Preliminary copy.
Not for public distribution.
Response will be welcomed.

Whitepaper:

Running
AC SMPS on DC

Comments to common questions about feeding DC to power supplies originally rated for AC.

By
Christer Boije af Gennäs
MSc.E.E
Netpower Labs, System Design
chris.boije@taki.se

This paper comments on a number of questions frequently asked on feeding 350 VDC to power supplies originally rated for AC.

The comments apply to to switch mode power supplies (SMPS) having a nominal input range 100 – 240 V or 220 – 240 V, 50Hz, 60 Hz AC run from 350 V DC (nominal).

The fact is there:

Many power supply units do work perfectly well on 350 VDC (nominal).
Some don't, for various reasons like design shortcuts (e g support-voltages generated by means of capacitive or inductive coupling) or deliberate blocking when fed from dc (sensing ac zero-crossings etc).

The following are some comments to the difference between ac feeding and dc feeding for typical power supply units. See Fig. 1 on page 4 for an explanatory illustration.

1. The internal voltages in the power supply will not be any higher when fed from 350 VDC than fed from a 230 VAC line.
   230*1.1* √2 = 358 V peak voltage which the AC power units must be designed to withstand continuously on the input. Most nominal 100V – 240 V AC SMPS are rated +10% = 264 V maximal input voltage - corresponding to 373 V DC. Thus 350 V DC gives some headroom for occasional overvoltages and transients etc.

2. The input dc voltage, with a battery across it, is virtually free from transients (overvoltage category I) whereas the ac power line is far from that (category II or III).
   Overvoltage category I states max 1500V impulse voltage, category II max 2500 V, overvoltage category III (fixed installations) max 4000 V, see appendix 1.

3. The currents in the input circuit will be lower when run on dc, both peak values and depending on circuit solution, often also RMS. See appendix for an example.
   This is valid also for power supplies with near-perfect PFC in the input because of the necessary AC filter components and diode commutation.

4. The stress on components will be lower as the regulator circuits don't have to work so hard.
   Recent research shows that silicon circuits indeed are subject to stress fatigue. In fact there is even an audible difference for many power units.

5. The active power components can work in a more relaxed mode since the repetitive swing in pulse width (PWM) will be smaller.

6. Electrolytic capacitors will see less ripple current.
   High ripple currents is what kills electrolytics.

7. Reservoir capacitors (electrolytics) for the switching circuit are normally designed with a 400 VDC rating.

8. Internal cabling will not be exposed to any higher voltages than when fed from ac.

9. Thermal load of cables and power components will be less because the RMS currents are lower.

10. Input filters contain X- and Y capacitors. Typically, most X and Y capacitors have a voltage rating of at least 250 VAC, 600 VDC.
    "…acceptable for use in any application with a voltage requirement up to and including 250 VAC. Note that 250 VAC equates to 350 VDC. Add the +10% tolerance onto both of these values and the actual maximum ratings are 275 VAC and 385 VDC."

11. Normally it is only the input circuit - upto and including the diode bridge - that has to be considered regarding creepage and clearances when comparing dc and ac operation. (See appendix 2 for explanation of creepage, clearance and tracking phenomenas.)

    Clearance: The norms are based on ac peak voltage, which compares to the dc voltage. Battery fed dc equipment falls into overvoltage category I but ac feeding means category II or III, see appendix 1. Consequently the clearance distances designed into equipment intended for ac will fulfill norms for category I dc operation with good margins.
    Creepage: The creepage distance for 350 VDC is specified as slightly higher than for 230 VAC operation. The working voltage in the norm tables sets equality between ac rms and dc voltage. This is mainly due to the assumption that electrostatic "tracking" and pollution effects are slightly more protruding with dc than ac.
    The printed circuit boards in SMPS are normally coated with layers of insulating laquer to handle above effects. Dielectric break-through usually occurs at a higher voltage for dc than for ac.

    Providing the equipment is designed according to sound design rules and is used in an environment without excessive pollution or moisture there should be only a little risk on this point. See also point 13 for failure mode discussion.

12. The mains switch in the power supply normally presents no problem with dc. Since the load side of the switch is capacitive both sides of the switch will have the same potential immediately after a ***break*** operation, meaning no arcing can occur. At ***make*** the power supply in most cases has a current inrush protection, needed for ac and dc alike.

13. Fuses and circuit breakers could be a problem. It is harder to break dc than ac in case of a short-circuit. Overcurrent protection for cables and connectors ***must*** be handled by using certified dc rated fuses. Either you replace an existing fuse in the equipment or, more common, you use an external certified dc fuse.
    This also takes care of unlikely, but possible, problems of suspicious creepage clearance. The failure mode for that case is short-circuit. A certified fuse will be able to protect in case of such a failure. John Akerlund of Netpower Labs AB has got authority approval for this solution.

14. About safety product certifications:
    Safety ought not to be a problem in reality. Both current and voltage stays within permissible limits.
    Danger for human health and life is less with dc than ac.

15. Manufacturer warranties for the power supplies will of course be void unless you are able to convince the manufacturer to certify it for dc as well.
    There should be no reason (as seen from above) for him to deny, as long as he trusts his design.
    If you introduce dc feeding for existing equipment it may wello be that the equipment is so old that the warranties are no longer in force anyway. If you get a failure it is very unlikely to be caused by the dc operation, see above. You have to buy a new power unit, **regardless** of ac or dc feeding, which is no big deal. Server center owners do that all the time, more often with ac.

16. Warranties for the connected equipment should still be valid. The output data of the power supply is not changed.
But that is of course a discussion. If taken to court it will be up to the manufacturer of the connected equipment to prove that his equipment is maltreated by the fact that the power supply was fed from dc. A bunch of lawyers will become even richer.

Conclusion
The total picture of running SMPS equipment originally designed for 230 VAC on 350 VDC is that it will present very few problems. Far from being harmful to the equipment it is likely to improve both safety and the lifetime of it.
The only potential issue is if the equipment should happen to be designed with excessively narrow margins regarding creepage distances in the input circuit. This case will effectively be handled by inserting a DC rated fuse in the in circuit.
It entirely is up to the reader, based on this and other information, including own judgement, to decide whether he wants to run existing ac units on dc or not.
It would in most cases not cost the power supply manufacturer a lot to certify his regular ac product for dc as well. Demand that, and save lots of valuable energy!

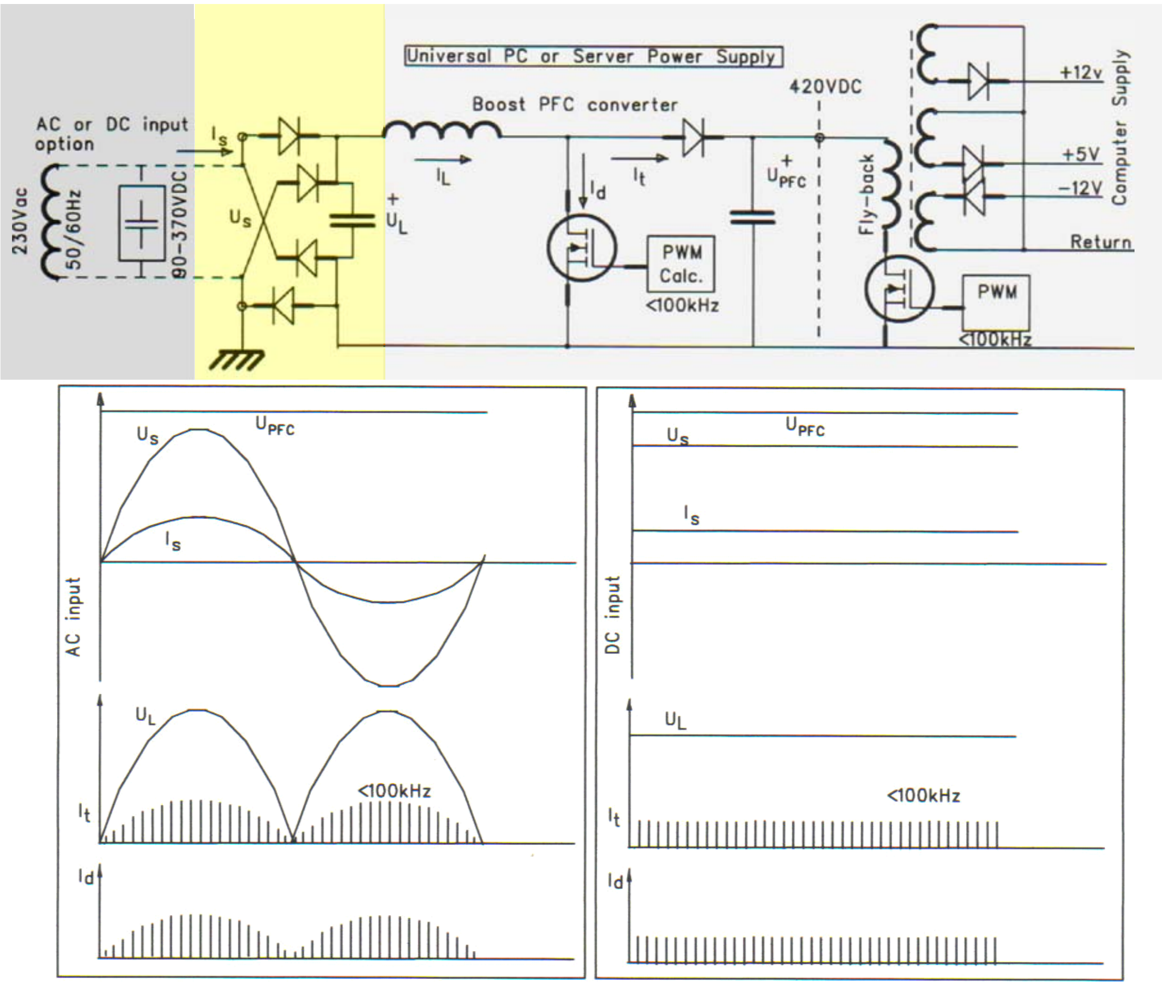


Fig 1. Typical circuit digram for switch mode power supply with active power factor correction circuit. The voltage/current graphs illustrate the difference between ac and dc input.
Note that only the yellow area is affected voltagewise by change from AC to DC feeding.

Appendix 1: Overvoltage categories

The overvoltage category (also known as installation) is divided into four categories according to ***IEC 60664***:

Overvoltage category I
For equipment used in devices or in parts of installations where no overvoltages may occur.

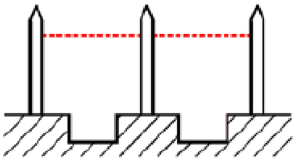
Overvoltage category II
For equipment used in installations or in parts of them where transient overvoltages have not to be taken into consideration, but where overvoltages generated by operation of the equipment may occur.
This applies i.e. to electrical appliances.

Overvoltage category III
For equipment used in installations or in parts of them where transient overvoltages have not to be taken into consideration, but where overvoltages may occur. In view of security and availability of the equipment or depending nets there are special requirements.
This applies to equipment for fixed installations.

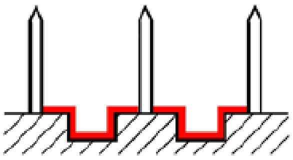
Nominal net voltage for a.c. voltage system acc. to DIN IEC 38 in V	**Rated impulse in V for for overvoltage category**			
	I	**II**	**III**	**IV**
230/400 277/480 1)	1500	2500	4000	6000
400/690	2500	4000	6000	8000
1000	4000	6000	8000	12000

1) Including the nominal net voltage of 500 V

Appendix 2: Clearance, creepage and tracking



Clearance



Creepage

Clearance distance:
The shortest distance through the air between two conductive elements.

Creepage distance:
The shortest distance along the the boundary surface of an insulating material and air between two conductive elements.

Tracking:
The formation of conductive (norm. carbon) paths along the creepage suface. It is depending on creepage distance, material choice, working voltage (ac rms or dc), time, and degree of pollution.