Description

Apparatus for buffering the DC voltage at the output of a power supply

When loads are supplied via a mains-powered power supply, precautions are normally taken for the situation in which the mains system which drives the power supply fails briefly. As a rule, such a mains system is an AC mains system. Alternatively, it may also be a DC mains system.

The failure of the supplying mains system, or its voltage falling below a specific value, is, as a rule, identified and reported by special detection devices at the input of the power supply. These devices then, for example, connect a battery to the loads, by means of a relay or a semiconductor switch. As soon as the supplying mains system has reached a specific voltage value again, the switch is opened again. Furthermore, power supplies are frequently intended to be designed such that they provide an output DC voltage which is safely isolated from the supplying mains system at the input. This is the case in particular when the mains system is a 400V or 230V AC mains system. In this case, it may be necessary for the power supply to emit a so-called SELV DC voltage in accordance with EN 60950 (EN: European Norm) for example with a value of 24V (SELV: Safety Extra Low Voltage).

In such a case, it is likewise necessary for the detection device for the voltage which is monitored on the mains system input side to satisfy the requirements for safe isolation. This is disadvantageous since the large air gaps and leakage paths required, inter alia, for this purpose necessitate an increased cost and space outlay, and correspondingly costly components.

A further disadvantage of direct detection of the supplying mains system voltage on the input side of the power supply is seen in the fact that, in the event of a failure of the power supply itself, the battery is not connected since the detection device in it does not identify a fault because the mains system voltage is present without any change. However, because of the high stress in terms of current, voltage and temperature, power supplies are among the particularly severely stressed devices and therefore, as a rule, fail earlier than most of the loads supplied by them. Such apparatuses therefore do not identify, for example, failure of the drive of the primary transistors, the power supply transiently not running up, or any component or a connection in the primary or secondary circuit becoming open circuit. The battery is connected only in the particularly serious case in which the power supply fails as a result of a primary short-circuit and an upstream automatic protection device disconnects the supplying mains system as a consequence of this.

A further problem is that many loads on the DC side require high starting currents, for example on connection, for example incandescent lamps, DC/DC converters, capacitors, DC motors, switching contactors with a DC economy winding and the like. Some power supplies disconnect immediately in the event of an overload. This is disadvantageous since a sudden, complete interruption occurs in the supply to the load. Other power supplies have automatic current limiting, as a result of which the output voltage collapses in accordance with Ohm's Law $U = R_{load} \times I_{current\ limiting}$. In this case, the loads are supplied with an unacceptably low voltage in a disadvantageous manner for the time period of the voltage drop caused by high starting currents.

In known circuits, the return of the output DC voltage of the power supply can be identified, independently of the mains system input voltage

by a diode which is connected in the output line, which carries the positive potential, between the power supply and the load. The load voltage, for example the 24V output DC voltage of the power supply less the forward voltage of the diode V1 when the battery is disconnected or the battery voltage when the battery is connected, is present on the cathode of this diode. The actual output DC voltage of the power supply can be detected on the anode of the diode. If the power supply is not supplying any output voltage, then the voltage on the anode of the diode is virtually 0 volts. A control signal can be derived from this which maintains the connection of the battery. If the voltage at the anode rises above a value which can be predetermined, the battery is disconnected from the loads again in order that it is not unnecessarily discharged. In the steady state, the diode thus makes it possible to decide reliably whether the DC voltage on the load is being provided by the power supply or the battery. The use of such a diode has the disadvantage that a voltage drop, caused by the output DC voltage, of about 1 volt, a high power loss and an increased space requirement for a large heat sink occur.

In contrast with this, the invention is based on the object of specifying a more universal apparatus for buffering the DC voltage at the output of a power supply which, on the one hand, is to be designed without major complexity and, on the other hand, provides buffering of the output DC voltage even in the event of a failure of the power supply itself and in the event of overloads on the output side of the power supply.

The object is achieved by the apparatus specified in Claim 1. Advantageous further embodiments of the same are specified in the subclaims.

The invention will be explained in more detail with reference to the exemplary embodiments which are illustrated in the figures, which are described briefly below and in which:

Fig. 1: shows a block diagram of the apparatus according to the invention,

Figs. 2a and 2b:
show the profile of the essential voltages of the apparatus according to the invention during a buffering process, using the example of a power supply which has an internal auxiliary voltage supply for the regulator of the output DC voltage, and

Figs 3a, 3b and 3c:
show the profile of the essential voltages of the apparatus according to the invention during a buffering process, using the example of a power supply which has a storage capacitor for the auxiliary voltage supply for the starting up of the regulator of the output DC voltage.

The apparatus according to the invention, which is designated by the reference symbol DC-UPS in the block diagram in Figure 1, is used for buffering a DC voltage Ua at the output of a power supply SV. In the example in Figure 1, this apparatus is supplied on the mains system side by an AC voltage Un, so that the power supply SV represents a so-called AC-DC module. In the case of another version, which is not illustrated, the power supply can also be supplied from a mains system DC voltage.

The apparatus according to the invention contains at least one buffer battery BATT. This may also be a rechargeable battery which can be charged via the power supply SV itself. In such a case, means are additionally present for systematic charging of the rechargeable battery, which means produce, for example, charging

current limiting. These means are not illustrated in Figure 1, for reasons of clarity, and may also be integrated in the control unit CU there.

According to the invention, the control unit CU connects the buffer battery BATT when the actual value of the DC voltage Ua is less than a predetermined minimum value Uamin. This comparison is carried out by the control unit CU. If this comparison turns out positive, that is to say it is necessary to back-up the output DC voltage Ua, then the battery BATT is preferably connected by driving an electronic switching element V via a switching signal SI emitted by the control unit CU. The output DC voltage Ua is then backed up by the battery and assumes the value of the currently available battery voltage Ub.

At the same time that the battery BATT is connected, a predetermined buffer time period tm is generated in the control unit. The duration of the buffer time period is advantageously chosen to be short, preferably in the order of magnitude of seconds, for example with a value tm = 1 s. After the end of the buffer time period, the buffer battery BATT is first of all positively disconnected again. If the output DC voltage is then once again below the predetermined minimum value Uamin, then a sequence of such connection and disconnection cycles takes place until the output DC voltage is no longer less than the predetermined minimum value Uamin as a result of the output DC voltage Ua having returned, and, in consequence, no further battery connection cycles are any longer generated. The return of the output DC voltage Ua can be caused, for example, by the supplying mains system returning or the disappearance of a blocking condition in the interior of the power supply itself.

In the case of a practical example, the value of the directly monitored output DC voltage Ua of the power supply SV

is +24V DC. In this case, the minimum value Uamin can advantageously be predetermined to be +23V DC. Thus, if the value of the output DC voltage Ua falls, for whatever reasons, by 1V to less than 23V, then the DC-UPS buffer apparatus connects the battery BATT, which has previously been charged by it, electronically to the output virtually immediately. The minimum voltage which occurs on a load at the output thus in practice does not fall below the predetermined minimum voltage value of, for example, 23V DC, which is still considerably above the theoretical limit for low voltage, which is about 18.5V. It is advantageous if the buffer battery BATT has a no-load voltage Ub which is greater than the nominal value Uanom of the DC voltage Ua. If the nominal value of the output DC voltage Ua of the power supply SV is +24V, this condition is satisfied, for example, by a buffer battery having a no-load voltage of about 27.3V.

The possible return of the output voltage of the power supply can be identified in that, according to the invention, the battery BATT is disconnected cyclically from the buffer apparatus DC-UPS at the end of each buffer time period tm, which buffer time periods tm preferably have a duration of about 1 second. The actual value of the DC voltage Ua present on the load is measured in such a pause between two buffer time periods tm. If the power supply is still not supplying any voltage, the output DC voltage Ua, whose value is that of the battery voltage, will fall within a short time during the disconnection phase to the minimum voltage value, which can be predetermined, of, for example, 23V DC. The buffer apparatus DC-UPS then automatically connects the battery to the loads again and a further buffer time period tm elapses. If, in contrast, the output voltage of the power supply returns before the end of the buffer time period tm, the voltage is no longer below the minimum voltage value Uamin after disconnection of the battery as the buffer time period runs out. As a rule, the output voltage Ua is then kept stable by the power supply

at the level of the nominal value Uanom, the battery is no longer connected and, if required, is charged again by the power supply SV.

The apparatus according to the invention is also fully functional if the failure of the output DC voltage of the power supply has been caused by the absence of any supplying input AC voltage. In this case, a regulator in the interior of the power supply, which has the object of stabilizing the output DC voltage in normal operation, detects the actual value of the output DC voltage Ua, after the return of the input AC voltage which is less than the required value, during a pause time after the end of a buffer time period tm. Such a regulated power supply starts up automatically again when the supplying input voltage returns.

In many cases, the mains-powered power supply SV has a capacitor at the DC voltage output DC, which is charged by the buffer battery BATT during a buffer time period tm. This capacitor is discharged in accordance with $Q = I \times t = C \times U$, where $du/dt = I_{\text{load current}}/C$, in a pause time at the end of a buffer time period. If there is a failure in the output DC voltage Ua, the buffered voltage Ua thus does not fall suddenly after the end of one of the cyclically successive buffer time periods but decays with a time constant to the predetermined minimum value Uamin. This has the advantage that the pause times between the buffer time periods are not too short and, if appropriate, the load is loaded with unacceptable switching spikes.

Without the apparatus according to the invention, it is not directly possible to identify whether an output DC voltage, in particular such a voltage in the region of the nominal value, is being provided from a power supply which is active again or from the connected battery.

The apparatus in this case has the advantage that the return of the output DC voltage of the power supply can be identified effectively without major complexity. The battery can thus be disconnected from the loads quickly again after a fault has decayed and is not unnecessarily discharged. As a result of the invention, it is not necessary to provide, for example, a diode in the output circuit for DC voltage detection. The disadvantages linked to this of a forward voltage drop occurring, a high power loss and large amounts of space being required for heat sinks can be avoided.

The apparatus according to the invention has the further advantage that it is not necessary to provide any costly, space-consuming measures for direct detection of the supplying mains system voltage at the input of the power supply. In the case of the invention, the loads continue to be supplied both in the event of a failure of the supplying input voltage and in the event of a failure of the power supply itself, since the output DC voltage, which is essential for the loads, of the power supply and the load input voltage are monitored. The apparatus according to the invention can thus be connected additively downstream of a power supply, without any intervention in its design being necessary.

The apparatus according to the invention has the further advantage that it automatically connects the battery as a back-up even in the case of temporary drops in the output DC voltage of the power supply which are caused, for example, by high inrush currents of loads, as soon as the load voltage falls below a minimum value, which can be predetermined, of, for example, 23V DC. The invention thus enables a virtually continuous transfer and back-up of the output DC voltage in a multiplicity of fault situations. Furthermore, as a result of the positive disconnection according to the invention at the end of a buffer time period, the battery can be disconnected very quickly in every case

after normal output DC voltage conditions return. This avoids parallel operation of the power supply and battery which, under some circumstances, may last for a very long time and could otherwise not be ended until after the battery had gradually discharged after a relatively long time.

Furthermore, additional current is also supplied in the event of load short-circuits since, as a result of the monitoring of the output DC voltage, the battery is connected in every case as soon as this voltage falls below the predetermined minimum value. In consequence, for selectivity purposes, automatic protection devices which are connected upstream of the loads can be tripped more quickly and more reliably. In this case, the battery current is advantageously limited to a defined value of typically 120A for t = 20 ms by means of electronic short-circuit current limiting which is integrated in the buffer apparatus.

The invention will be explained in more detail with reference to two groups of voltage profiles which are illustrated in Figures 2a, 2b and 3a to 3c. In this case, it is possible to distinguish in principle between the operating behaviour of two types of power supply SV.

In the case of a first type, the regulator is equipped with an autonomous, internal auxiliary voltage supply, which is supplied from the mains system input voltage, for stabilizing the output DC voltage. This auxiliary voltage supply continuously keeps the regulator in a state of readiness even when the present output voltage Ua is above the required value Uanom as a result of the connection of the battery BATT. The regulator is disconnected in a defined manner in the absence of a mains system input voltage.

In the case of a second type, an auxiliary supply in the form of a storage capacitor is provided for starting up the regulator,

by means of which auxiliary energy is provided for a specific time. After start-up has been completed, the storage capacitor is charged via a high-value resistor, for example from the mains system voltage, and the regulator is supplied via an auxiliary winding of the main transformer of the power supply. This second type of power supply has the disadvantage that there is also no stable supply of energy for the regulator in the absence of an input voltage. In consequence, this causes a sequence of continual, unsuccessful attempts to start up the power supply SV in the situation in which the output DC voltage Ua is above the required value because of the battery being connected.

Nevertheless, the apparatus according to the invention can be coupled to the output from both types. With both types, it is possible with aid of the buffer apparatus according to the invention to isolate the battery from the load quickly and in a manner which is simple and produces low power losses after the end of the actual buffering process, that is to say, for example, after a mains system failure has ended or after dynamic load spikes have disappeared.

For further explanation, Figures 2a, 2b show the profiles of the essential voltages of the apparatus according to the invention during a buffering process, using the example of a power supply which, corresponding to the above first type, has an internal auxiliary voltage supply for the regulator of the output DC voltage.

In this case, it is assumed according to Figure 2a that the mains system which supplies the power supply fails at the time t1 and returns at the time t8. As a result of the failure at t1, the output DC voltage Ua falls according to Figure 2b within a first back-up time period ts1 from Ua = Uanom to Uamin, the voltage profile depending on the capacitance of the output capacitors of the power supply, and on the magnitude of the load current Ia. At this time t2, the buffer apparatus according to the invention connects

the battery BATT. As a consequence of this, Ua rises from Uamin to a value Ub - dU at the time t3, Ub indicating the no-load voltage of the battery and dU indicating the voltage drop via a switch which activates the battery. As a result of the load, the battery voltage falls slightly below the no-load value Ub after t3. In parallel with this, a buffer time period tm is generated at the time t2.

After the end of tm at the time t4, the battery is positively disconnected and there now follows a further buffer time period ts2 within which the output DC voltage Ua once again falls to Uamin. The battery is connected again at this time t5, a further buffer time period tm is generated, which lasts until t7, and Ua rises once again to the value Ub - dU at the time t6. This sequence is repeated as long as the mains system voltage Un has not returned.

The mains system voltage Un returns at the time t8. On completion of the present buffer time period tm which is taking place at this time t8, the battery is permanently disconnected, automatically, at the time t9. The output DC voltage Ua falls to Uanom at the time t10. After this time, the power supply takes over the further supply of the load, and the regulator of the power supply keeps Ua as constant as possible at the value Uanom. The battery remains disconnected, since the output DC voltage no longer falls to the predetermined minimum value Uamin.

Particularly in the case of a long-lasting failure of the power supply, it is possible for a special case to occur in which the battery is discharged to such an extent and [sic] the actual value of the DC voltage Ua, which corresponds to the battery voltage Ub, no longer exceeds the minimum value Uamin during one of the many following buffer time periods tm. In this case, it is advantageous for buffer time periods tm no longer to be generated by the control unit CU and, in consequence, for the buffer battery no longer

to be disconnected when, after being connected, the actual value of the DC voltage Ua remains less than the predetermined minimum value Uamin. The buffer battery BATT is advantageously disconnected again by a separate logic device in the control unit CU when buffer time periods tm are no longer being generated and the actual value of the DC voltage Ua is again greater than the predetermined minimum value Uamin.

The load on the battery during the buffer times tm results in the battery gradually being discharged. Its no-load voltage Ub and the value of the output DC voltage Ua = Ub - dU which occurs during the buffer time periods fall slowly. This process cannot be illustrated in Figures 2a, 2b, 3a, 3b, 3c, for reasons of clarity.

Finally, in a manner comparable with Figures 2a and 2b, Figures 3a to 3c show the profiles of the essential voltages of the apparatus according to the invention during a buffering process using the example of a power supply which, corresponding to the above second type, has a storage capacitor for the auxiliary voltage supply for the start-up of the regulator of the output DC voltage.

In this case, the sequence in Figures 3a and 3b corresponds, up to and including the time t8, to that in Figures 2a and 2b. Figure 3c is included in addition and shows the profile of an auxiliary voltage Uh which is used to supply a regulator in the power supply.

After the time t8 which designates, for example, the return of a mains system voltage which supplies the power supply, or the end of a condition which blocks the power supply, the auxiliary voltage Uh rises from 0 to a threshold value Ustart. This is achieved by charging a storage capacitor via a resistor in the power supply. The regulator of the power supply starts to operate on reaching this threshold at the time t9.

The arrow, which is continued from Fig. 3c to 3a at t9 and is illustrated in the form of a dotted line shows that a buffer time tm is just active. Since, as a result of the unchanged connection of the battery, the output DC voltage Ua at the time t9 is still greater than Uanom, although the regulator discharges the storage capacitor, the power supply cannot, however, start up. The regulator is stopped when Uh = Ustop at the time t11, and the charging of the storage capacitor starts again. This is a result of the fact that the output DC voltage Ua is still greater than Uanom at this moment t11 although the buffer time period tm ended at the time t9 before this, the battery has been disconnected and, as a consequence of this, Ua falls.

The sequences "start/end of buffer time periods tm" and the connection/disconnection of the battery linked to this as well as "regulator start/stop" initially run asynchronously with respect to one another after the mains system voltage Un returns. This is indicated in Figures 3b and 3c by the times t12, t13 and the double wavy lines after them. The asynchronicity does not end until the conditions "regulator operating" and Uamin < Ua < Uanom occur together. This is the case at the time t15 in the example in Figures 3b and 3c. Since Ua is now < Uanom, the regulator has a virtual "regulation requirement" and continues to operate. As a consequence of this, the output DC voltage Ua no longer falls further to Uamin but, driven by the mains system voltage Un which has returned, is increased to Uanom at the time t16. The battery is thus no longer connected since it is no longer possible for the voltage to be below Uamin. In addition, after t15, the auxiliary voltage Uh of the regulator exceeds the upper threshold Ustart until the storage capacitor is completely charged.

In practice, it has been found that, on average, the power supply starts up and the battery remains disconnected after completion of about 5 buffer time periods tm after the return of the mains system voltage

and/or after cancellation of a condition which interrupts the operation of the power supply at the time t8 in the example in Figure 3c.

The no-load voltage Ub and capacity of the buffer battery BATT are advantageously selected such that the battery voltage Ub = Ua is discharged, during a buffer time period tm when a load current Ia is present which is approximately in the region of the nominal value, only to a voltage value which is preferably considerably above the nominal value Uanom of the DC voltage Ua. In practice, this condition can be satisfied if the no-load voltage Ub of the battery BATT has a value of at least 27V when Uanom = 24V.



Patent Claims

1. Apparatus for buffering the DC voltage (Ua) at the output of a mains-powered power supply (SV), having

a) at least one buffer battery (BATT), in particular a rechargeable battery which can be charged via the power supply (SV), and

b) a control unit (CU) which

b1) connects the buffer battery (BATT) when the actual value of the DC voltage (Ua) is less than a predetermined minimum value (Uamin), and

b2) generates a predetermined buffer time period (tm) and disconnects the buffer battery (BATT) again, cyclically, after this time period has elapsed.

2. Apparatus according to Claim 1, buffer time periods (tm) no longer being generated by the control unit (CU), and the buffer battery (BATT) no longer being disconnected when, after it has been connected, the actual value of the DC voltage (Ua) is less than the predetermined minimum value (Uamin).

3. Apparatus according to Claim 2, the buffer battery (BATT) being disconnected by the control unit (CU) again when buffer time periods (tm) are no longer being generated and the actual value of the DC voltage (Ua) is greater than the predetermined minimum value (Uamin).

4. Apparatus according to one of the preceding claims, the no-load voltage (Ub) of the buffer battery (BATT) being greater than the nominal value (Uanom) of the DC voltage (Ua).



5. Apparatus according to Claim 4, the no-load voltage (Ub) and capacity of the buffer battery (BATT) being selected such that said buffer battery (BATT) is discharged, during a buffer time period (tm) when a load current is present which is approximately in the region of the nominal value, only to a voltage value which is above the nominal value (Uanom) of the DC voltage (Ua).

6. Apparatus according to one of the preceding claims, the mains-powered power supply (SV) having a capacitor at the DC voltage output (DC), and the capacitor being charged by the buffer battery (BATT) during a buffer time period (tm).