Application Note
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Wide Range Inputs in Switched-Mode Power Supply Units

Marketing gimmick or a reasonable proposition?

What could sound nicer than building a single power supply unit for all worldwide voltages into systems and machines, which can be operated without any additional adjustment?

No manual intervention during start-ups, a simple technical documentation of the system and reduced logistical costs are the worthwhile advantages.

The marketing experts at some power supply manufacturers like to extol switched-mode power supply units with the so called wide-range input as the best solution. On the other hand, with the switching concepts known and used today, there are substantial losses with regard to safety in terms of mains faults, higher susceptibility to malfunctions in the event of voltage spikes, as well as a lower degree of efficiency and greater heat production. So which is better? As is so often the case, the solution lies somewhere in between, or depends first and foremost on the application in question.

Situation

If machines and systems are to be sold and used throughout the world, their power supply units have to be able to process in one form or another the globally different voltages of the respective power grids. Table 1 shows an example of different countries with different supply voltages with single or three-phase networks. In order to allow a power supply to be operated both at the lower and the higher voltage ranges, the input stage of the power supply has to be designed accordingly. This means covering rated voltage ranges of 100-120V and 220-240V in single-phase networks. Most networks allow a tolerance of +/- 10%, giving permissible input ranges of 90-132V and 198-264V ac. Thus a 100V network can only allow 90V, and a 220V network 198V. In order to prevent the power supply from having insufficient supply and shutting down in the event of brief voltage interruptions, for example, due to switching on large loads, the manufacturers of power supply systems add an additional downward reserve. Conventional input ranges for switched-mode power supplies are therefore 85…132V and 185…264V ac.

Country	1-phase-network	3-phase-network
Australia	120/240Vac	415Vac
China	220Vac	380Vac
Japan	100/200Vac	-/-
USA	120/240Vac	208/460Vac

Table 1: Worldwide network voltages

Possible Realisation

Developing a switch-mode power supply, manufacturers can choose between the input stage.

Auto-select Input:

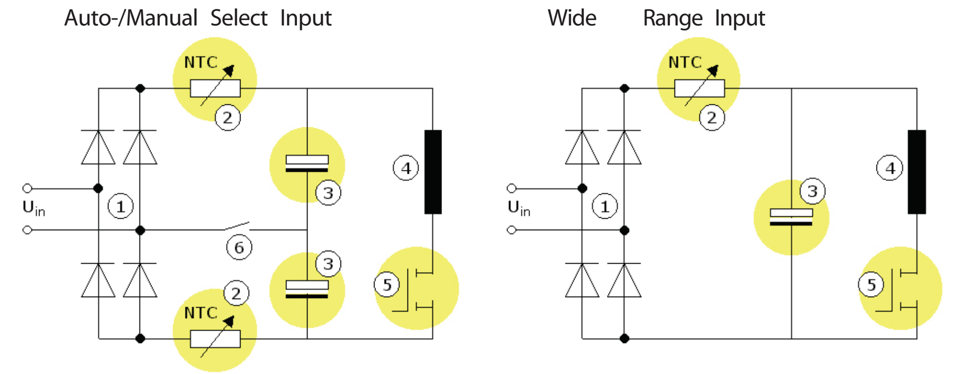
Initially of all, the voltage doubler circuit optimally exploits all components in the permissible range of the upper voltage range. If a mains voltage of the lower range is applied, the device switches over and doubles the input voltage via the doubler circuit in the internal input circuit. Again, all components are used optimally. The switchover can be performed by means of an electronic circuit in the device. The latter first tries to run the power supply unit up to speed in the upper range, and if this fails due to insufficient input voltage, it switches over to the doubler circuit. The device automatically adapts to the upper or lower supply voltage. A time constant prevents the device from switching over briefly in the event of under-voltage (in the upper range) or over-voltage (in the lower range) and thereby possibly causing a fault.

Manual-select Input:

Here, a manually operated switch replaces the electronic changeover system relays. This obviates the need for the electronic components required to control and determine the input voltage, which saves space and money. In addition, slightly less power is consumed in the device itself, which increases the efficiency by a further 0.5 to 1% depending on the situation.

Wide-range Input:

In the case of a wide-range input the circuit is designed so that it processes all input voltages from the lower through to the upper limit. This means that the components, essentially capacitors and semi-conductors



1) Bridge rectifier (4 diodes)
2) Making-current limiter (e.g. via NTC or actively via semi-conductor components)
3) Electrolytic capacitors for smoothing and buffering
4) Transformer
5) Switch for transformer
6) Changeover switch for lower/upper voltage range (mechanical, relay or electronic)

(MOSFETs / IGBTs), must be designed for the entire voltage range as well as the respective downward and upward reserves. And this is where some disadvantages arise:

Disadvantage No. 1…

… is a poor degree of efficiency in the lower input range which is associated with a higher power loss and heat production, because for the same power output P=U*I twice as much current flows through all components of the input circuit at half the input voltage. These are the bridge rectifier (=4 diodes), the semi-conductors for an active PFC-controller and/or input-current limitation and switching of the transformer. Since these components are encumbered with a voltage drop of between 0.4 and 0.8V respectively, their power loss is therefore doubled. This lost performance is then missing in the output. In addition it has to be cooled off via additional heat sinks, which in turn entail a greater space requirement and a larger device, and also additionally heats up the power supply unit and the control cabinet. Depending on the manufacturer and degree of efficiency, in the case of a 480W power supply unit, the difference between operation on 240V and 120V networks can amount to an additional power loss of 10 to 25W. In regards that a temperature increase of 10°C doubles the probability of the device failing (MTBF = Mean Time Between Failure) and halves the life expectancy, a higher power loss has definitely a negative impact to the robustness of the power supply. And of course also of the other components in the control cabinet. Fig. 2 compares the 72W PULS MiniLine ML70 with manual-select and wide-range input in the lower voltage range of 85…132V at 24.5V output voltage and full load. The test results in an improved efficiency of 1.5% on average.

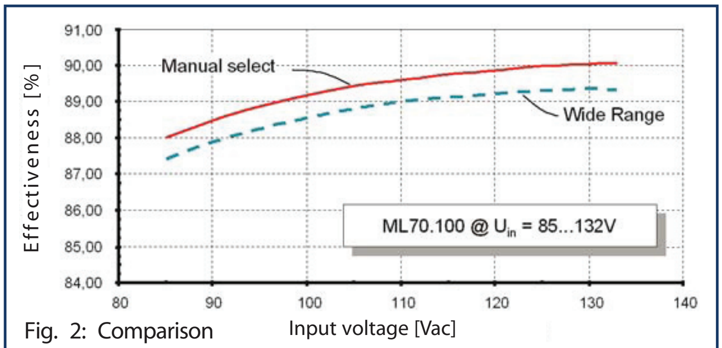


Fig. 2: Comparison

Disadvantage No. 2…
… is the considerably lower holdup time or buffer time of the power supply during operation in the lower input voltage range. In the currently known and used circuit designs the smoothing electrolytic capacitor in the input circuit is also used simultaneously for buffering power. This makes it possible to bridge the gap caused by brief voltage interruptions or failures. The energy stored in the electrolytic capacitor can be seen as the square of the voltage ($E=C*U^2$). That means that for half the voltage only a quarter of the energy is stored. This very greatly reduces the holdup time of the power supply unit in the event of voltage interruptions. The power supply unit switches off its output earlier and thereby endangers the application. Naturally a buffer unit like the PULS SLV 20.200 could compensate for this disadvantage, but only by an additional device at additional costs. Alternatively, the input electrolytic capacitors could simply be designed with quadruple capacity, but this would in turn require a four times greater input current, a considerably longer charging time (= start-up time) of the power supply unit and, above all, a larger construction size and larger space requirement. Thus, for example, a 25x50mm electrolytic capacitor has a capacity of 1,000µF at 200V, and just 330µF at 400V.

Disadvantage No. 3 …
… In order to prevent the power supply unit from being permanently damaged in the event of transient events and over-voltage pulses in the supply network (e.g. lightning strike, short circuit in a major consumer or voltage pulse when large circuit breakers are trapped), all components in the power supply unit must have sufficient specification, particularly regarding their disruptive strength, to withstand the largest over-voltages that can possibly be anticipated. For operation in the upper voltage range this is the upper supply voltage plus permitted tolerances. The VDE0160-impulse describes a standardised pulse test against possible and anticipated voltage pulses. It stipulates that the power supply unit must withstand 2.3 times the over-voltage of the max. permissible input voltage Û for a duration of 1.3 ms without being damaged. Based on the example of a 240V supply network, the power supply unit including the permissible +10% upwards tolerance would have to be capable of handling $240V_{ac}$ + 10% = $264V_{ac}$ times the square root equals $373V_{dc}$ plus the VDE pulse times 2.3 = $858.6V_{dc}$ of peak voltage. Thus for a wide-range power supply unit, all components must be selected, which, on the one hand, demonstrate higher current load during operation in the lower input voltage range and, on the other hand, demonstrate a high degree of voltage endurance during operation in the upper input voltage range, which in turn affects the price. If savings are made at one end, usually resistance against voltage peaks, this frequently leads to incomprehensible or unidentifiable breakdowns in power supply units with all their consequences.

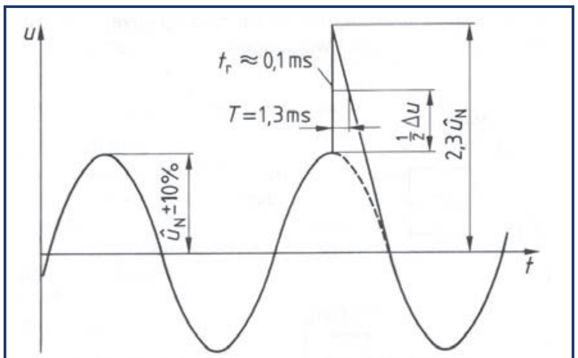


Fig. 3: VDE0160 pulse

So when should which input be used?
The trend towards ease of use – one power supply unit for all voltages – is thus immediately negated by tangible disadvantages. An optimal solution is not possible using the circuit designs known to date. So when does it make sense to use a switched-mode power supply with a wide-range input or auto-select? This question will ultimately have to be answered by the users themselves depending on the application in question. However, the following can be used as a guideline:

a) In the case of power supply units with lower output, e.g. up to 50W, the poorer efficiency has only a limited impact in the form of excessive heat production with wide-range input power supplies.
b) Devices with auto-select inputs achieve a considerably greater degree of efficiency with less power loss and heat, and are thus better suited to higher performances. Similar to wide-range devices, they automatically adapt to the connected input voltage range, but do not cover the intermediate range between the lower and upper input voltage ranges.

c) Power supply units with a manual-select input are almost identical to auto-select devices. Here a manual switch is used

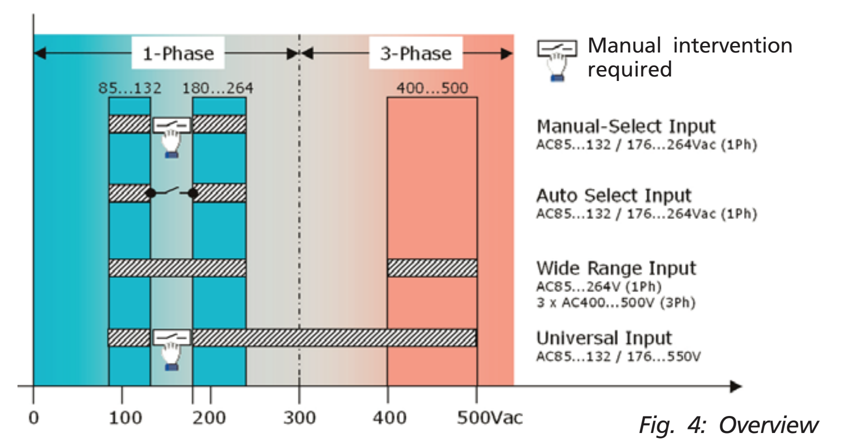


Fig. 4: Overview

instead of the electronics system to adapt to the connected input voltage. In this way, the efficiency can be increased yet again with an optimal circuit design, but the device has to be adjusted accordingly by hand for supply networks in the lower voltage range.

Universal input from 85...550V$_{ac}$?
Recent times have seen the appearance on the market of power supply units (see fig. 4), which not only cover the voltage range within a single-phase or 3-phase network, but also try to cover both ranges together. This means they can be operated from 85…550V. A truly optimal solution from the point of view of maintaining stores and reduced logistics. This solution is questionable from a technical standpoint, however, because it is designed in such a way that the device has to be switched manually (manual select) from the lower range of the single-phase network, i.e. 100-120V to the upper range, 220-240V. It then operates with a wide-range input in the 220-550V range. When operating in single-phase 220-240V networks, the user then has to live with disadvantages 1) and 2) of the wide-range input, and wide-range disadvantage No. 3 kicks in when operating in 3-phase 400-500V networks. If the device is being operated on single-phase 100-120V networks, it is even necessary to switch over to this input voltage by means of a manual switch during installation. Finally, it has to be asked whether these disadvantages can offset the advantage of more favourable stores maintenance/logistics.

So where are we headed?
In order to circumvent the disadvantages of a wide-range input, PULS offers switched-mode power supply units both with wide-range inputs and with auto-select inputs. The question is whether it will be possible to develop a power supply unit that can handle all input voltages without the buffer time being compromised, efficiency being seriously impaired or the device losing security against mains faults and over-voltages/transient events?
And, furthermore, a unit which perhaps works even more reliably, is considerably smaller and even has a lower purchase price?
The answer is, yes – it will be possible with a completely revised circuit design. The first devices of this type will be on the market and available in 2004.