WHY THREE-PHASE?

An overview of the benefits of a three-phase network

White Paper

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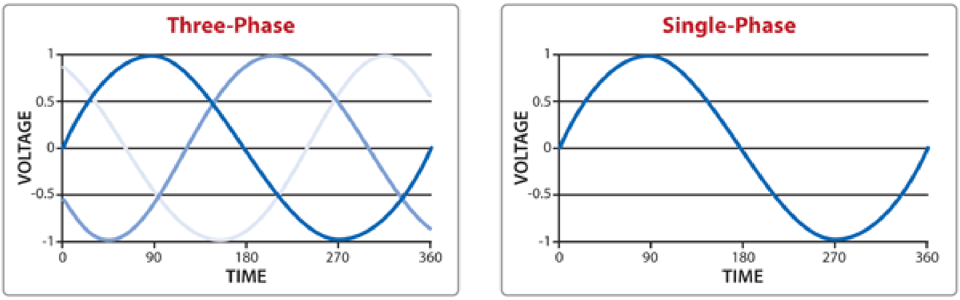
INTRODUCTION

When it comes to the residential PV (Photovoltaic) segment, single-phase inverters are more prominent because the type of network that the electricity distributor offers for household purposes is mostly single-phase. On the other hand, three-phase PV inverters are gaining more popularity because of the rising energy demand and the potential benefits to end consumer if considering readying their home for a renewable energy future. In this white paper we shall discuss the benefits of a three-phase network and three-phase inverters.

Electricity is connected at 230, 240 volts (single-phase), 400 or 415 volts (three-phase). Single-phase enters the home via two wires: active and neutral. Three-phase has four wires: three actives (called phases) and one neutral, which is earthed at the switchboard. Three-phase electric power is more cost effective than a single-phase or two-phase system with the same voltage, mostly because of savings in conductor material.



Source: http://www.tripplite.com

Advantages of a three-phase network

Grid stability and future demand

Local utility interconnection standards typically set a minimum value for imbalance between the phases in order to minimise stability issues in the grid. By using a three-phase inverter in a three-phase supply rather than a single- phase inverter, power fed into the grid is distributed evenly among the phases, creating a more balanced system.

In some states in Australia, according to state service and installation rules, the accumulative voltage rise from PV inverter to mains switchboard, and mains switchboard to consumer mains must not be more than 1% [Service & installation Rules - NSW].

Let's assume there is a 4mm^2 cable running between a 5kW inverter and the mains switchboard (MSB), and a 10mm^2 cable running between the mains switchboard and the consumer mains. The below table shows the difference in percentage of voltage rise when the same cable sizes are used with a single- and three-phase supply.

Network/ Connection type	% Voltage rise Inverter to MSB	% Voltage rise MSB to Consumer Mains	% Total voltage rise
Three phase with a 5 kW three phase inverter	0.38	0.15	0.53
Single phase with a 5 kW single phase inverter	2.1	0.83	2.9

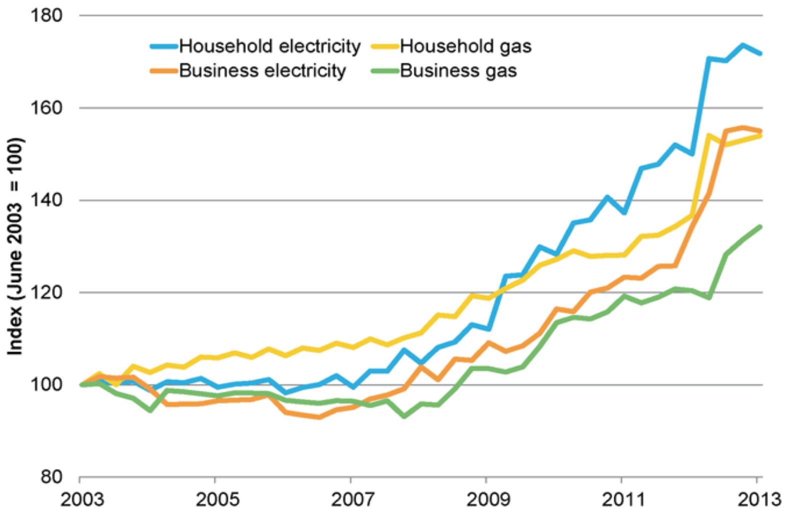
The voltage drop above is calculated using values from Table 42 of AS/NZS 3008.1.1: 2009 Electrical installations - Selection of cables. From the above table it is evident that voltage rise in a single-phase network is significantly higher than that of a three-phase network (to compensate for this voltage rise extra cabling is required, which means extra expense). The penetration capacity of PV in a three-phase network can be greater than that of a single-phase network, which is a significant advantage considering increasing energy demand and prices.

Potential benefits to the end consumer

With rising prices of gas & electricity and increasing demand (refer to graph below), our goal is to optimise the levelised cost of energy (LCOE) by integrating energy storage. By integrating energy storage and being able to install a higher PV capacity by choosing a three-phase network, the end consumer is able to meet his/her energy demand more independently.

For example, with some electricity distributors an end consumer can only have up to 5kW of PV capacity if he/she has a single-phase network whereas the same PV system can be sized up to 15kW (5kW per phase) if a three-phase network is chosen. The result:

- Less dependency on grid for energy,
- Better self-sufficiency,
- Reduced electricity & gas bills.

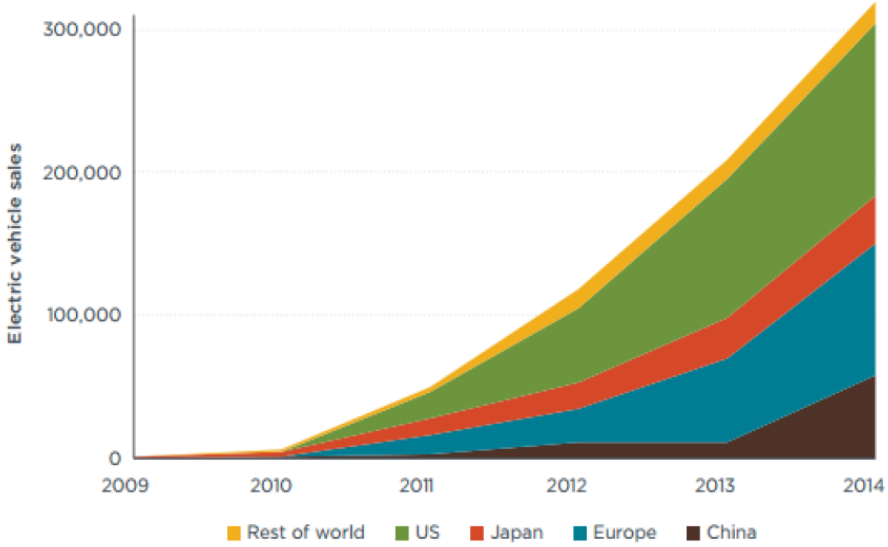


Source: http://www.aph.gov.au/

Faster charging of electric vehicles

An electric car is powered by an electric motor instead of a gasoline engine. The electric motor gets energy from a controller, which regulates the amount of power—based on the driver's use of the accelerator pedal. The electric car (also known as an electric vehicle or EV) uses energy stored in its rechargeable batteries, which are recharged using common household electricity.

We can no longer claim EVs as a future technology since EVs are penetrating the automobile market rapidly (refer to graph below). One of the rising challenges for EV manufacturers is battery charging speed. The time taken to charge EV batteries also depends on the electricity network being used in the owner's home, which may be single- or three-phase.



Source: International Council on Clean Transportation (2015)

Let's consider that an electric car, which has a storage capacity of 85kWh at full charge can cover a distance of up to 500 km. Therefore 1kWh = 5.88 km.

Currently there are three different options for charging EVs at home:

1) 10A charger for single-phase connection
2) 15A charger for single-phase connection
3) 32A charger for three-phase connection*

*The three-phase charger can be configured to operate at different currents (for example 32A and 16A) depending on the circuit breaker available.

Using the above home-charging options, let's calculate the time needed to attain a full battery charge of 85kWh:

10A single phase → 10 A x 230 V = 2.3 kW = 13.52 km/hr = 36.98 hrs to attain full battery charge
15A single phase → 15 A x 230 V = 3.45 kW = 20.286 km/hr = 24.64 hrs to attain full battery charge
32A three phase → 3 x 32 A x 230 V = 22.080 kW = 129.83 km/hr = 3.87 hrs to attain full battery charge
16A three phase → 3 x 16 A x 230 V = 11.040 kW = 64.91 km/hr = 7.7 hrs to attain full battery charge

From the above calculations, we can see that charging is significantly faster when using a three-phase connection. Therefore, by having a three-phase supply at home, one can ensure faster charging of electric vehicles.

Conclusion

From the above calculations we can justify choosing a three-phase network on the following grounds: less voltage rise, higher PV penetration, improved self-consumption rate, faster charging of electric vehicles, and contribution to a better grid stability.