www.teknolojikarastirmalar.com
ISSN : 1305-631X

Electronic Journal of Constructional Technologies
2008 (1) 59-66

TECHNOLOGICAL
RESEARCHES

Short Communication

Analysis of Failure of an Uninterruptible Power Supply of Office Building as an Instructional Case Study

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ABSTRACT

In the engineering education, along with the instructions via theoretical basis and laboratory and workshop studies, the students should meet with the real life problems in their education period. This provides the problem solving ability to the students in their professional life. The department of electrical education has a course on the determination and elimination of failures in an existing electrical system. The subject is designed as a student centered education in which the student must investigate the possible reason and solution of the problem and report it accordingly. Recently a case of failure of an uninterruptible power supply (UPS) system is reported. The use of UPS is widespread especially for sensitive equipments to the variation of current voltage. This equipments is used for both as an energy source for the cut offs and as a regulator for the discrepancy. The failure in the system caused a fatal defect to the Isolation Gate Bipolar Transistors (IGBT) on the UPS system. In the present study, the case of failure for the UPS system used in a three storey office building is analyzed as an instructional case study.

Anahtar Kelimeler: Failure analysis, Uninterruptible power supply, Power quality, Wiring

INTRODUCTION

The students in the Electrical Department in the Faculty of Technical Education, Kocatepe University, Turkey will take a course which deal with the real life problems of electricity. The course is taught at the forth year (7 th semester) after they complete the courses such as Circuit analysis, Electrical wiring technology, Electric machines, Analog Electronics, Digital Electronics, Power Electronics, Electrical measurements, etc. These courses give the necessary information for inspections and analysis of the real life problems. In the present course, the students are divided into groups of 5-6 students. Each group deals with a special real life problem encountered in domestic or industrial areas and office buildings. Students should analyze the case, inspect the reasons of the problem, report it accordingly and give possible solutions of the case.

The present paper is given to the students as an example of the report they should prepare as a result of their study.

THE REAL LIFE PROBLEM

The fundamental needs of humankinds include food, clothes, house, energy and communication. These and other necessary goods and services should be produced. The most widely used type of energy to accomplish the aforementioned needs, goods and services is electricity. The availability of the electricity

only is not enough for today's requirements, but, its quality is also very important. The electrical current should have a constant voltage and frequency as well as its permanence. The following conditions must be considered for a high quality permanent electrical current [1];

- Appropriate production of electricity
- A suitable voltage control
- A proper frequency control
- The installation of energy network with high quality materials and a good labor
- A periodic maintenance of the whole network from production to the end user.

In the developing countries these requirements can not always be met. This results the use of extra equipments especially for the voltage and frequency sensitive devices. The uninterruptible power supply (UPS) devices are the only choices for small and medium scale networks. In the telecommunication field, the UPS is gaining a widespread use and the studies to utilize the devices for longer durations are continuously increasing [2].

The increase of the efficiency of UPS devices is another study area [3]. On the other hand, the use of the UPS for all of the equipments using the electricity may not be feasible, instead, the sensitive equipments are powered with the UPS and other equipments use the electricity directly from the network however the electrical current has some improper conditions as in the present example.

In the present study, analysis of a failed UPS device is carried out. The properties of the UPS are considered firstly. Then, the network fed via this UPS is investigated to determine the needs and capacity relation between the network and the device. The possible reasons of the failure are discussed under these conditions.

Sample UPS System

According to the user manual of the investigated UPS; the system provides a bypass system and contains all the protection measures for both itself and the equipments fed via the UPS [4]. It feeds the loads with stable voltage (frequency and amplitude). In the case of mains blackout or back to the normal mains, there is no transfer time in question in an on-line structure. With a view to provide stable operation of the load, responsive microprocessor control mechanism is implemented in the UPS design thus ensuring quality output, especially needed for the devices sensitive to minor voltage changes.

The static by-pass unit of the UPS continuously keeps the mains as a stand-by supply. In the case of an overload, the UPS transfers the load to the mains to protect itself from damage. As soon as the load returns to the normal conditions the UPS starts to provide pre-defined, stable frequency and voltage by means of the static by-pass system. In a UPS fault case, the static by-pass unit behaves the same as it was mentioned above and protects the load from energy interruption.

During the mains failure, UPS needs batteries to supply the load. As only the DC energy can be stored in a battery, the UPS system operates in double conversion method to keep the batteries fully charged with direct current and to produce alternative current by using this energy when a mains failure occurs (Figure 1).

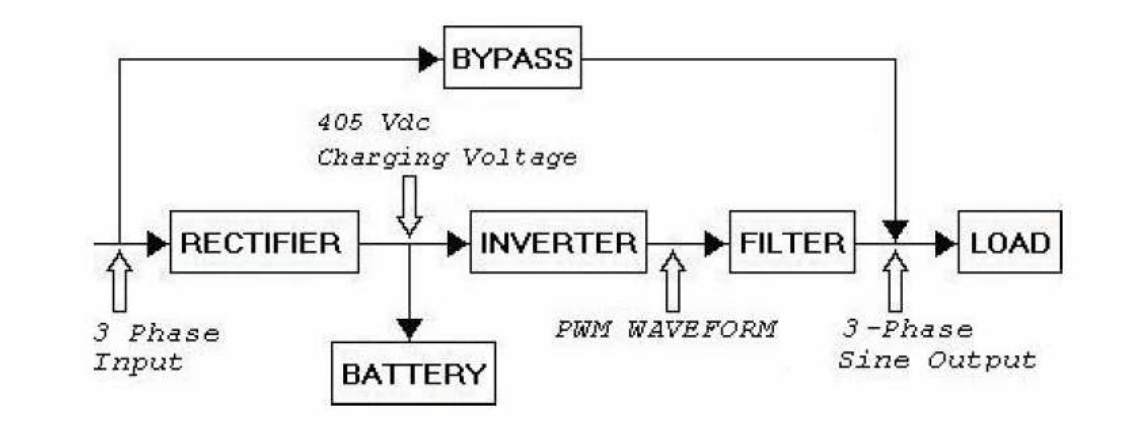

Figure 1. Block Structure of the analyzed UPS [4]

In the UPS, a 3-phase mains (AC voltage) is connected to the UPS input and rectified to DC voltage by the rectifier unit. A battery bank is connected to the rectifier output. The DC bus bar voltage is applied to the inverter input. A sinusoidal output is produced by Pulse Width Modulation (PWM) technique in the inverter unit. As a result, when the mains fail, the inverter starts feeding from the battery voltage.

The output of the rectifier passed through a DC filter constitutes a common bus bar along with battery bank. The inverter unit converts DC voltage to maximum possible AC voltage having no harmonics and feeds the load at the output. Isolation Gate Bipolar Transistor (IGBT) blocks mounted on heat sinks are used as power semi-conductors in this unit. In order to protect the IGBT blocks against the voltage peaks, a snobbery circuit is used. The protection capability of the system against over-current or short circuit is performed by electronic tests [4]. Cooling process is performed by forced air-conditioning with fan. The inverter driver stage provides inverter control signals as well as the protection against over-current and short circuit. In order to reduce both the influence of the harmonics and noise level, the inverter is run at 20 kHz switching frequency.

All the IGBTs used in the UPS are controlled by suitable driver units. By means of power stage, the driver units maintain the relations between the two sides by establishing an interface to the low voltage electronic control units. In this way, the electronic controls are also physically decoupled by power transistors.

In case of any possible fault of UPS or if the load starts drawing over the power, the static by-pass system activates the load providing power from the mains. The unit consists of two parallel & oppositely connected thyristors. The structure is formed with a block of thyristors mounted on a heat sink. The snobbery circuit is used and a forced air by means of a fan is applied for removing the excess heat in order to protect the system against peak voltage. The power rating of the thyristors is chosen to be twice that of the UPS. The transfer of load from inverter to mains and vice versa is constantly supervised by a microprocessor control. This transition conditions are very important and still under investigation [5, 6]. In order to get rid of voltage distortion during the transition, microprocessor ensures the synchronization of the UPS output frequency and phase with those of the mains.

There are six thermal-magnetic circuit breakers over the input-output connection panel. These automatic circuit breakers operate on the static bypass, input, manual bypass, output, battery and fan.

The mains and bypass are thought to be from different sources although in most cases the users employ the same source for both. The bypass is continuously sampled and watched. As a result, upon bypass failure or highly distorted condition, the device takes instant decision of feeding the load by inverter. If

the source of the mains is different than bypass, upon bypass and/or mains condition, several operational changes in rectifier and inverter units can occur:

- If mains fail but bypass exists then bypass takes the output, rectifier unit remains out of operation and the inverter run by battery.
- If mains exist but bypass fails then inverter takes the output, both rectifier and inverter run by mains and the batteries are charged if necessary.
- If the mains and bypass fail at the same time, then rectifier remains out of operation, inverter runs by battery and feeds the load at the output.
- If the mains and bypass exist at the same time, then bypass takes the output, rectifier and inverter run by mains and the batteries are charged if necessary.

Investigation of the Network

The investigated UPS is used in three storey office building. The architectural plan of the first floor of the building is given in Figure 2. There are 80 offices in the building. The plan view and electrical network of three offices are given as a sample in Figure 3. As can be seen from the figure, each office has 3 UPS sockets. Computers, printers and scanners are connected to these sockets only for the elimination of any interruption during the working of computer related jobs. In addition to the elimination of interruption, the UPS system also protects the equipments from unexpected and costly failures. The total of IT equipments powered from the UPS system reaches up to 110. For the uninterruptible power supply to the mentioned building, a UPS system whose structure is described above is applied.

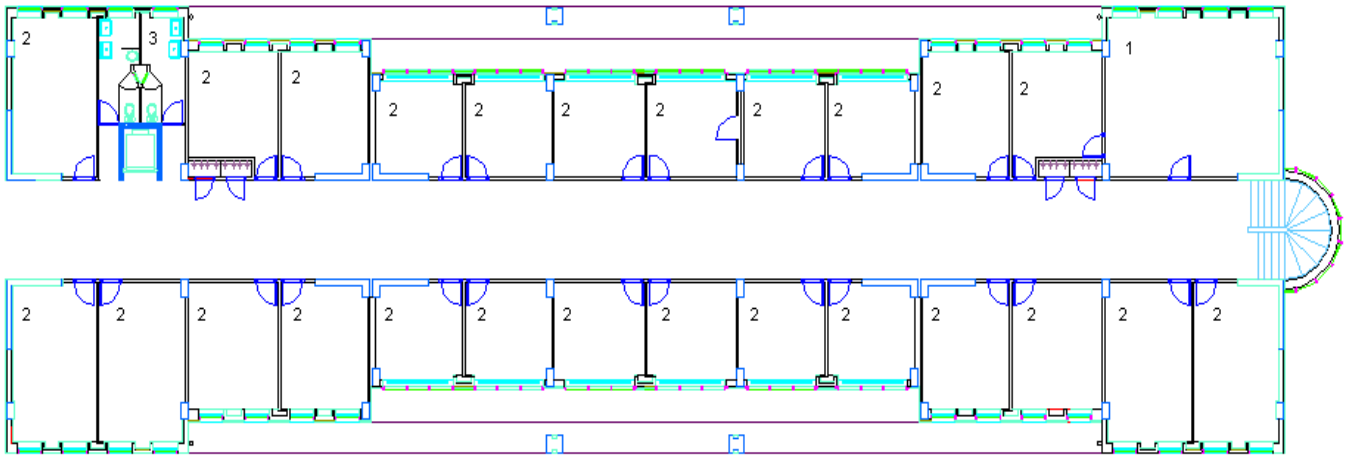

Figure 2. Architectural plan of the investigated office building (1: Managers room, 2: Offices, 3:Toilet)

The electrical energy enters to the main panel of the building via the underground electricity cable. The power is distributed to the floor panel from the main panel. A cable from the main panel also feeds the UPS. The energy from the UPS is also distributed via a special network to the offices. Each office has three UPS outlets, three main power outlets, two outlets for telephone and two outlets for the internet. Because some personnel use electric water heaters in the offices for preparation of tea, coffee etc., a training workshop for the personnel is carried out to realize the importance of UPS sockets employ for only the IT equipments. A schematic power demand from the UPS system is shown in figure 4.

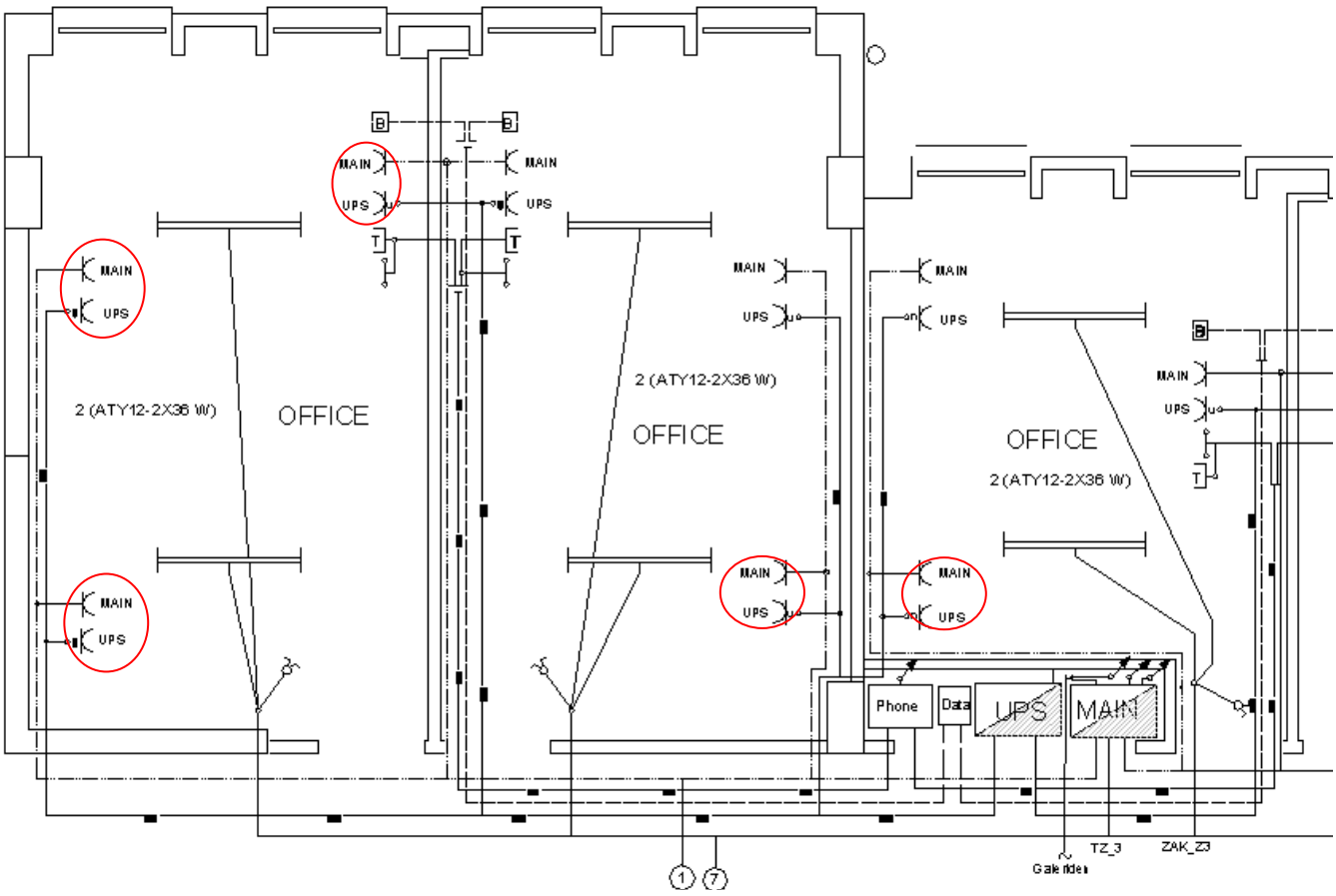

Figure 3. A sample electricity network for the offices: UPS and Main power connections

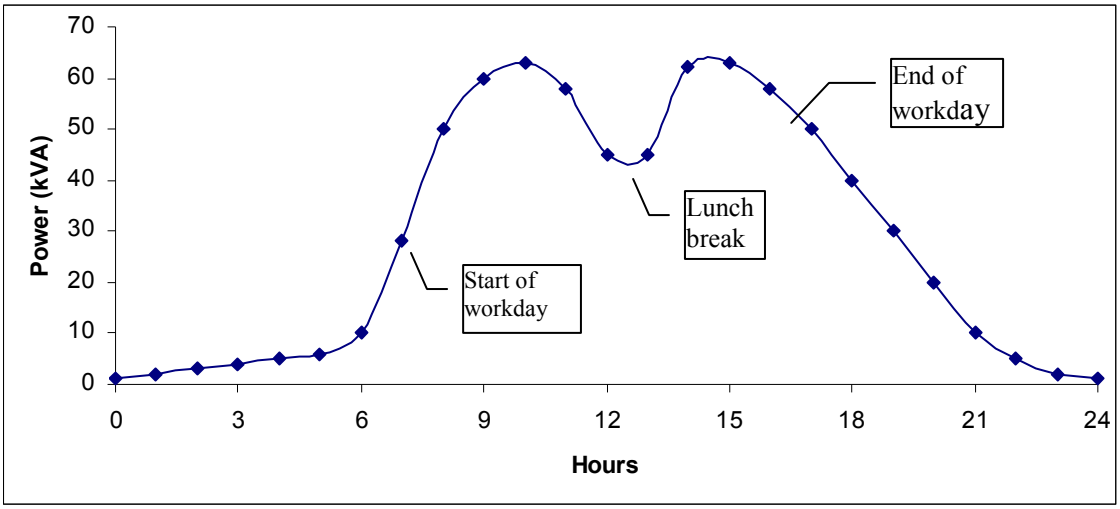

Figure 4. Daily energy demand from the UPS system (schematic)

ANALYSIS OF FAILURE

The UPS system encounters a malfunction in an almost monthly period. At the beginning, the problem was a sign of insufficient energy level. If the energy levels depart out of a particular limit, the UPS works in the bypass position which means that the UPS sockets connect directly to the main power supply. As a result, some of the IT equipments encountered malfunction while connected to the UPS sockets.

Later, the IGBTs and their driver cards encountered some failure. These failures are generally in the form of burning of IGBTs and their drivers (Figures 5). After the burning of these elements, the authoritative firm has changed the cards with new ones.

Figure 5. Front and back view of the failed card and IGBTs

As can be seen from the figure, even the power stage and low voltage electronic control stage are isolated from each other by an optocoupler, the driver card also burned out. According to the user manual, the inverter is taken out of order during the overloading period by means of the static by-pass system. In the present example, the IGBTs, whose preserving capacity is limited to its internal structure, are broken into pieces [7]. At an extraordinary case, the rectifier circuit fuse is also broken (Figure 6).

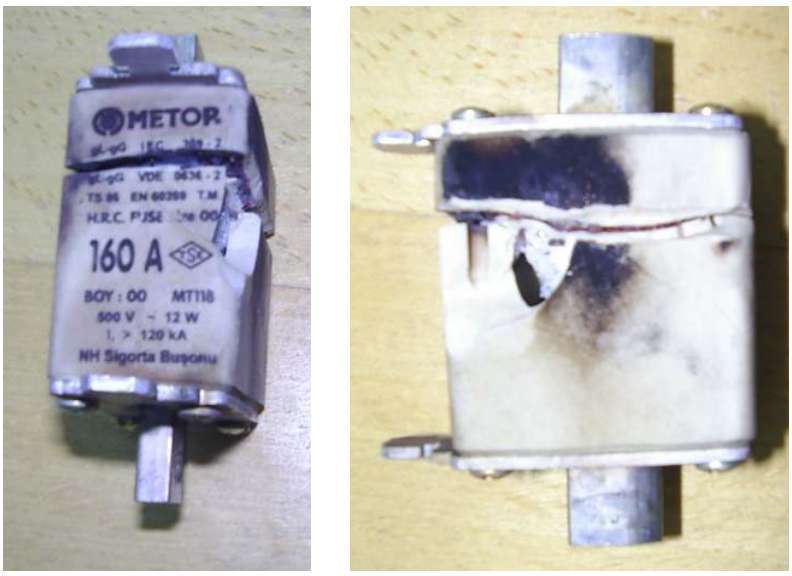

Figure 6. Front and back view of the broken rectifier circuit fuse

However the cause of the failure could not be determined neatly, the following reasons possibly explain the situation;

1. The malfunction due to the UPS: The static by-pass system may not be working as explained in the user manual. The inverter must be taken out of order in microseconds in the case of improper voltage situations [8]. The present UPS may encounter a timing error when connecting the circuit to the output initiating the coincidence of main energy and inverter output.

2. The malfunction due to the network: A wrong connection at a location in the building could be taken place. As a result, the UPS circuit and the main circuit could be confronted. No protection is present in the network considering the confronting of the circuits.

3. The inverter output could be forced manually to give energy to the external circuit.

RESULTS OF INVESTIGATION

The failure of a 60 kVA UPS is analyzed. The UPS supplies energy up to 110 IT equipments. The system has a static by-pass system with an on-line structure. The frequently encountered failures prevented the supply of uninterrupted, high quality energy supply.

As a result of the investigation, as the failure takes place at the IGBTs at the exit stage of the inverter, it is considered that the possible reason for the malfunction could be the confronting of the main and the UPS circuits. The location of the confronting must be determined to maintain the problem. This could be done by;

1. The voltage variations at the UPS enter and exit must be observed to determine the possible meteorological effects on the UPS.

2. The main circuit and UPS circuit should be controlled and an insulation test must be carried out.

CONCLUSION

Students are faced with the real life problems during their education period under a supervision of experienced teaching stuff. In this paper, a real life problem given as an example, they probably meet in their professional life is explained in detail including safety precautions for field studies, possible reasons and locations of failure generally omitted in the field. Another gain of the student should be the knowledge of possible worker faults which causes important problems during the service life of the entire wiring system. As a result of this course student will gain skills as a technical person who can use knowledge from different courses as in the present example: Power Electronics and Electrical Wiring Technology.

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