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Investigation of the cause of the damage to the low voltage power supplies being used in LEP separator ECAs

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Abstract

On 14th June 1994 several low voltage power supplies in the equipment controllers of the LEP separators were damaged by a 400 kV line incident. Another 400 kV line incident on 26th July 1994 caused the breakdown of 20 low voltage power supplies, about 25% of the installed units. Much other equipment in LEP was also affected. The cause of this massive damage was investigated. This report gives the results of these investigations and describes the actions which have been taken to improve the tolerance to mains overvoltages.

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J. H. Dieperink

European Organization for Nuclear Research (CERN) - SL Division
CH - 1211 Geneva 23, Switzerland

Abstract

On 14th June 1994 several low voltage power supplies in the equipment controllers of the LEP separators were damaged by a 400 kV line incident. Another 400 kV line incident on 26th July 1994 caused the breakdown of 20 low voltage power supplies, about 25% of the installed units. Much other equipment in LEP was also affected [1]. The cause of this massive damage was investigated. This report gives the results of these investigations and describes the actions which have been taken to improve the tolerance to mains overvoltages.

I. INTRODUCTION

Since the startup of LEP in 1989 a number of the low voltage (LV) power supplies of the separator ECAs have broken down. It was noticed that some of these breakdowns coincided with incidents on the 400 kV line. However, the failure rate due this cause was not greater then the normally, in this period, expected failure rate. Thus, no steps were undertaken to improve the reliability.

Models of two different manufacturers, WIENER model SP52 and VERO model PK60, have initially been used for the +5 V power supplies. They were bought from the CERN stores under the same SCEM number. Defective power supplies have always been replaced by VERO models. The failure rate of the WIENER models was initially much higher then the failure rate of the VERO models. Due to this higher failure rate about 20 WIENER models still remained in the installation.

For the ±12 V only VERO models PK60 have been used, which were also supplied by the CERN stores.

The 400 kV incidents on 14th June 1994 and on 26th July 1994 caused the breakdown of more than 20 low voltage power supplies. All concerned the VERO models PK60.

II. INVESTIGATION TO DETERMINE THE CAUSE OF THE BREAKDOWNS

II.1 Origin of the LV power supplies

The CERN stores delivers LV power supplies conforming to a specification drawn up by a CERN committee in 1987. The specification was made in view of the large peak consumption needed for the construction of LEP. The price inquiry, following the specification, resulted in the selection of two manufacturers for delivery to the CERN stores, WIENER GmbH + Co. and VERO Electronics GmbH. The CERN stores held for some time units of both manufacturers in stock, however after a few years the WIENER units were not more purchased and only VERO remained as CERN supplier.

II.2 Experience in the SL Power Converter group

In view of the large quantity of units which have been distributed in CERN it would be rather unlikely that only the controls of the LEP separators has problems.

The SL-PC group, which is probably the largest consumer with more then 800 units for the controls on the LEP power converters, encountered at the start of the operation of LEP a lot of problems with the VERO Tri-volt model PK55 [2, 3].

The large number of units in use in the power converters could not simply be exchanged for another type but needed an improvement in reliability. A careful analysis showed that in many cases at least the 'mains' fuse was blown. The origin of this was the conduction of the voltage spike protection resistor (VDR) across the mains input. Usually fuse and VDR are dimensioned for voltage spikes coming from a lightning flash over on the power distribution lines and not for 400 kV incidents of the type CERN had. Tests in collaboration with VERO demonstrated that the voltage at which the VDR starts conducting should be increased from 250 V_{eff} (350 V_{DC} @ 1 mA) to 275 V_{eff} (430 V_{DC} @ 1 mA) without degrading the safety for the components of the rectifier and regulation part.

During an annual shutdown all installed power supplies were modified by the SL-PC group. Since then VERO delivers power supplies with the modified protection to the stores.

Once this improvement program was terminated the following failure rates have been obtained for the PK55 power supplies in the LEP power converters:

- In 1992: 0.6 % of the installed number
- In 1993: 1.15 % of the installed number
- In 1994: The few hazards caused by the 400 kV incidents are insignificant in relation to the number of installed modules.

From these results can be concluded that the peak voltage due to an 400 kV incident has an upper limit of about 450 V.

It should be noted that the VDRs can absorb about 45 J of energy in about 10 ms. This rating is safe enough for voltage spikes coming from lightning but insufficient for disturbances coming from the 400 kV incidents in CERN which probably have a much longer duration (200 ms or more) [4].

II.3 Another experience in the SL Beam Transfer group

The SL-BT group experienced in the past also a high breakdown rate with the VERO PK55 model, used in the controls of the LEP injection kickers. Fortunately a small number of units were concerned which have successfully been replaced by power supplies of another manufacturer but which had a connector with a different pin layout [5].

II.4 The damaged power supplies of the separator system.

In addition to the 20 defective power supplies of 26th July 1994 there were 14 other units, damaged on earlier occasions, available for analysis. The total number of 34 model PK60 power supplies comprises 30 units of the +5 V type and 4 of the ±12 V type.

A quick inspection showed that all ±12 V types had a blown fuse.

Amongst the 30 +5 V types only six had a blown fuse. This small number can be explained by the fact that in our laboratory an attempt has been made to repair the damaged units by replacing the fuses. No record has been kept of the number of fuses which were originally blown.

Most units have been used since the beginning of LEP. Thus only a small number of them already had the modification with 275 V_{eff} VDRs.

After inspection all 34 units were sent to VERO for repair and possible modification. The following points are observed on the fault reports which returned from VERO with the repaired units [6]:

- In the units where the fuse was replaced, the protection Zener diodes were also replaced.
- In the majority of the units, where no fuse had to be replaced, many components of the regulating circuitry were broken. Some of these components may not have been defective but were replaced as precaution when a typical component has been damaged. It is thus, unfortunately, not possible to draw any conclusion about the origin of the damage. Also part of the damage could have been caused during the attempt to repair the units in our laboratory.
- One unit had a mechanical defect. Another one had the crowbar thyristor replaced.
- All the faults in the ±12 V units concerned the fuse and the diodes. It is interesting to see that these models have the same construction as the model PK55 !
- The damage due to mains overvoltages to the +5 V units model PK60 is different from that in the units with the construction of model PK55.

It should be noted that the trigger level of the overvoltage protection (OVP) of +5 V units could have been adjusted too sensitive. Tests in the laboratory have shown that short interruptions of the mains voltage may lead to small overshoot voltages on the output. A triggering of the OVP causes a short-circuit across the +5 V and the power supply starts dissipating excessive power from this moment on. When in addition the ventilation is deficient, components in the power supply may become too hot and become damaged. This hypothetical cause should not be overlooked.

III. POSSIBLE IMPROVEMENTS AND THEIR CONSTRAINTS

III.1 Uninterrupted Power Supply (UPS)

The ECAs mounted in a fixed 19' rack can be connected to the UPS to which the controls computers have been connected. For most ECAs this was already the case.

The ECAs which control the high voltage (HV) power supplies have been lodged in the mobile racks housing the rectifier and corresponding regulator units. These racks are individually powered from a main distribution point with a 6 kW rating.

It would be possible to power the power supply ECAs separately from the UPS mentioned above. This solution has some drawbacks. It would for instance require an additional mains distribution and probably an increase in power rating of the UPS. Also certain HV power supplies are located too far from the computer area for such a solution.

Another possibility is the installation of a common UPS for all HV power supplies. Such an UPS would also protect the thyristor bridges of this equipment. However, there is no real need for this. The norm, applied by the SL-PC group, is to specify that all thyristors used in a power converter should have ratings of at least a factor 3.7 higher than the mains voltage (thus > 850 V). This is largely satisfied by our HV power converters [7, 8].

The price of this solution, inclusive of installation in the 8 LEP areas, is estimated at about 300 kCHF [9].

III.2 Other manufacturer of LV power supplies

It has been shown that with the modified VERO power supplies acceptable failure rates are obtained [2, 3]. The question whether another manufacturer can deliver power supplies with a better failure rate is difficult to answer. Many other parameters may cause problems in our applications. One of the least well known parameters is the 'delivered batch' which may have some typical problems due to an unreliable component.

It can not be proven that VERO power supplies have a low quality. On the contrary, once the weak points were known, VERO made, in the past, an improvement which gave full satisfaction. The CERN stores have purchased more than 700 units of the model PK60 only since begin 1989. All these have been distributed in CERN in small quantities to many users. Whether all are still in use is difficult to find out. At least it is known that no quality complaints have been received by the stores.

The supplier of the replacement power supplies for the VERO model PK55 of the BT group is not able to make the statement that their models have a better quality [10].

The opinion in the power converter group is that better quality can be obtained by means of purchasing with improved specifications and to accept the consequence of a much higher price to be paid [2].

Another difficulty in using power supplies from other manufacturers comes from the pin layout incompatibility of the connector. Most manufacturers have a different pin layout. This has as consequence that the crate in which the power supply is lodged must be modified. It also creates problems in standards if not all equipment is converted.

IV. CONCLUSION

A conclusion must be made in relation to the severity of the consequences to the operational level of LEP due to damaged power supplies in the LEP separator system.

Generally, when 400 kV incidents occur due to thunderstorms or equipment breakdowns, the accelerators are out of operation for several hours, even days. The urgency of getting the separator system again operational is thus not of the top first priority. The most important point left is that the repair of the separator system can be made in a reasonable time. Up to now this has always been the case, even on the last occasion where 25 % of the installed LV power supplies broke down.

Therefore in this perspective:

- The ideal solution with in each underground area an UPS for the HV power supplies seems to be too expensive and thus not justified.
- The solution where the HV power supply ECAs are powered from the existing UPS needs cabling and probably upgrading of the UPS capacity. This also needs funding but can be envisaged.
- Taking into account that recently only on one occasion 20 units were damaged, and that since 1989 perhaps another 20 units broke down due to several other causes, a good and economic solution would be to have sufficient spares to cover such a catastrophic event as last summer. In other words there must always be sufficient (say 25) spares available. This is a small investment of about 7,5 kCHF.
- Modification of the installed power supplies and the spares with another VDR, as the SL-PC group has done in the past, will reduce the breakdown rate.
- Careful adjustment of the overvoltage protection level is recommended in order to exclude future erratic triggering.

V. ACTIONS WHICH HAVE BEEN TAKEN

- During the shutdown 94/95 the VDRs of all installed and spare power supplies of the LEP separator system have been modified with the correct type. In addition the OVP has been tested and adjusted, in situ, to the correct level of +5,5 V.
- The HV power supplies of Passoni & Villa have also VDRs across the mains input connections with a rating of 260 V_{eff} (400 V_{DC} @ 1 mA). As they could have been damaged by an overvoltage of long duration a visual inspection of the VDRs in these HV power supplies has been executed. No damaged VDR has been found.
- For the sake of having standard maintenance procedures all existing WIENER units have been replaced by VERO units. They will be kept as emergency spares in addition to the spare stock of 25 % VERO units.

VI. RECOMMENDED ACTION FOR THE FUTURE

For future applications it is recommended to review the CERN standard stores LV power supply specification which is almost 8 years old. The connector pin layout must then be reconsidered in order to have a wider choice of manufacturers available for the provision of the CERN stores.

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