

Lab no.1
(introductory review)

**THE PLACE AND THE IMPORTANCE
OF POWER ELECTRONICS**

The energy aspects present an eloquent image on the level reached in its development by a civilization. Up until now the progress has been associated with the growing demand of energy. Due to limited resources and ecological issues (pollution, greenhouse effect, wastes etc.), the quantitative vision of energy has been replaced by a qualitative one that emphasizes the efficiency of its use. Thus, the technological creative effort of today's society is focused with priority over the solutions capable of reducing consumption and over the increased use of the renewable sources. In this approach, the power electronics plays an important role and well defined.

The usable forms of energy are kinetic, heat, light and chemical energy. In the beginning, people have been generating these energies directly from the primary energy forms: solid and liquid fuels, hydro, wind, solar and the geothermal energy. Today, the energy obtained from the primary forms is almost entirely transformed into electrical energy as an intermediate form between the producer and the user, the consumer. The use of the electrical energy was determined by its flexibility and its distinct benefits compared to other forms of energy: produced in specialized units (power plants) with high efficiency, long distances transport with low losses, inexpensive and easily distributed to consumers, converted into any usable form of energy by the receiver.

The receiver or the load is the last link in the chain of power production and distribution. A first classification of the loads can be operated according to the type of the usable energy obtained from the electrical energy. Thus, the loads can achieve an electro-mechanical conversion (electrical motors, electromagnets), an electro-thermal conversion (ovens, plates, radiators, welding machines etc.), an electro-chemical conversion (electrolysis, electroplating, batteries etc.) and a conversion of the electrical energy into light (lamps, bulbs etc.). A single class may contain multiple types of loads, e.g. electrical motors can be DC, AC, stepped or switched reluctance type.

Each of these electrical loads accepts at the input a certain form of electrical energy (DC or AC) with certain parameters. On the other hand, these loads achieve at their output mechanical, thermal, light or chemical *processes* that must be ***controlled***. Taking into account these two requirements, an interface (equipment) is needed not only to adapt the energy parameters between the electrical source and the load, but also to control the power flow for a further control the process variables. These

equipments are named *converters* and as shown above, they have to accomplish an *electric-electric conversion* in a controlled manner.

Before power electronics appeared as a distinct technical field, the electric-electric conversion was usually avoided in applications. The main cause was the difficulty of implementation at that particular moment. The alternative was to use the *rotary converters* formed by groups of electrical machines (generator-motor set). The disadvantages of this solution are obvious: it is expensive, low reliability due to rotational elements, low conversion efficiency, high size and mass, noise, etc.

Along with the development of semiconductor technology, the first power diodes were made, and in 1956 the thyristor is designed as the first *power semiconductor device* with a control terminal. Based on these new devices, power electronics had a fast developing process through the emerging of *static converters* also known as *power electronic converters*. Their advantages are complementary to the rotary converters. First, the *static conversion* removes the movement from the conversion process and therefore the mechanical wear. This aspect will avoid the periodic maintenance and will increase the converter's lifespan. Moreover, static converters have lower size, are lighter, cheaper, less noisy, etc. As a drawback a lower robustness is revealed in comparison with rotary converters when are overloaded.

Since the arrival of the first power electronic applications until now, the developments in this field have been impressive. A plethora of circumstances can be highlighted as contributors to this progress, especially if these ones have worked synergistically. A first factor was the market. Applications from various domains obliged the power electronic converters' to be more efficient in terms of overall performance. The perspective of a market with high sales and profits has pushed powerful companies (Siemens, International Rectifier, Semikron, Eupec, IXYS, ABB, Danfos, Fuji Electric etc.) and universities with tradition to heavily invest in research and development. The first objective was to raise the performances of the power semiconductor devices as basic elements from the *power structure* of static converters. The design of 100% controllable devices with high switching frequency was creating the prospect of a new generation of converters with simple topology and reduced size. Technologies and research results have been transferred and exploited from the area of low power semiconductor devices (microelectronics) to the area of high power devices with spectacular results. In the race against time to sell more, the big firms began to rapidly launch on the market transistors known in microelectronics (**B**ipolar **J**unction **T**ransistors - BJT and MOSFET) with higher power, as well as new devices such as: the **G**ate **T**urn-**O**ff Thyristor (GTO), the **I**nsulated **G**ate **B**ipolar **T**ransistor (IGBT), the **M**OS **C**ontrolled **T**hyristor (MCT), etc.

Meanwhile, complex integrated circuits (drivers) were designed and built especially for the control of power semiconductor devices. All these new components have facilitated the construction of compact power electronic equipments, cheap and with very high performance. Consequently, the selling of converters and power devices has grown constantly, creating a phenomenon with a double and contradictory effect in electronics: higher performances and lower prices. This positive reaction has

extended the number of the power electronic applications in all areas of human activity. Experts estimate that today more than 50% of the electric energy consumed in a developed country flow via the power electronic equipments and this percentage is growing. These equipments have engulfed the entire chain of production, transport, distribution and consumption of electrical energy. There is a large process of “electronification” of the electric equipments through which the latter gain new functions and features.

In order to have a clearer picture of this global phenomenon, there is presented an overview in the lines that follow of some areas in which electric equipments incorporate *power electronic systems*:

- **The industrial field**: all the adjustable drives (with electrical motors) of various industrial installations, machine tools and robots, electric furnaces, heat treatment installations, welding machines, electrolysis and electroplating installations, etc.
- **Transport of goods and persons**: locomotives or electric trains, electric underground railways, tramways, trolleys, hybrid or full electric cars, elevators, cranes with electric drives, etc.
- **Energetics**: equipments for classic power plants (thermal, hydro, nuclear), equipments for wind plants, solar, geothermal, etc. that use the renewable energy resources (RER), equipments for micro-grids (μ -grids, smart grids) that implement the modern principle of *distributed generation* of electrical energy from one or more renewable sources, equipments for to high voltage DC power transmission, energy storage systems, etc.
- **Residential appliances**: vacuum cleaners with adjustable speed, automated washing machines, electric plates with controllable temperature, microwaves ovens, food processors, lamps with adjustable light, heat and air conditioning installations, computers and audio-video devices that incorporate switching DC power sources, etc.
- **Commercial and business field**: escalators, elevators, heat installations, ventilation systems, air conditioning and cooling systems, ornamental lighting, fire equipment, television with closed circuit, code readers, computers, uninterruptible power supply (UPS);
- **Telecommunications**: the DC power sources, battery charging installations, uninterruptible power sources, guided radio antennas, etc.
- **Medicine**: laboratory and surgery robots, radiological investigation equipments, computed tomography and nuclear magnetic resonance, air conditioning installations, elevators, medical equipments, etc.

- **Aeronautics and aerospace:** planes of all types, satellites, surveillance and communication installations, launch bases, etc.
- **Military domain:** radar surveillance installations, rockets, guided launch ramps, military vehicles, guided antiaircraft batteries, installations for guidance;

It should be noted that from the all applications that include power electronic systems, a high percentage is represented by those in which the kinetic energy is generated or the movement is determined by the electric motors. These *electric drives systems* are the main power consumer (around 70%) of the generated energy. Thus, many power electronics applications are found in the field of electrical drives. For this reason the study of power electronics often interferes with other domains such as electrical machines, electrical drives, as well as with other disciplines that are tied to the control of power electronic systems such as: microelectronics, digital systems with microprocessor (microcontrollers - μC , digital signal processors - DSP), automatics, control theory, electronic measurements, etc.

A conclusion cannot be written about a general evaluation of power electronics without taking in consideration the effects of some static converters on the power grid. Thus, a classic converter (line-frequency rectifier) connected to a grid pollutes it with current harmonics (*harmonic pollution*), with reactive power absorption and with electromagnetic interference phenomena. Until the 1980's all the power electronic applications were few and found mostly in the industry. For this reason, their effect on the grid was, in general, considered negligible. But today, the number of applications has grown exponentially and there is a cumulative effect of harmonic pollution. Consequently, important losses in the grid are registered and many consumers are affected by the voltage waveform distortion. Following this ascertainment, there was a need for a regulation that was supposed to limit the disturbances from the grid induced by the power electronic converters and other non-linear loads. Thus, new international standards (IEC, ANSI/IEEE), as well as European (CENELEC) have been developed; in the European Union these new standards became imperative national law. The EU imposed itself as a deadline the year 1994 in order to adopt this new legislation and the date of June the 6th 1998 to enforce it all over the Union. Once Romania became an EU member (2007), this legislation became mandatory for our country; consequently, the users of converters tied to the power distribution network had to take measures to fulfill the legal requirements concerning the grid pollution. These measures included the use of converters absorbing sinusoidal currents (active rectifiers) or that of efficient active and passive filters completing the polluting converters.

The *active power filters* are also power electronic equipments and therefore are treated inside the same area of study. The structure and the operation of an active power filters do not differ very much from that of known static converters and could

be, by extension, included in their category. However, taking into consideration their role, the active power filters occupy a rather distinct role inside the curriculum, being taught separately from the converters.

There are other power electronic equipments, having different names from that of normal static converters or from that of active filters, which contribute to energy management or to power quality.

- ✓ **Power factor static compensators** (PFC – *Power Factor Correction*, STATCOM – *Static Compensator*, UPFC – *Unified Power Flow Controller*) – electronic structures which enable a power factor correction, a voltage stabilization and a control of power flow in the grid.
- ✓ **Dynamic voltage restorer** – enables the real-time correction of delays and waveform deformations of the grid voltage.
- ✓ **Transfer switches** – enable the consumer switching between different power supply lines;
- ✓ **Static breakers** – enable the connection and disconnection of various loads, as well as the isolation during short time the area of grid faults;
- ✓ **FACTS equipments** - all the power electronics equipments forming a Flexible Alternating Current Transmission System (FACTS) used in an AC grid to increase the power transfer quality.

Taking into account the diversity of power electronic equipments and the option that many of them could be brought together inside a given application, it has emerged the notion of electronic power system.

Definition: *A power electronic system is an ensemble, having a very well defined functional role, which can include one or more static converters, power active filters, static compensators and other structures that contain power semiconductor devices together with the drivers and the digital control circuits.*

Basically, any structure with power semiconductor devices and other circuit elements (inductances, capacitors, resistors) in association with the control circuits can form an electronic power system. Taking into account this observation, one can say that ***the power electronics studies the power electronics systems***.

A complete study of power electronics presupposes a complex staged approach:

- a) The study of the power semiconductor devices, as well as their control and protection circuits; the study of the modern power modules - the integrated and the intelligent power modules.
- b) Defining and classifying the power electronic converters; the study of principles forming the basis of static power conversion.

- c) The study of usual topologies of static converters and the control techniques of each converter type.
- d) The study of other power electronic structures: active filters, static compensators, etc. and the control techniques of them.
- e) The study of the reference applications of the power electronic systems.
- f) The design and manufacturing of power electronic systems.

An important and modern aspect that is tied to the issue of design, as well as to the didactic process, refers to the modeling and simulation techniques employed for the power electronic systems' analysis. To this end, more programs have been written especially to run on standard computers for modeling and simulation the electronics circuits. Ones of them are the PSPICE and ORCAD programs.

Objectives and procedures:

1. With the study of this introductory review, it is intended to understand some power electronic notions, such as: static power conversion, power semiconductor device, static converter, power electronic system, etc.
2. A thorough analysis will also include the significance and the role played by power electronics today in the reduction of consumption and pollution, in the use of renewable energy, in the processes' control, in the comfort increase of everyday life, etc.
3. It will ascertain the large use of power electronic equipments in all human activity;
4. The most significant equipments from power electronics and their role will have to be kept in mind;
5. The requirements of power electronics studies, as well as the competences related to the field mastery, will be analyzed.

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