

# The Ideal Green UPS



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Next generation of „green“ UPS technology gives the DP300E series of 3 phase UPS products unique performance.

## Introduction

Traditional Double-conversion UPS increasingly become a problem for utilities and for power consumers that are not protected by a UPS.

This is because of the harmonic currents, such traditional UPS send upstream the powerlines. Such harmonic currents disturb the voltage quality on the power line which in turn may cause sensitive equipment to malfunction, power factor controlling capacitor banks to explode as well as distribution transformers to over-heat.

Traditional Double-conversion UPS waste a lot of energy because of the inherently high losses, and as UPS are normally operated 24 hours a day, 365 days a year, the waste amounts of energy lost really count on the energy bill, as well as

impacting the global resources of energy in a negative direction.

Traditional Double-conversion UPS do not efficiently utilize the utility network and the local installation because of a low input power factor on the UPS.

This leads to requirements for over-dimensioned power installations, locally, on distribution level and eventually on the transmission level. Also an optional diesel generator would have to be significantly oversized.

This has all been changed with the introduction of Silcon's next generation of „green“ UPS technology called Delta-conversion, for the first time applied in the new DP300E 3 phase on-line UPS systems.

Compared to traditional Double-conversion UPS, the new technology provides:

- Energy waste reduction from presently 10% down to 3%
- Harmonic current reduction from presently 30% down to less than 3%.
- Utilization of power installation etc. from presently 80% up to 99%.

## Basic principles:

In fig 1, 2 and 3 the three principles Double-conversion, Single-conversion and Delta-conversion are shown in single line schematics.

The Double-conversion scheme is readily understood, the rectifier charges the battery and supplies the inverter with DC power, the inverter supplies the load with continuous, regulated AC power and during mains outages energy is taken from the battery until the mains is available again. The rectifier then charges the bat-

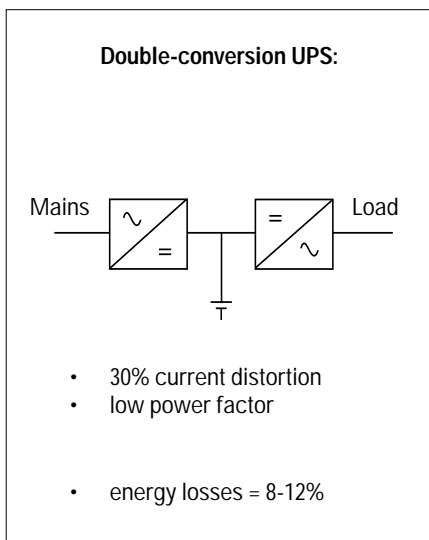


Fig. 1

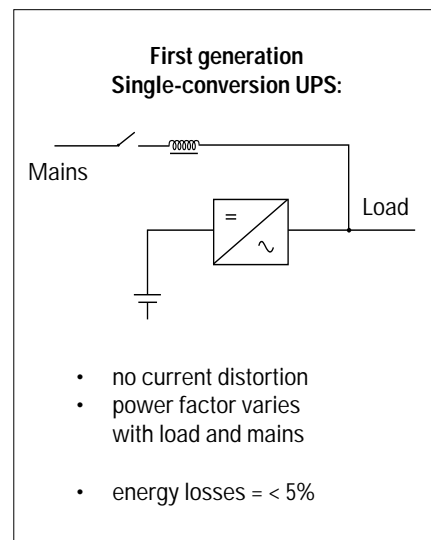


Fig. 2

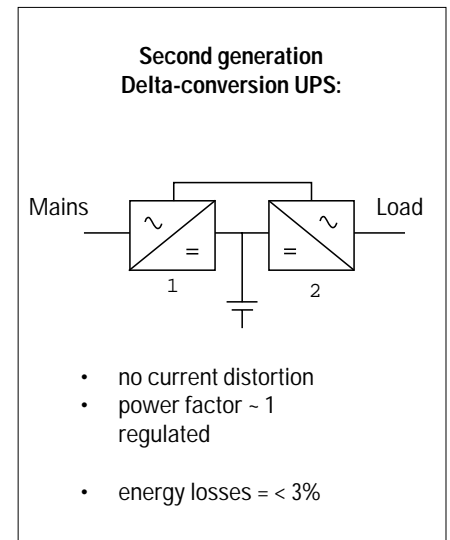


Fig. 3

tery again while still supplying the inverter with DC power. All transitions from mains to battery operation and vice versa take place without any interruption on the output and the load is thus supplied by a continuous, regulated AC voltage of high quality.

Such qualities are inherent qualities of on-line UPS systems and such qualities are therefore also found in the Single-conversion UPS as well as in the new Delta-conversion UPS shown in fig. 2 and 3. All types are normally equipped with an electronic bypass switch and this will not be discussed here.

In fig. 2 showing the well proven Single-conversion scheme, the biggest difference to fig. 1 is the lack of a separate rectifier. Instead the inverter is of the 4-quadrant type meaning that it can pass power in either direction. Therefore it can replace the rectifier.

In normal operation, the mains switch is closed and power is taken from the mains. The majority of power is passed on to the load via the choke, thus the power is not converted twice as in the Double-conversion system. This means very low losses compared to the Double-conversion system.

It may not be obvious, but the inverter is still controlling the output voltage although the majority of the power is not converted.

Since the voltage is always sinusoidal, it follows that the current taken from the mains via the choke is also sinusoidal, thus there are no mains harmonic currents from this system. This is in contrast to the Double-conversion type with its well known thyristor controlled rectifier, burdening the mains with heavy harmonic currents.

In case of a mains outage the Single-conversion system performs identical to the Double-conversion type, energy is simply taken from the battery, and the inverter, which is continuously running

and in regulation, now supplies the load from the battery. In order not to feed back into the mains during battery operation, the mains switch is opened.

Upon mains restoration the switch is closed again and the load is now again supplied via the choke from the mains, but the inverter still controls the output voltage. At the same time the inverter now also works as a rectifier, charging the battery in a controlled way simply by passing power in the reverse direction into the battery.

Thus the Single-conversion UPS seems pretty ideal with its low losses, sinusoidal mains current and simplicity, but it has one drawback common with the Double-conversion system and that is a relatively low power factor to the mains. Furthermore the power factor varies with the mains voltage and partly with the load.

Thus, utilization of the mains installation is not optimum.

Also, at high mains voltage (+10% to +15% of nom.) losses increase in a Single-conversion system as shown in fig. 2.

This is because of increasingly higher reactive currents that the inverter has to support when the difference between mains voltage and output voltage is high (large voltage across the choke). Even with such small drawbacks, the Single-conversion system is by far superior to the Double-conversion UPS.

## The Delta-conversion principle

Continuous search for improvement, and new technology becoming available have led to the next generation UPS technology called Delta-conversion.

This technology eliminates the small drawbacks of the Single-conversion UPS and comes very close to an ideal solution.

As can be seen from fig 3. the system has 2 inverters connected to a common

battery. Inverter 1 is rated at typical 20% of the output power of the UPS, and is connected via a transformer in series with the mains supplying the load. Inverter 2 is a fully rated inverter and has basically the same function as the inverter in the Single-conversion UPS.

Both inverters have 4 quadrant capabilities.

Inverter 2 keeps the voltage to the load stable and precisely regulated be it in mains operation or in battery operation or during transitions from mains – to battery operation or vice versa.

Inverter 1, called the Delta inverter, makes up for any difference between the voltage on the output of the UPS and the voltage from the mains.

The Delta inverter also controls the input power factor to unity as it is controlled to take up current from the mains that is sinusoidal and in-phase with the mains voltage.

Furthermore the Delta inverter controls the charging of the battery.

The mains switch has the same function as in the Single-conversion UPS namely protection against back-feed into the mains.

Let us recall the performance differences between the 3 different types of UPS. In fig. 4 the heavily distorted input current of a Double-conversion UPS is seen to distort the mains voltage severely. Especially the notches in the voltage waveform should be noted, they result from the unavoidable commutation process in the thyristor controlled rectifier. Such notches can cause other equipment, connected to the same mains, to malfunction and can cause extremely high peak currents to flow in compensation capacitors, with a high possibility of destroying such capacitors.

In fig. 5 we have the current from the Single-conversion UPS and since this current is nicely sinusoidal in shape there is no resulting distortion of the mains volt-

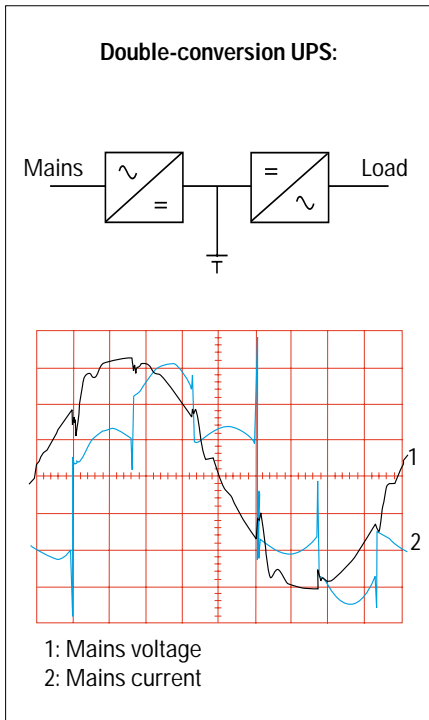


Fig. 4

age. But it can also be seen that there is a certain phase deviation between voltage and current, hence the power factor is not unity, which is desirable for the best utilization of the power grid.

Fig. 6 shows the „ideal“ UPS, the Delta-conversion type.

As can be seen there is no current distortion or voltage distortion and voltage and current are nicely in-phase, hence unity power factor.

So far so good, but haven't we made a UPS with the losses of Double-conversion type now that we have two converters?

Not at all, this new system is much more „clever“ than it seems at a first glance.

Let us go through some different operating conditions and watch the power flow, size and direction, during these different conditions.

Fig. 7 shows the nominal condition i.e. there is no difference between mains and output voltage, batteries are fully charged and load is 100%.

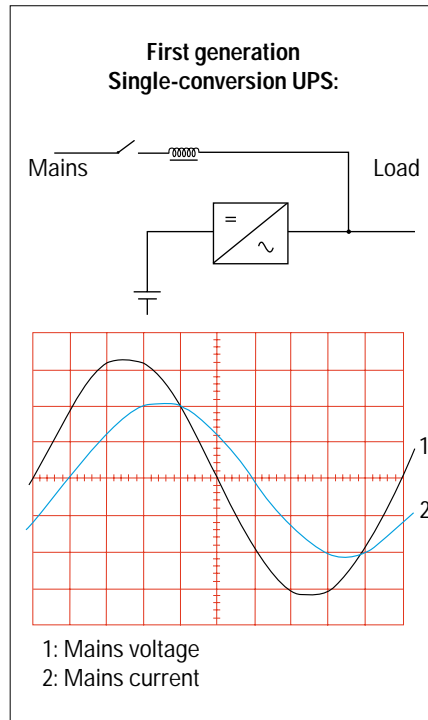


Fig. 5

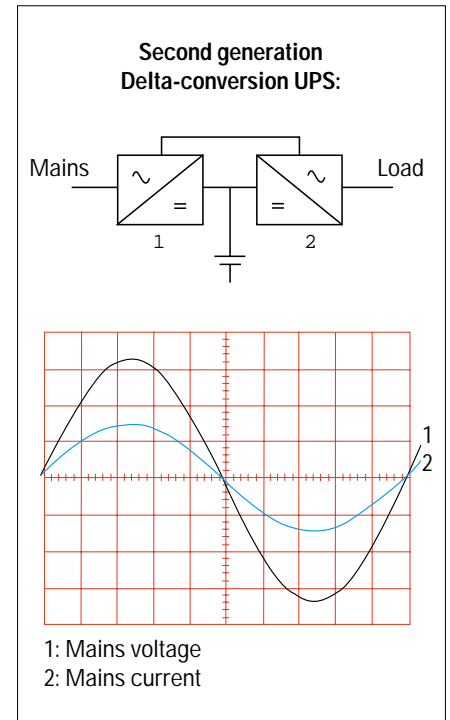


Fig.6

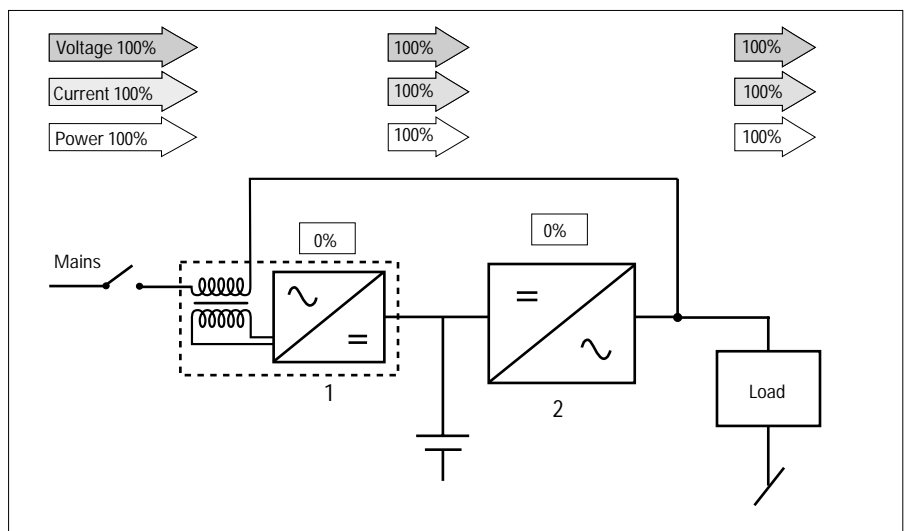


Fig. 7

The Delta inverter (1) is only supporting the mains current, which in this case is equal to the load current (linear resistive load assumed). Since the „delta voltage“ across the transformer is zero it follows that the netpower from or to the Delta inverter is zero.

Also the main inverter (2) is idling since its regulated output voltage is exactly equal to the mains voltage.

So in the idealized form all power is going directly to the load, nothing is converted, hence no losses. In practice there are of course small losses from the idling

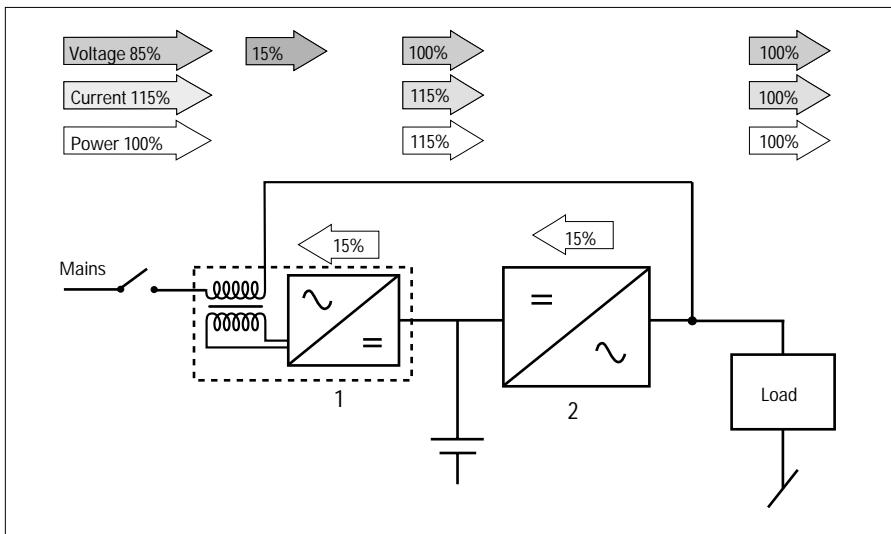


Fig. 8

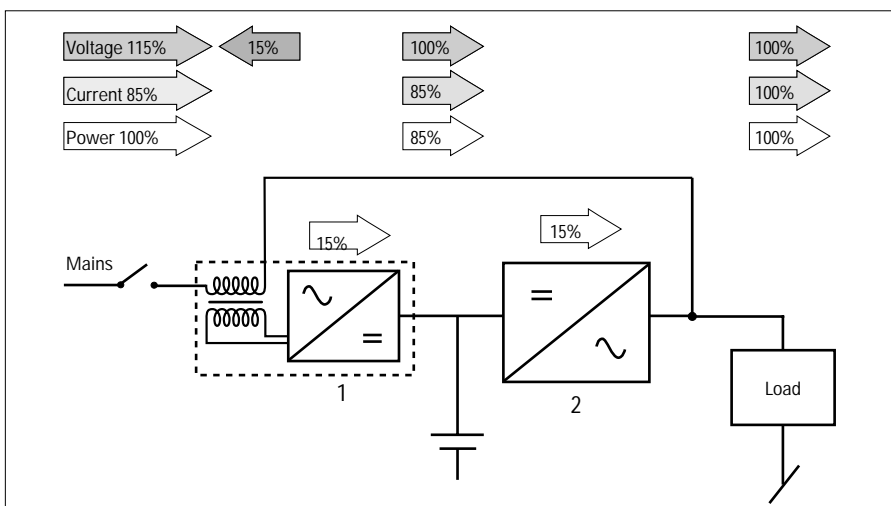


Fig. 9

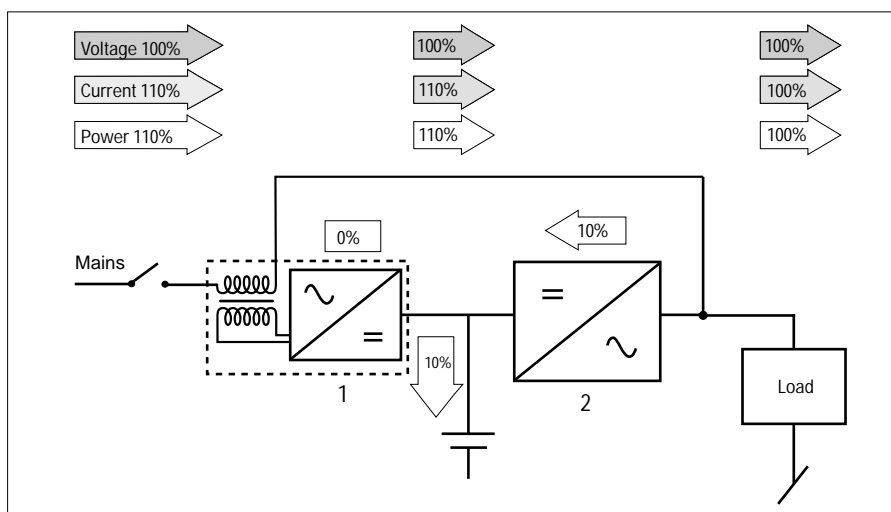


Fig. 10

power circuitry, magnetic components and fans.

In case that the load is not resistive but also has a reactive or a harmonic part, such reactive or harmonic currents are supported by the main inverter since they cannot be taken from the mains (this is prevented by the way the Delta inverter takes up the mains current).

Such reactive or harmonic currents will increase the total losses slightly but efficiency is still exceptionally high.

In fig. 8 it starts to get really interesting. Here we have a situation with under voltage on the mains, in this case -15%

Since the output voltage must remain stable and regulated to within +/- 1%, it follows that the Delta inverter via its transformer must „add 15% to the mains voltage“.

But where does this additional power come from?

It is simply taken from the mains via the output of the main inverter, passed backwards through this inverter, via the DC link and finally forwards through the Delta inverter to the transformer.

This is a true Double-conversion process with related losses, but the big difference here compared to traditional Double-conversion is that it is only the delta between input and output that is converted, so if we f.ex. assume the total losses in a traditional Double-conversion UPS to be 10%, and assume that our two inverters together have a similar efficiency, then it follows that our total losses in the -15% mains case will only be  $0,15 \times 10\% = 1,5\%$  because only 15% of the total power is converted.

At -10% mains the losses would then be  $0,10 \times 10\% = 1\%$  and so on.

Fig. 9 shows the case of high mains voltage.

Now the Delta inverter must „absorb 15% of the mains voltage“ to make the balance.

In this case 15% of the power is passed via the Delta inverter, via the DC link and finally via the main inverter to the load. Again a Double-conversion process, where the same loss considerations as in the fig. 8 case apply.

In fig. 10 we again have a nominal situation except that the battery is being charged.

Here we see 110% power being taken from the mains and since the load is not taking more than 100% the remaining 10% is passed backwards through the main inverter and absorbed in the battery as charging current.

There is an interesting „job sharing“ between the two inverters.

The main inverter just keeps synchronized to the mains and controls the output voltage in all operation modes. (In battery operation its frequency is controlled by an internal frequency reference as in all other on-line UPS).

The Delta inverter controls the input power factor, the charging of the battery by „importing“ more or less power from the mains than necessary for supporting the load, and finally it makes up for any difference in voltage and waveform between the mains and the output voltage.

In the battery charging mode the main inverter is passing the „excess“ mains power into the battery, but the control of the charging is done by the Delta inverter.

### Performance of the new system

In the following various performance curves are shown, to prove the advantages of the new topology.

Fig. 11 shows the overall efficiency as a function of load and mains within  $\pm 15\%$ . It is seen that the efficiency is exceptionally high, the curve is flat and virtually independent of the mains voltage. This all means low losses, also under non ideal conditions.

Fig. 12 shows the input power factor under similar conditions as in fig. 11.

Again we notice an extremely high power factor of more than 0,99 in a very wide operating range.

In fig. 13, just to avoid any misunderstanding as to whether this type of UPS is on-line or not, output voltage is shown during transitions of mains outage and mains recovery.

As can be seen the output voltage is unaffected by such transitions, proving on-line capability.

### Comparison and conclusion

In fig. 14 a comparison between the three UPS types is made. It is seen here that the Delta-conversion UPS comes close to an ideal „green“ UPS, i.e. minimum energy waste and no mains pollution.

The Double-conversion UPS will certainly have a hard time among energy conscious engineers and customers in the future, now that a true „green“ UPS is available.

It is also interesting to note what it would take to make a traditional Double conversion UPS match the Delta conversion UPS, just on the mains side qualities.

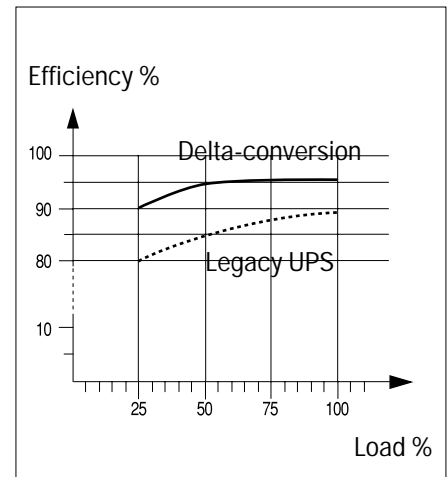


Fig. 11

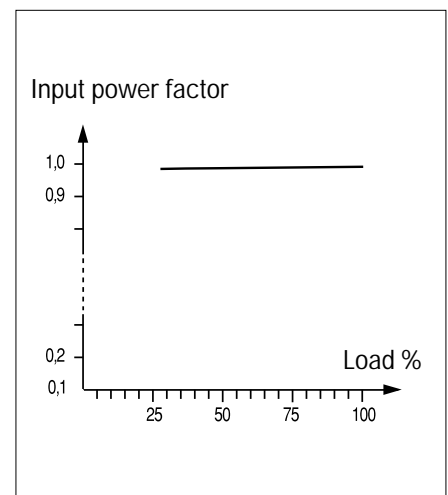


Fig. 12

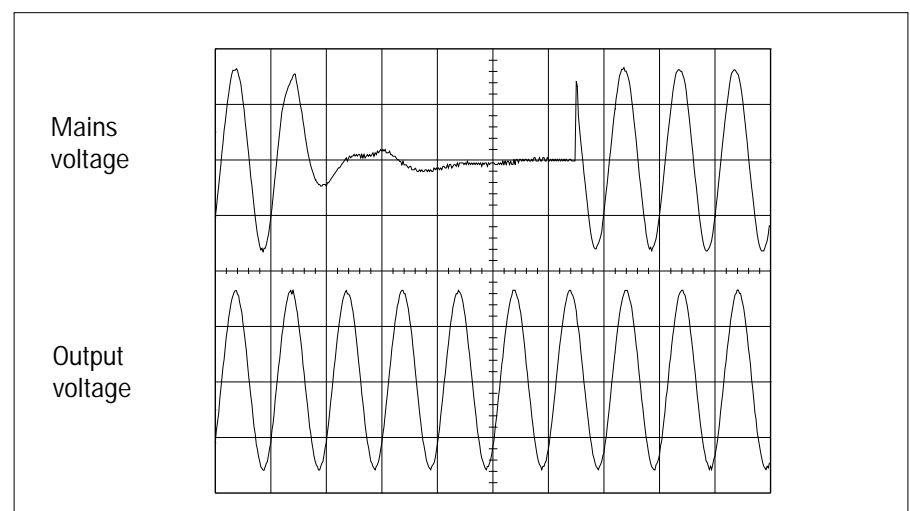


Fig. 13

This is shown in fig. 15.

Even adding all this hardware which costs a horrendous amount of money, the Double conversion UPS will never be able to match the efficiency of a Delta conversion UPS.

One should be careful to believe in certain extremely high efficiencies claimed by some vendors of double conversion UPS.

These figures only apply in the by-pass mode where there is no regulation of the output voltage and hence the system is an off-line system or may be it is an on-line type, but then operated in the off-line mode.

Some systems are claimed to be „intelligent“ and normally operated as off-line, then if there are too many problems with the mains they switch to on-line automatically. But then it is probably too late and the customer may have lost his computer. Anyway, when such systems are working in the on-line mode they are not more efficient than they used to be, so the whole manoeuvre seems to be to mislead the customer with confusing specs.

With the new 300E performance it is understandable that competitors, offering Double-conversion UPS are terrified, but it is still not very nice to mislead customers!

Comparison chart			
Basic properties	Double-conv. UPS	Single-conv. UPS	Delta-conv. UPS
True On-Line function	Yes	Yes	Yes
True two-way filter function	Yes	Yes	Yes
Input side harmonics	Yes >30%	No	No
Unity input PF	No	No, but can be compensated	Yes
Energy losses, small systems < 10 kVA	> 10-15%	< 8%	< 5%
Energy losses, large systems > 10 kVA < 100 kVA	> 8-12%	< 5%	< 4%
Energy losses, very large systems > 100 kVA	> 6,5-10%	< 4%	< 4%
Capability of running SMPS			

Fig. 14

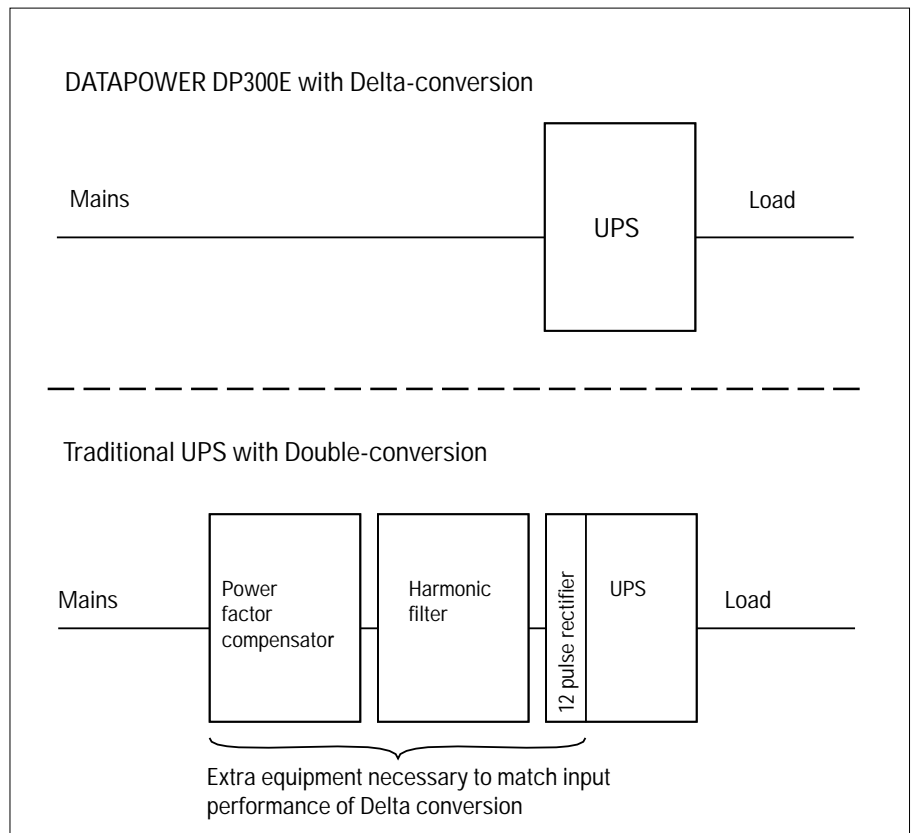


Fig. 15



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