m/\sqrt{2}$$

$$I_{rms} = \text{RMS Current} = I_m/\sqrt{2}$$

V_m and I_m the maximum values of the sinusoidal voltage and current

This average power formula is the basis to calculate the power consumed by the load over longer periods, for example your monthly electric energy bills are based on this power calculation. Note that the average power is also called 'Real', 'True' or 'Active' power within the industry, and is measured in Watts (W). At Wattics we talk about Active Power.

In ideal inductors and capacitors, voltages are respectively 90° ahead and behind the phase of the current, meaning that ideal inductors and capacitors do not, on average, take active power from the circuit ($\cos\phi=0$). Current is instead used to charge a capacitor, or to create the magnetic field around a coil, as opposed to creating heat or lifting loads.

In real-world environments where resistors, inductors and capacitors are all combined within complex machines, the power that is wasted and not used to do work on the load is represented by the Reactive Power, calculated as:

$$\text{Reactive Power} = V_{rms} \times I_{rms} \times \sin\phi \text{ (VAR)}$$

Note that the Reactive Power is also called 'Wattless' power within the industry, and is measured in VAR (VoltAmpereReactive). At Wattics we talk about Reactive Power.

Apparent power represents the power that is supplied to the circuit (voltage multiplied by all

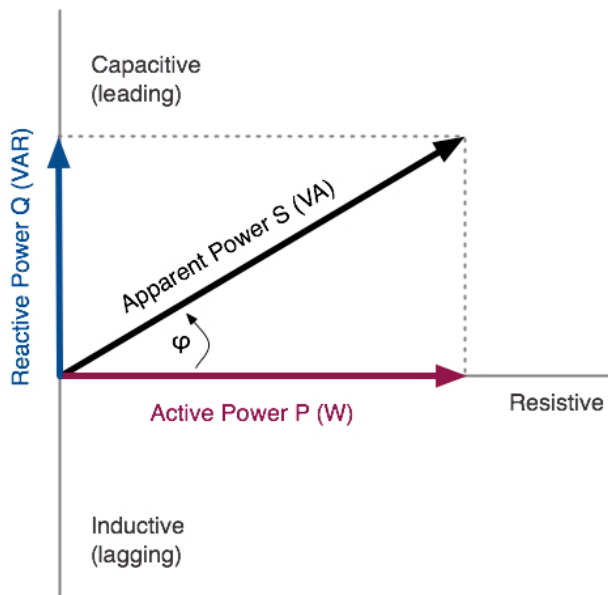
the current that flows in it), and is measured in volt-amperes (VA). Apparent Power is calculated as follows:

$$\text{Apparent power} = V_{\text{rms}} \times I_{\text{rms}} \text{ (VA)}$$

The power factor is defined as the ratio between Active Power and Apparent Power:

$$\text{Power Factor} = \text{Active Power} / \text{Apparent Power}$$

The relationship between Apparent Power (S), Active Power (P) and Reactive Power (Q) is often expressed as a vector-sum definition, which shows how each of them evolves based on whether the electrical load is resistive, inductive or capacitive.



There is one main difference between single-phase and three-phase electrical systems. The instantaneous single phase power is sinusoidal. In a balanced three-phase system, each phase instantaneous power is pulsating, but the three pulsating power waves are 120 degrees displaced from each other. At such, at any instant of time the total of these three

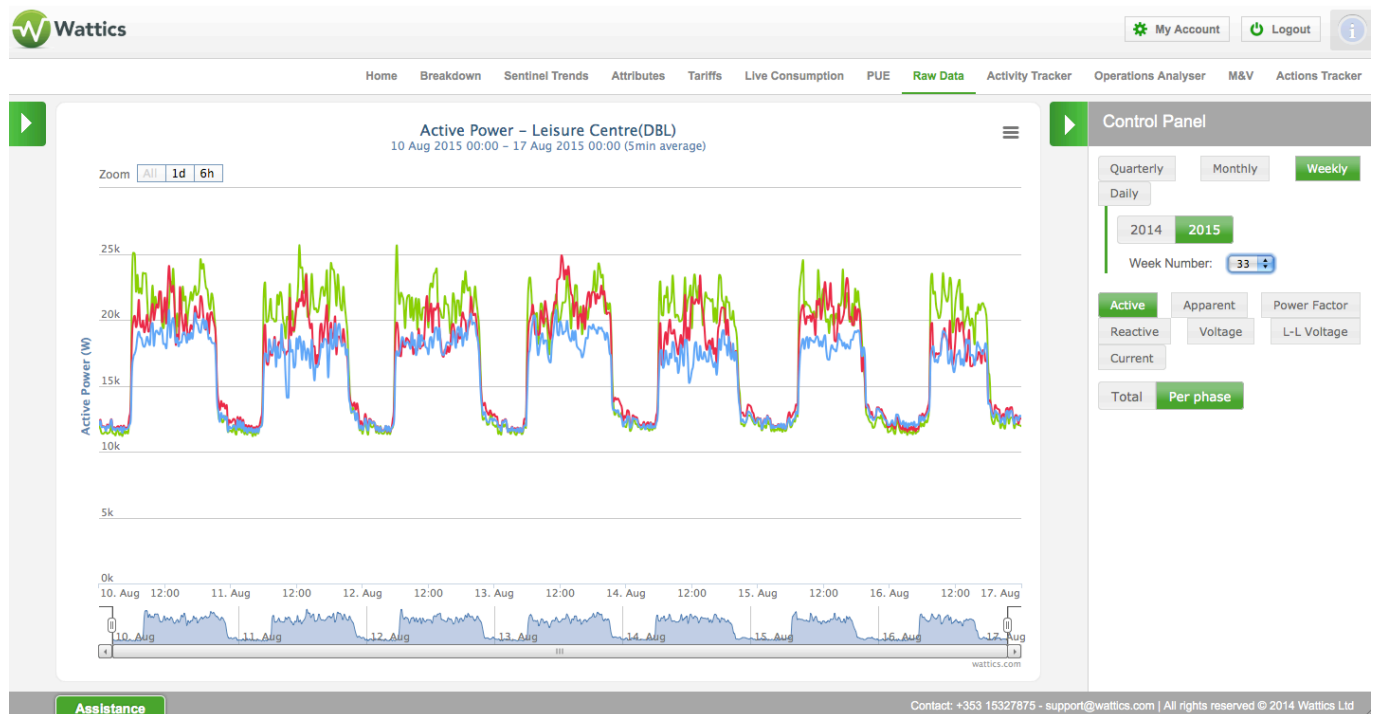
instantaneous power waves is a constant which is $3 \times V_{rms} \times I_{rms} \times \cos\phi$. As a result, the total power consumed in a three-phase balanced system is not pulsating, which is a very desirable pattern for rotating machines requiring high-starting torque.

More theory can be found at [1].

The practical part

Analysing Active Power variations (W)

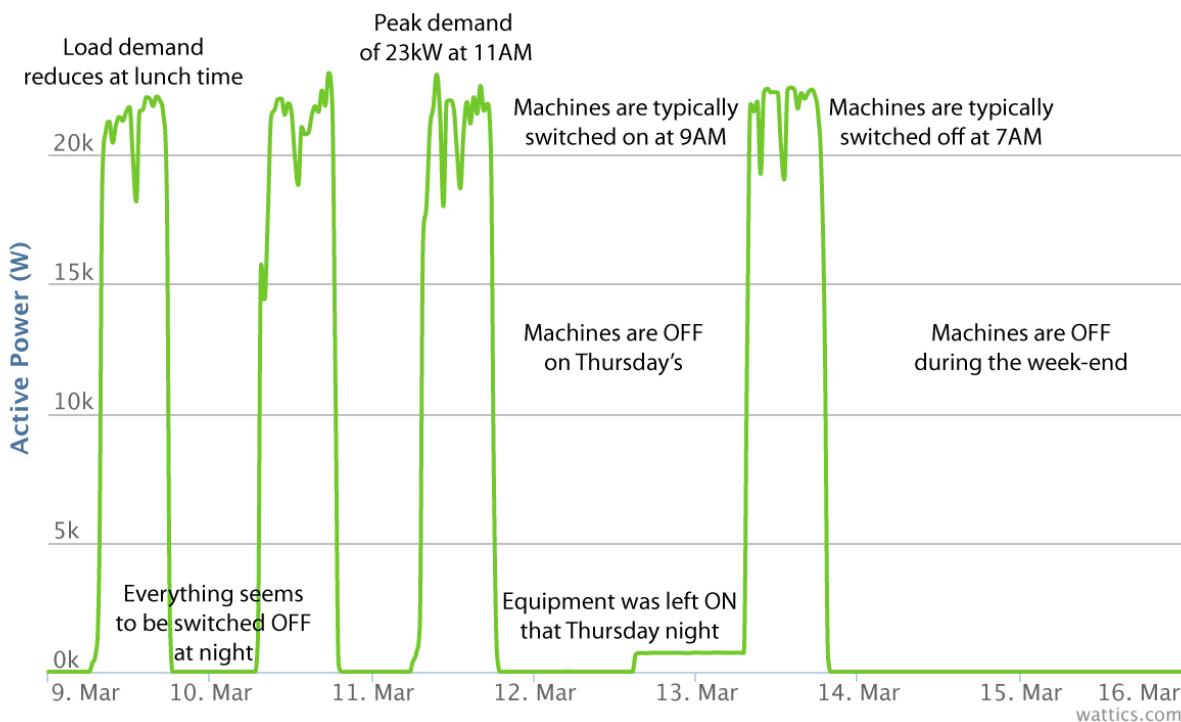
The Wattics Dashboard allows you to investigate Active Power measurements collected from your electrical meters. Remember that active power relates to power delivered in an electrical, mechanical, thermal or any form we want, and can therefore be easily associated to business operations, electrical equipment power activity, space occupancy and so forth.



Don't be scared by raw measurements, active power variations over a 7-day period are full of valuable insights that are easy to uncover.

Sometimes one daily kWh figure does not reflect what's happening during the day. We like to approach active power analysis with a business-oriented mind, meaning that what you are looking for here are discrepancies between how active power varies over time (i.e. load demand patterns) and how you expect your business to operate:

- Check overnight demand levels, are they high compared to daily levels? If after hours demand is abnormally high, does it mean that equipment is left on and could be switched off?
- Identify high consumption start/end hours (when demand starts to increase and decrease), does it match your business hours?
- Seek down-time periods when demand decreases (e.g. lunch time breaks, week-ends), does your staff operates equipment efficiently by making sure that all that can be turned off is effectively turned off?
- Keep an eye on unusual demand peaks (e.g. peak at night or drop during the day), what could have caused this, has electrical failed and shown signs of inefficiency?



Examples of what you can discover from the analysis of your load demand variations.

Now that you know how to identify whether your electrical loads operate as expected, you can:

- Go back to your staff and call for action (awareness campaign to switch off equipment when not in use during breaks, overnight and at weekends)
- Set up alerts in your dashboard (static alerts or Sentinel alerts) to be notified when abnormal demand is detected
- Revisit your BMS and timer settings throughout your site to align them with business hours and space occupancy (for major potential savings on HVAC and Lighting)
- If more than 15% of your consumption is at night (e.g. 11pm-8am) and if you are on a flat tariff, you may consider switching to nightsaver tariff structure with lower rate overnight (but slightly higher during daytime hours). You should first check that you are not wasting energy at night, e.g. equipment & lighting left on unnecessarily etc., and you should seek to reduce your night consumption before considering a tariff change.

Another important feature for you to check is your site's Maximum Demand (MD), which is the highest level of electrical demand measured during the day. To avoid penalty charges, it is critically important that you do not exceed your Maximum Demand Level (kW). Try to avoid unnecessary usage during the MD measuring periods of the day, and if possible re-schedule tasks outside MD periods and avoid large loads operating at the same time.

Analysing Apparent Power variations (VA)

When applying for a grid connection, the most important decision is the capacity level your site requires. The capacity of your connection, often call the Maximum Import Capacity (MIC) is an important figure for several reasons:

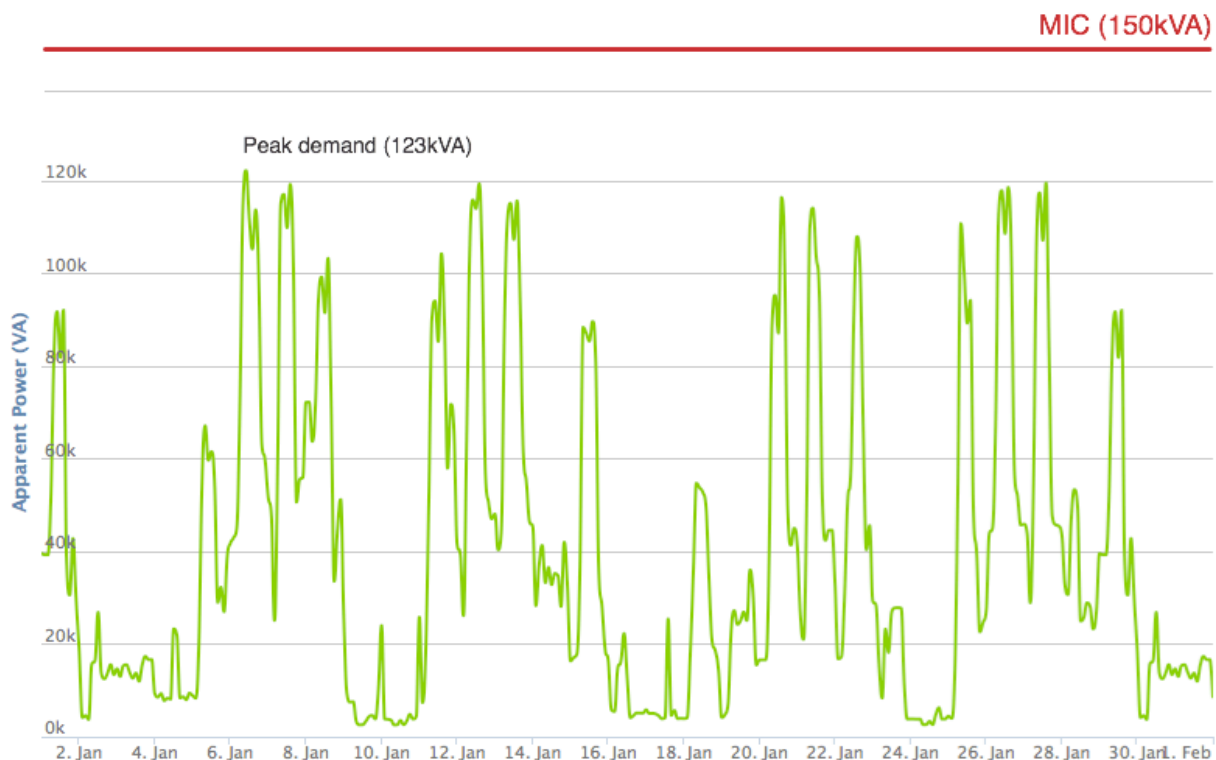
- It is the capacity that the grid operator commits itself to deliver to your premises.

- It places an upper limit on the total electrical load you can use.
- It is a determinant for connection charges.

Your MIC may be too high or too low for your needs – either way it will cost you money:

- If the MIC is too high, you may be paying for more capacity than you require.
- If the MIC is too low, you may incur an ‘Excess Capacity’ charge.

You must be registered for the capacity that meets your needs, which is generally much lower than the sum of the kilowatt ratings of all the equipment installed.



Example of Apparent Power variations.

You should also review the Apparent power variations within your dashboard. If your Apparent Power analysis shows that your peak kVA demand for the entire site is far below

your registered MIC, you should discuss your MIC with your electrical contractor / consultant. Inappropriate MICs are common (too high or too low), expensive and straightforward to fix. You can also check for Excess Capacity Charges on your bill. If these charges are significant, you should contact your supplier to discuss increasing your MIC.

You can calculate your appropriate MIC by reviewing the contracted MIC and the actual Maximum Demand from your dashboard and your bills over the last year. A best practice recommendation is to calculate the appropriate MIC as:

$$\text{MIC} = (\text{Maximum Demand} / 0.95) \times 1.1$$

If your contracted MIC is significantly higher than the appropriate MIC over an extended period and you do not anticipate your MD changing in the near future (extension, expansion etc.), then contact your electricity supplier to discuss a reduced MIC.

Similarly, you may recognise that you need to increase your level of supply if:

- you add a significant new extension to your premises
- you begin to use new equipment that requires significant extra power

More on this can be found at [6].

Analysing Reactive Power and Power Factor variations (VAR and PF)

High reactive power and low power factor values will generally occur for a number reasons:

- Most of the AC motors that can be found in industrial environments are induction motor type with low lagging power factor. During light loads the induction motors will work at a power factor of 0.2 to 0.3 while during full load condition they will work at 0.8 to 0.9 (for which they have been designed).
- Arc lamps, electric discharge lamps and industrial heating furnaces operating at low lagging power factor are used.
- The load on the power grid system is varying. It will be high during morning and evening hours and lower at other times. The supply voltage is increased during low

load period, which increases the magnetisation current, resulting in low power factor.



Example of Power Factor variations.

Because current is inversely proportional to the power factor for fixed power and voltage, the lower the power factor, the higher the load current. This results in the following disadvantages:

- Poor power factor means more line loss dissipation and low transmission efficiency.
- More capital investment for line conductors to provide the expected transmission efficiency
- All electrical equipments in connection with generation, transmission, distribution of ac power such as alternators, transformers, switch gear, cables etc are rated on KVA basis. The lower the power factor the larger is the KVA rating. Large KVA rating of equipment meaning larger size and more expensive equipment.
- Poor voltage regulation. Large current at low power factor causes greater voltage drops in electrical equipment. The result is reduced voltage at the supply end. In order to keep the receiving end voltage within permissible limits, additional devices like voltage regulators are required.

The impact of a high reactive power and resulting low power factor principally matter to grid operators. Yet, penalties on low power factor are generally imposed to end-consumers for power factor values below a certain threshold, e.g. 90%, as a way to enforce controlled power factors levels.

How to manage poor power factor now that you have identified it? At the demand-side, the following power factor correction devices are generally used for power factor improvement before the meter:

- Static Capacitors: they provides leading current which neutralise (totally or approximately) the lagging inductive component of load current.
- Synchronous Condensers: a synchronous motor over-excited at low load provides leading current and works like a capacitor drawing leading current and partially eliminates the re-active component.
- Over excited synchronous motors have to be used in place of induction motors. They are smaller in frame size and economical too.
- Induction motors have maximum power factor when fully loaded, so they should be used at full load condition.

If you are incurring wattless charges despite having power factor correction capacitors in place, it means that they may be damaged or require tuning. You should contact your electrical contractor to confirm that they are operating correctly.

More on this can be found at [2] and [3].

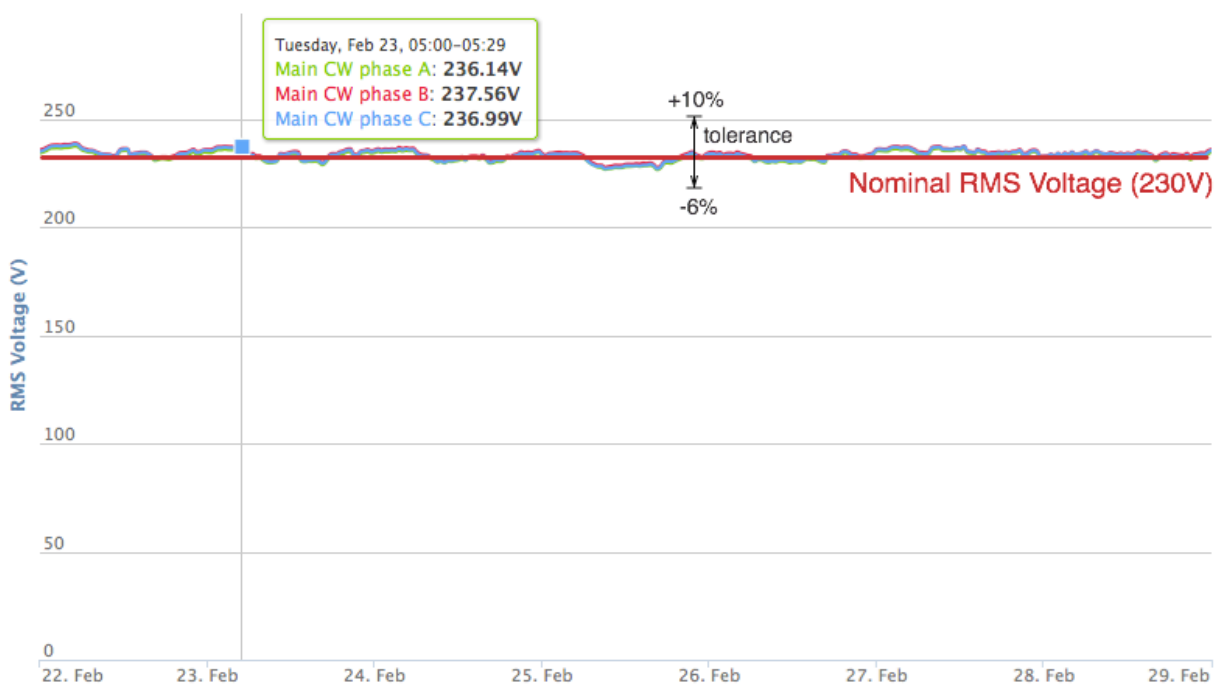
Analysing Voltage measurements (V)

Undesirable issues may arise due to voltage problems in your premises or on the grid network. Such problems can manifest themselves in a number of ways. Examples include:

- Lights that dim when other appliances are in use.

- Computer screens become unstable when other appliances are in use.
- Electrical motors that fail to start first time.

It is important to review voltage fluctuations to discover voltage drops, power outage characteristics and patterns of low and high voltage levels.



Conservation Voltage Reduction (CVR) is a proven technology for reducing energy and peak demand. It is generally implemented upstream of end service points in the distribution system so the efficiency benefits are realised by consumers and the distributor. CVR consists of controlling the voltage on a distribution circuit to the lower end of a tolerance band, meaning that end-use loads draw less power when voltage is lowered.

CVR has been estimated by Pacific Northwest National Laboratory to produce between 0.5–4% energy savings on circuits where it is implemented, with 80–90% of that occurring on the customer side of the meter. Because benefits in the form of energy savings accrue to customers, utilities have little or no incentive to invest in CVR. CVR systems deployed at the

customer side of the meter are however on the market and prove to be a suitable source of energy savings with viable payback. More about CVR can be found at [7].

[Try out on your Wattics dashboard now](#)

You are now ready for deeper analysis of your electrical demand and supply. Of course, we are always there should you need clarifications on how to use your energy management dashboard, so please feel free to [get in touch with us](#) at any time.

- [1] <http://www.skm-eleksys.com/2011/06/complex-power-and-power-triangle.html>
- [2] <http://www.electricalbasicprojects.com/low-power-factor-disadvantages-tutorial/>
- [3] <https://www.quora.com/What-is-the-importance-of-reactive-power-in-transmission-lines>
- [4] <https://www.esb.ie/esbnetworks/en/business-customers/mic/mic.jsp>
- [5] <https://www.esb.ie/esbnetworks/en/business-customers/mic/index.jsp>
- [6] http://www.seai.ie/EnergyMAP/Learning_centre/Quick_ways_to_start_saving/Bills_analysis/
- [7] <http://blogs.dnvgl.com/energy/is-conservation-voltage-reduction-truly-energy-efficiency>

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