

In this document I've attempted to lay out some of the historical perspective and reasons on why UPS systems were, and now are, rated the way as they are.

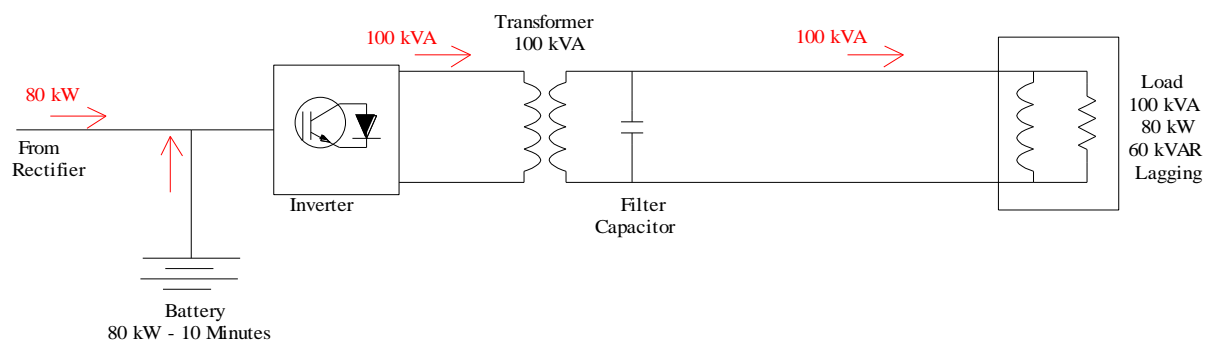
There's a fair amount of 'hand waving' style explanation and the layout and maths isn't rigorous, but I hope that the pertinent points come across. I've used a generic 100 kVA in the explanations for ease of use.

There are a few major reasons why UPS systems were typically tested at 80% of their nameplate kVA capacity, with a resistive load.

UPS systems, in the dim dark past, were normally given an output specification at a certain power factor, with the caveat that the power factor was assumed to be lagging – inductive. Normally this was given as a 0.8 PF, so that a 100 kVA system was rated at 80 kW.

This meant that the DC section of a UPS – Rectifier, batteries etc – could be designed to provide 80 kW of load. A system that was called upon to provide 10 minutes of back-up time (autonomy) would have the battery designed to provide enough energy to give 80 kW for ten minutes (excluding inverter losses).

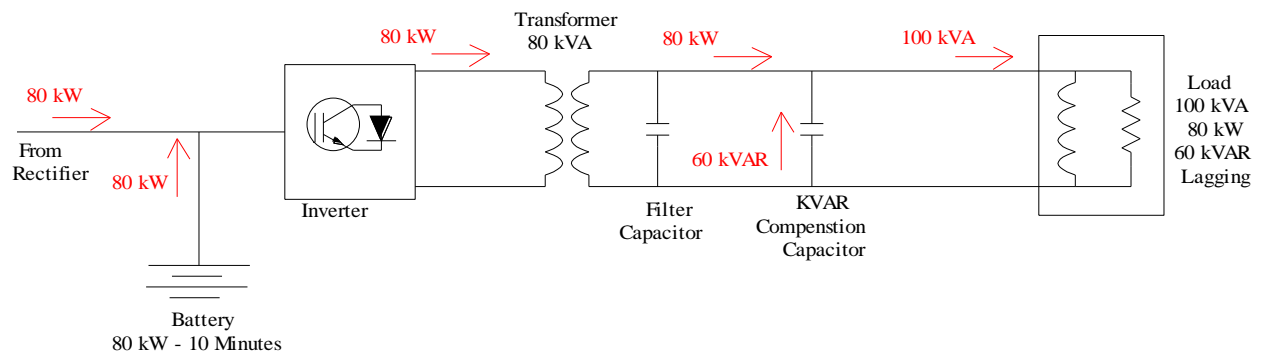
I've tried to show, in the next few diagrams, why this all came about. I've simplified terribly and made some wild assumptions, but hopefully the general idea is driven home.



Above is shown a standard 100 kVA PWM UPS. For ease of explanation I've assumed that it's a perfect UPS in that there are no losses in any section. For a specified 100 kVA at 0.8 lagging P.F then we have 80 kW of resistive load and 60 kVAR of inductive load. The kVAR portion of the load shuttles back and forth between the load and the inverter of the UPS, so that the transformer and inverter sections need to be sized to carry 100 kVA worth of current (sic), with the anti-parallel diode of the switching device carrying the inductive current when the device has switched off. The rectifier and the battery only need to provide the resistive component of the load (80 kW) and were therefore sized accordingly.

So in this scenario placing a resistive load of greater than 80 kW on the output meant that you may have been stressing the DC link in the UPS, as in this case it will have to provide more than the 80 kW it was designed to meet. Also, as the battery is only designed to provide 80 kW for ten minutes, if the load is greater than this you won't meet the expected autonomy time.

It was then realised by some smart engineer that we could offset the KVAR portion of the load and therefore save money on the size of the inverter and transformer in the UPS, as I've shown in the next diagram.

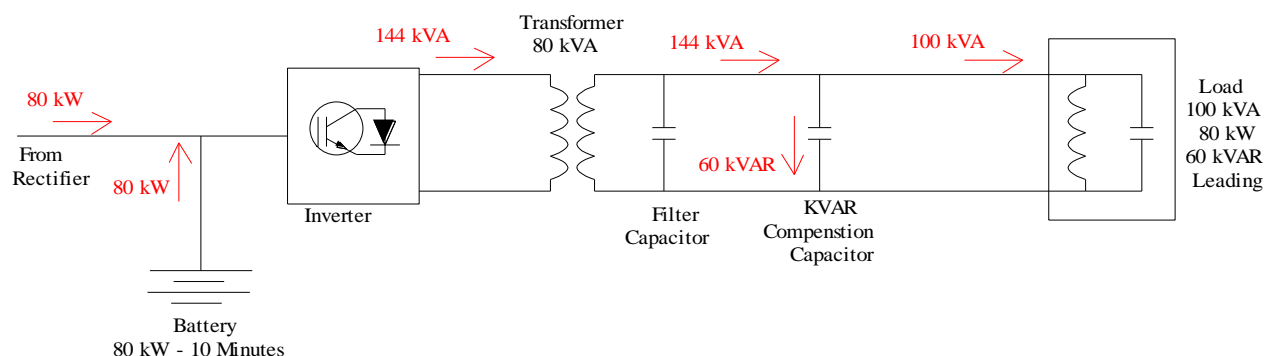


In this case the load has remained the same. What has been included is a large capacitor (60 kVAR) for kVAR compensation. As the inverter and transformer now no longer need to provide the loads kVAR current they can be downsized. In the above case the transformer is now 80 kVA.

If you now tried to test this UPS with a 100 kW load you'll not only be stressing the DC components but also the inverter and transformer which have only been designed to cope with the resistive part of the load, the kVAR compensation capacitor there to offset the inductive current required by the load. I realise that in practice, with just a resistive load, that the inverter and transformer will need to provide the kVAR current to the compensation capacitor – but I've ignored this for simplicity.

This was a widespread practice amongst UPS manufacturers and allowed them to cost and weight down on their systems. It stood them in good stead for many years, until design changes in computer power supplies came and bit them in the arse.

In the late '90s there was the push towards more efficient computer power supplies which saw smarter switched mode power supplies enter the market. These supplies had a power factor far closer to unity and in many cases the power factor actually became leading – capacitive. This had a fairly detrimental effect on the older style UPSs as I show below.



This is the same UPS as shown in the second diagram, except in this case instead of the load being inductive it is now shown as capacitive. Instead of now being a compensation capacitor, this capacitor now is seen as a load by the inverter / transformer which also has to supply the capacitive

kVAR of the load, so a total of 120 kVAR of capacitive load needs to be provide for as well as the 80 kW of resistive load. This led to a lot of overheated UPS systems as an 80 kVA transformer attempted to provide 144 kVA of load. So in the late '90s and the early part of this century there were a lot of UPS engineers and technicians running around and telling their clients that they need to derate their UPS systems, in some cases quite severely.

The capability curve of a UPS can be shown with a Heyland diagram. On this diagram the X axis is kVAR, the Y axis is kW and therefore the lines leading to each of the power factors shown is the kVA.

The first one I've shown below is for a UPS that had a 40% compensation capacitor fitted to its output. The area of 'normal' operation is shown within the res lines. This is for a UPS specified as 0.8 power factor – Lagging (inductive). The inclusion of the offset capacitor severely limits the amount of kVA the UPS can provide in the leading kVAR section (left hand side) of the diagram.

At a power factor of 0.8 lagging (right hand side) the UPS can provide 100 kVA.

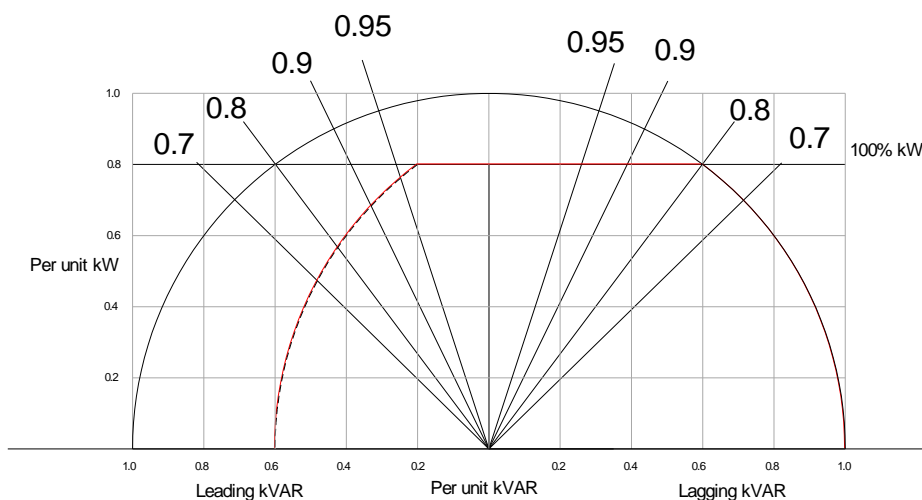
At a power factor of 0.9 lagging (right hand side) the UPS can provide 89 kVA.

At a power factor of unity the UPS can provide 80 kVA.

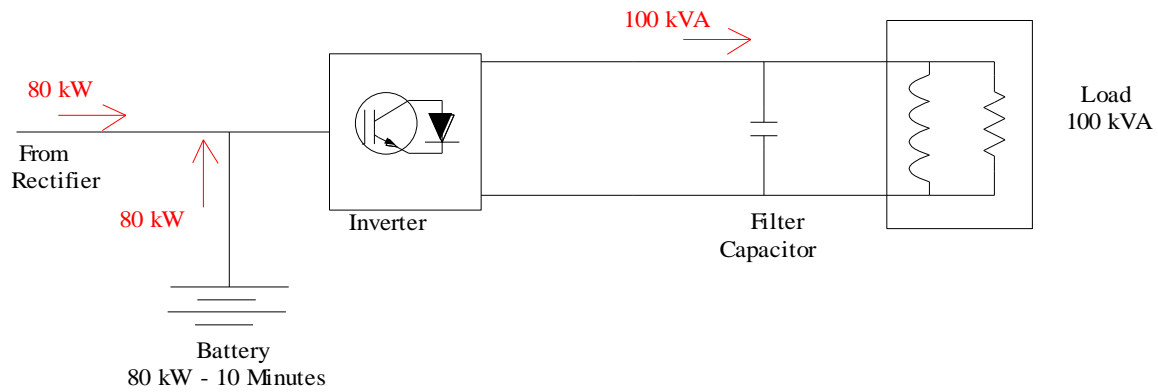
At a power factor of 0.9 leading (left hand side) the UPS can provide 76 kVA.

At a power factor of 0.8 leading (left hand side) the UPS can provide 70 kVA.

In the early part of this century it was quite common to see computer loads with power factors of 0.92 – 0.93 leading, at least where I'm located – Australia, and so telling customers that they could only use approximately 75% of their rated nameplate was quite common, if somewhat disconcerting for the engineer who had to provide the advice ☺.



And so to the present. The transformer within the UPS has been done away with as has the kVAR compensation capacitor. Manufacturers have realised that the power factor may be leading or it may be lagging or it may even be unity and so have adjusted their UPSs to suit. There's now actually two main streams of UPS, those that still come with a specified power factor, be it 0.8 or 0.9, and those that are now called 'fully rated' in which if the UPS is a 100 kVA it is also a 100 kW machine. Like anything else in life you get what you pay for and the devil is in the detail.



The Heyland diagram shown below is for a UPS rated at 0.8 power factor. Assuming a 100 kVA UPS we get the following:

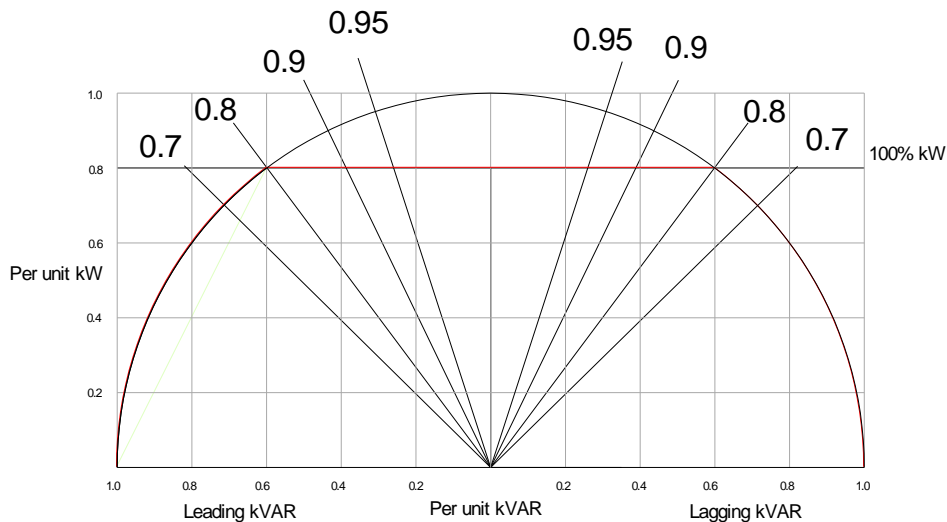
At a power factor of 0.8 lagging (right hand side) the UPS can provide 100 kVA.

At a power factor of 0.9 lagging (right hand side) the UPS can provide 89 kVA.

At a power factor of unity the UPS can provide 80 kVA.

At a power factor of 0.9 leading (left hand side) the UPS can provide 89kVA.

At a power factor of 0.8 leading (left hand side) the UPS can provide 100 kVA.



As with the earlier systems, the rectifier and battery will only be sized for the resistive load with this style of unit and attempting to increase the load above the specified 80 kW may cause stress on the DC link components.

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