The nominal voltage in Australia had been set at 240 volts since about 1926. In 1980, the International Electrotechnical Committee (IEC) decided to rationalise the 220, 230 and 240 volt nominal voltage levels to a consistent 230 volt standard internationally. This rationalisation was allegedly made to improve the economics of manufactured appliances by allowing manufacturers to produce appliances with only one rated voltage – 230 volts. In 1983, the IEC issued the sixth edition of its voltage standard IEC60038 which adopted 230/400 volts ±10% as the new international standard distribution voltage with a further 4% voltage drop within electrical installations. Countries such as Australia that had a nominal 240 volt system were to have a lower limit of 230-6% at the point of supply.

Standards Australia issued AS 60038 in 2000 with 230 volts as the nominal voltage with a +10%, -6% range. AS/NZS 3000 Wiring Rules still allows a 5% voltage drop within electrical installations. New Zealand has a range of ±6% and the further 5% allowed by the Wiring Rules. Figure 1 shows a comparison of the voltage range in Australia under the old 240 volt standard (AS2926), the range prescribed by the current Standard in Australia and the 230 +/- 6% range that has existed in New Zealand (Electrical (Safety) Regulations 2010) for some time.

Some states of Australia have been slow to adopt the new 230 volt standard although they haven’t changed the way they operate their network except to use the increased lower level to defer augmentation work. In other states, such as Queensland, the 240 +/- 6% voltage range is mandated in their Electricity Act - this conflicts with the range prescribed under the Australian Standard.

This paper seeks to detail some of the issues of discord between the different state based requirements and voltage and product standards. It does not analyse the logic
behind the move to a nominal 230 volt standard, the effect on 240 volt appliances of widening the allowable voltage range at the lower end of the range or the efficiency of equipment over the full utilisation voltage range (the voltage range at the outlets or at the terminals of equipment).

Standards and State Based Requirements
Table 1 details the various voltage level requirements of each state in Australia by network company and that of New Zealand. It can be seen that there is a lack of consistency between the voltage levels and the ranges of voltage, particularly in Australia.

Equipment Standards
Table 2 sets out the differences in rated design voltage and operating ranges, as set out in a sample of Australian Standards, for various equipment classes. Figure 2 graphically highlights these differences.

Analysis and Design Options for Equipment
It is clear from Table 1 that there is no consistency in the way the Australian voltage standard is applied by the different states. There is also conflict between the range of voltages defined in the Standard and the Electricity Act in some states. Therefore, there needs to be agreement on the allowable voltage range. The finalising and adoption by all Australian states of the now draft Australian and New Zealand Standard AS/NZS61000.3.100 would seem to be the logical way of achieving consistency.

Figure 2 clearly shows that there is a gap between equipment design requirements as determined by Australian Standards and the Australian voltage Standard. A reduction in the Wiring Rules’ allowable voltage drop within electrical installations to 4% (in line with international practice) would help to narrow the gap for some of the equipment detailed in Figure 2 and provide greater consistency with international standards. This recommendation does not consider whether the increased cost within an installation is justified when compared to the reduced losses and the cost of manufacturing appliances to operate over a wider voltage range.

The most significant equipment incompatibility with the range of voltage is for motors. From the Australian Standard (AS/NZS60034.1), motors are to operate within ±5% of 230 volts (Zone A – see Figure 2). Motors can operate within Zone B, (the range widen to ±10% - see Figure 2) but this relies on motors generally being underrated for the work being performed with excursions into this zone limited in value, duration and frequency of occurrence. Essentially, fully loaded motors designed only to the Australian Standard will not cope with the range of voltages allowed within Australia. Even for lightly loaded motors there is a compatibility gap evident at the bottom of Zone B as the lower utilisation voltage limit is below the design requirements for Zone B.

Electronics could be installed on the front end of all motors to ensure motors could cope with the full range of voltage but this would cause unnecessary expense especially given that not all sites receive voltage towards the outer extremities of the distributor’s allowable voltage range and that not all installations fully utilise the allowable 5% voltage drop. Motors are presently available with various nominal voltages and voltage ranges specified and it is the responsibility of the designer and/or installer to choose a motor that can cope with the allowable voltage range or fit a variable speed drive to the motor.

There is also a major compatibility issue with lighting, as AS/NZS60589.1 specifies a range of 240 volts ±10%. Electronic ballasts are still not often used in larger wattage light fittings, such as is used for street or sport field lighting. Light output is very dependent on voltage in these sorts of lights, and consequently lighting design needs to take voltage levels into consideration to ensure light levels meets the requirements of the Australian Standards. Electronic ballasts capable of operating efficiently over wider voltage ranges are becoming more common for smaller wattage lights.

Using electronics to control voltage to many types of heating appliances is a cost...
An effective way of coping with the full allowable voltage range. For stoves, the element could be designed to work efficiently on the lower end of the voltage range and the controller could incorporate electronic voltage control to the element instead of the more traditional simmerstat. The same could be said for toasters, fan heaters, etc. This would add minimal cost to the initial purchase price, but would improve temperature control and efficiency. Heating appliances such as electric blankets, hot water systems, bar heaters, jugs and electric oil heaters/radiators will simply take longer to heat up at lower voltages. These should therefore be designed for the highest allowable voltage.

Clearly the discord between appliance and voltage standards as highlighted in Table 2 and Figure 2 needs to be resolved.

Minimum Energy Performance Standards (MEPS)
A sample of Australian/New Zealand Standards for MEPS for various classes of equipment were investigated to see what voltage is specified for testing for the star rating for the equipment. It was found that the test voltage is maintained with ±2% of the rated voltage for the majority of tests across the various types of equipment (refer Table 3 for more detail).

This may mean that a piece of equipment with a low star rating may actually perform better at the extremities of the 230 volt utilisation voltage range than better star rated equipment. It also means that the MEPS rating is meaningless for most equipment connected to the typical voltages Australian distributors are currently delivering.

Conclusions
Requirements for voltage and voltage range needs to be consistent across Australia. The Australian National Electricity Rules (NER), rather than state-based regulation, needs to specify requirements for voltage in Australia. This could be achieved by defining the required standard in the NER.

A major overhaul of Australian equipment standards is recommended with all standards nominating the rated supply voltage as 230 volts with an operating range of ±10%. All equipment nameplates should specify the nominal voltage and effective operating range. Consistency is required within Australian/New Zealand MEPS standards and the star rating needs to provide a proper indication of equipment performance over the full utilisation voltage range.

The Wiring Rules allowable voltage drop should be reduced from 5% to 4% to align with international standards and to allow equipment to operate more effectively.

Manufacturers will need to consider the design of their products to achieve the requirements of any revised equipment standard and to operate over the allowable voltage range. Harmonics will need to be managed by careful design of equipment to ensure trouble free operation of the equipment and to prevent more widespread problems.

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| Table 3 – Test Voltage for MEPS from Australian Standards for Various Types of Equipment |
|-----------------|-----------------|-----------------|-----------------|
| Equipment                  | Standard                  | Test Voltage                  | Test Voltage Range |
| Air Conditioners and heat pumps | AS/NZS3823.1.1:1998  | 230 or 240V depending on marking | ±2%             |
| Rotary Clothes Dryers       | AS/NZS442.1:1996     | 230V                          | ±2%             |
| Dish Washers                | AS/NZS2097.1:2005     | 230V or 240V depending on marking | ±2%             |
| Refrigerating appliances    | AS/NZS4474.1:2007     | 230V                          | ±2%             |
| Television Sets             | AS/NZS62087.2:2010    | 230V                          | Not specified   |
| Clothes Washing Machines    | AS/NZS2040.1          | 230V                          | ±2%             |