# DC SYSTEMS

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## 1.- INTRODUCTION

DC power supplies are an essential part of many industrial applications such as rail systems, telecommunications, energy distribution, energy production plants, etc. One of their principal uses resides in the charging of batteries for critical systems.

In most cases this systems are AC-DC, where the energy is taken from an AC grid and by means of different conversion components it is converted in a continuous voltage. This output voltage is adapted to the particular aspects of every application.

## 2.- DC SYSTEMS TYPES

DC Systems which are used on the market nowadays are mostly divided in two types: Thyristor based rectifiers and transistor based rectifiers.

The first of DC systems is based on an element called thyristor which is able to rectify AC voltage and convert it to DC in an easy and controllable way. This system generates a voltage which is pulsing and needs to be filtered by an inductor-capacitor system. The main advantage of these systems is the reliability of the thyristors, which can block large voltages and conduct big currents. However, the major drawback of this topology is the necessary transformer – inductor – capacitor group, which is large and heavy. Moreover, due to the time constant introduced to the system due to the inductor-capacitor filter, the transient response of the system to steep changes in the output load is much slower than those of switched mode units.

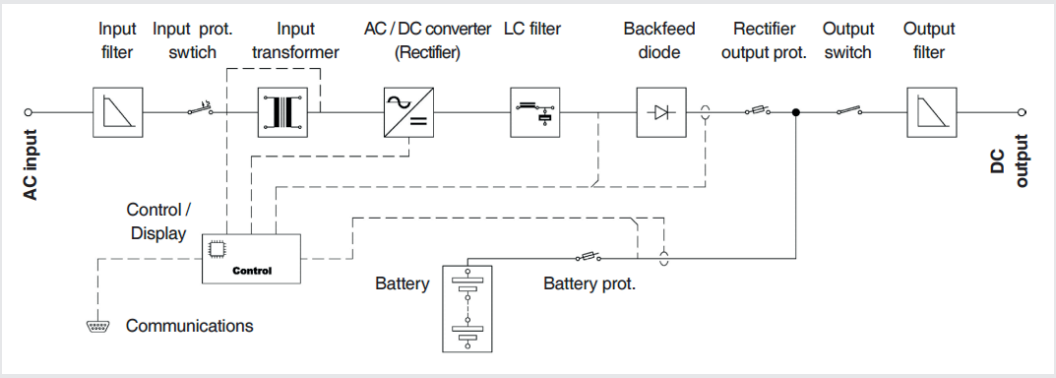


*Fig.1 Thyristor based rectifiers scheme*

The transistor based systems (also known as switch mode supplies) are based in the switching of the input voltage using transistors, using a high frequency transformer that reduces the voltage and isolates the system regarding to the mains. Current designs incorporate at the input a power factor correction circuit (known as PFC), in such a way that the distortion in the input is almost inexistent. The advantages of these Systems are their excellent power ratio, the high efficiency and the excellent dynamic response towards steep load changes and perturbations in the output power. The problem with this type of systems is in that the MTBF and the life cycle are usually lower than those systems that use thyristors. This is the reason why they are usually installed with redundant units to prevent failure.

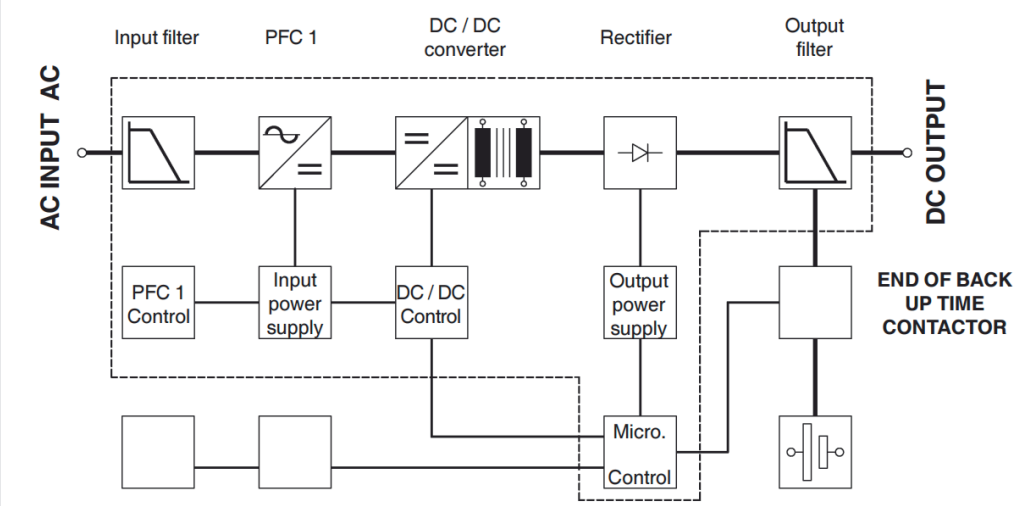


*Fig.2 Switched mode power supplies scheme*

## 3. THYRISTOR RECTIFIERS VERSUS THE SWITCHED MODE POWER SUPPLIES

Historically the systems based in thyristors have been the referent on battery chargers. Their reputation of high reliability and robustness still today overshadow some of the best switch mode Systems. However, switched mode power supplies go one step further in terms of power density, efficiency and availability. Those high levels are difficult to reach with Systems based in thyristors.

In the next table a set of characteristics of both topologies of rectifiers is displayed, highlighting both the advantages and disadvantages for each of them.

| Thyristor Rectifier | |
|---|---|
| **Advantages** | **Disadvantages** |
| Proved robustness | Low power factor |
| Usually built to work with passive cooling | Medium efficiency |
| Really low maintenance | Low power density |
| High lifecycle (>30 years) | Heavy and bulky |
| High MTBF | Hard to increase the power |

| Switched Mode Rectifier | |
|---|---|
| **Advantages** | **Disadvantages** |
| Power factor ~1 | Usually built with active cooling |
| High Efficiency | Medium maintenance (fans) |
| Really high power density | Medium lifecycle (10-20 years) |
| Compact and modular systems | |
| Easy to increase power (scalable) | |
| High availability | |

## 4. DIFFERENT BATTERY TECHNOLOGIES REQUIRE DIFFERENT CHARGE ALGORITHMS

It may seem that in order to charge a battery the only thing one has to do is to apply a voltage potential between the battery terminals and wait. However, the reality is quite different as one can find in the market different battery technologies.

Each battery demands a different charge method and it is important that the rectifier-charger is perfectly adapted to that specification to ensure that the battery is correctly charged and the expected amount of energy can be withdrawn from it. Only by using the correct charging method one can obtain the expected battery lifecycle declared by its manufacturer.

A modern battery charger must use hybrid charging algorithms, applying a constant voltage or a constant current depending on the stage of the battery charging. Those algorithms combined with charge compensation in function of the battery temperature and the control of the maximum current absorbed by the battery –which must be active at all times- determine the charging process.

It is also very important the correct detection of the time in which the battery is completely charged. The premature termination of the charging process represents a reduction of the stored energy, whereas an excess of charge implies a deterioration of the storage group. It should also be noted that some battery technologies, for example lithium batteries, do not accept overcharge because it implies a high risk of explosion or fire.

Other parameters which must be monitorized because they significantly affect battery life are the cell imbalance and the output current ripple. These two aspects accelerate the deterioration process of the battery, and they can be highly damaging depending on the used battery type.

## 5. RELIABILITY AND REDUNDANCY

When talking about DC units that power critic loads, it could be defined as securing the continuity of electrical supply to this system. A key point to ensure this continuity is the reliability of the DC unit which is used to power the load.

Regarding the DC equipment which use thyristors, reliability is obtained due to the robustness of the used elements (thyristors, transformers and inductors) and in favour of this reliability other aspects of the unit like the power density or the efficiency are cut down.

With the appearance of the switch mode rectifiers another concept gains importance: redundancy. ¿What is redundancy? In a very minimalistic way it could be defined as the fact of having duplicated elements in such a way that in case of malfunctioning of the principal element the second element, which is redundant, takes the place of the first one.

This concept is not new, as it is not difficult to find redundant thyristor systems, in such a way that different complete systems are connected in parallel in order to increase the global reliability of the system. The main inconvenience is the high initial cost that this redundancy represents and the amount of physical space needed in order to install redundant systems which use this topology.

In switch mode systems redundancy has increased in popularity, mainly because those systems are modular and scalable. This redundancy can be applied in terms of rectifier module and not in a system level. The economical impact is reduced to a fraction of what the entire system costs, and redundancy becomes an attractive solution because it compensates the lower robustness –which is intrinsic to the used technology- associated to the transistor based rectifiers.

## 6. AUTONOMY UNDER CONTROL

In the same way that the charging process of a battery needs to be thoroughly controlled, the discharging process of the battery must be precisely monitored in order to increase autonomy. This is used to estimate the battery state and as a consequence to be able to redirect the energy to the loads in a dynamic and selective way.

The implementation of a selective turn off of loads depending on the battery charge and the establishment of different levels to every load connected to the DC supply system implies a significant increment of the battery autonomy for the most critical loads. This system also enables a more optimum sizing of the battery capacity depending on the loads to supply and thus a saving in the initial cost of the system.

## 7. COMPATIBILITY WITH BATTERY MONITORING SYSTEMS (BMS)

It is widely known that the maintenance and working conditions of the batteries directly affect their lifecycle. The charge current, the current ripple and the temperature are the main factors which affect their life time.

Some standards for the correct maintenance of batteries depending on their type can be found. Between them the most remarkable ones are:

- IEEE 450 for Vented Lead-Acid Batteries
- IEEE 1188 for Valve-Regulated Lead-Acid Batteries
- IEEE 1106 for Vented Niquel-Cadmium Batteries

All this recommendations consider as good practices the performing of capacity tests and impedance tests.

The incorporation of a battery monitoring system must be considered when the number of elements in the battery group is high. This system leads to premature detection of anomalies in a cell level and as a result the ability to increase the battery life considerably.

The working principle of this systems is based in the individual monitoring of each cell of the battery, in such a way that when in a charge or discharge process a cell voltage differs from the voltage of the rest of the batteries the user is informed about it and correction measures can be applied to proceed to the re-equilibration of the battery. If a cell is deteriorated until a point in which it can not be re-equilibrated, the system alerts the user and thus the substitution of the cell can be performed before it affects the rest of the battery.

Clearly, it is desirable that when considering a rectifier system, it includes the possibility of incorporating a BMS system.

## 8. THE FINAL DECISION

Two different rectifier topologies have been discussed and the selection of one or the other topology will mainly depend on the requirements of the installation. One system is more robust but less scalable, whereas the other has all the advantages of modularity and scalability but when used in an application that does not evolve with time and has a longer life time it may need more maintenance.

In any case, regardless the final decision, the selected system must fulfil a set of minim requirements in terms of durability and reliability. The system has to incorporate an efficient battery management and an advanced control in charge algorithms, in such a way that the lifecycle of the batteries is not reduced because batteries have an important economic cost in case they need to be replaced.