PERFORMANCE OF POWER ELECTRONIC SYSTEM AND APPLICATIONS

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Abstract:
Global energy consumption continues to rise, as does the need to increase power capacity for production and distribution. Power electronics has played a significant role in recent decades. Power electronics will have incredible applications in the industrial, residential, commercial, transportation, aeronautics, military, and electric utility systems. Not only will power electronics have an increasing impact on global industrial automation and high-efficiency energy systems, but also on energy conservation, renewable energy systems, and electric vehicles.
Power electronics can enable utilities to more effectively deliver power to their customers while also increasing the reliability of the bulk power system. In general, power electronics is the process of controlling and converting electrical power flow from one form to another to meet a specific need. The relationship between the technological foundation and the system's performance then exists as a mathematical representation, whose optimisation ensures the best possible utilisation of the available degrees of freedom and technologies. Thus, power electronics is a multidisciplinary field that includes semiconductor physics, electrical motors, mechanical actuators, electromagnetic devices, control systems, and so on.
Keywords: Power Electronic System, Power electronics, Voltage Source Inverter, Power Semiconductor Devices,

Introduction:
The growing use of renewable energy sources and power electronics-based technologies that use power devices to efficiently convert electric power into the best characteristics. Power electronics contributes to the realisation of both a prosperous and comfortable way of life and a sustainable society by improving the energy efficiency and performance of various equipment [1]. The design and analysis of power electronics circuits include applications of circuit theory, electronics, control theory, electromagnetics, semiconductor devices, microprocessors, numerical methods, signal processing, computer simulation, heat transfer, electromagnetic compatibility, and artificial intelligence. Large power generation plants produce the majority of the power in traditional power systems, which is then transferred to large consumption centres via long distance transmission lines. The system control centres continuously monitor and regulate the power system to ensure the quality of the power, specifically frequency and voltage. However, as the overall power system evolves, many dispersed generation (DG) units are being developed and installed, including both renewable and non-renewable sources such as wind turbines, wave generators, photovoltaic (PV) generators, small hydro, fuel cells and gas/steam powered Combined Heat and Power (CHP) stations.

Power semiconductor device advancements have paved the way for newer devices like silicon carbide, gallium nitride field effect transistors (FETs), and power diodes. These devices excel in terms of wide band gap, which allows for high-voltage operation, thermal management, and efficiency. As a result, power electronics are now widely used, even in noise-sensitive areas, to replace lossy linear power supplies and voltage regulators. When compared to silicon devices, the main advantage of these devices is their ability to withstand high voltage. As a result, the systems can be designed with high-voltage capabilities, which reduces current and improves efficiency for the same amount of power delivered. Furthermore, operating the devices at higher switching frequencies reduces the size of passive components, making the systems more compact. Thermal designs are simplified when they can withstand higher temperatures. [4]

Power electronic systems are used in a wide range of applications, including:

- Power Generation
- Power Transmission
- Power Distribution
- Power Control

In all of these applications, power semiconductor devices switch the input voltages and currents to provide the desired outputs. To withstand high voltages and currents, the construction of basic semiconductor devices such as diodes, FETs, and bipolar junction transistors (BJTs) is altered. As a result, silicon-controlled thyristors (SCRs), power diodes, power metal oxide semiconductor field effect transistors (MOSFETs), power BJTs, insulated gate bipolar transistors (IGBTs), gate turn-off thyristors (GTOs), and other devices have been developed. Power levels, switching frequency requirements, efficiency, and the nature of inputs and outputs all influence device selection. For example, the power handled in an EV powertrain is on the order of kW. Power MOSFETs that can withstand high voltage and switch at higher frequencies are commonly used in such applications. Silicon-controlled rectifiers (SCRs) are used in power transmission where the handled power is of the order of a few megawatts. [5]

The figure below depicts the block diagram of a typical power electronic system.

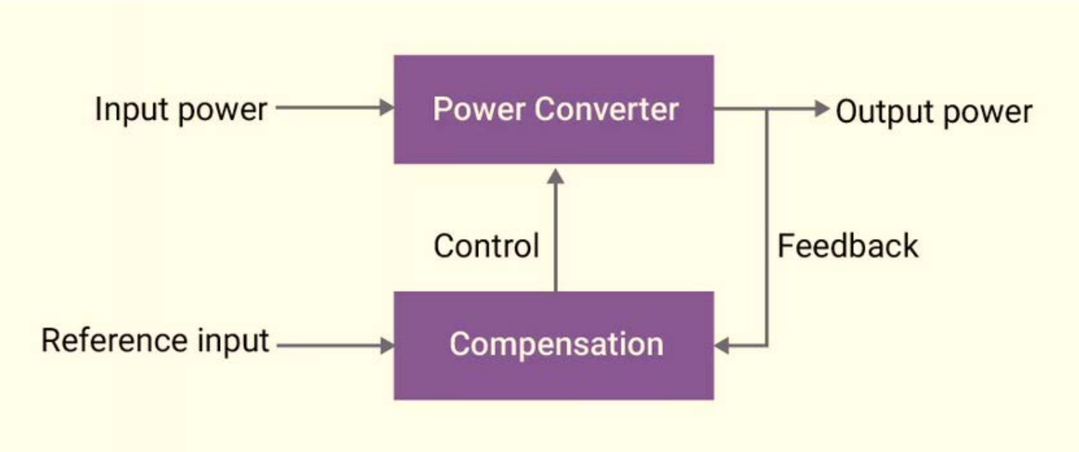

Figure 1: Block Diagram of Typical Power Electronic System

Power Electronics is a multidisciplinary field that combines power, electronics, and control theory to control and convert electric power. It can be considered a subset of system engineering. Power Electronics has already established a significant role in modern technology, and it is now used in a wide range of high-power products. The numerous advantages of power electronics for power control and processing of industrial applications have contributed to the rapid growth of the power electronics revolution [6]. It's also used in renewable energy sources that feed into the electrical grid, and it's becoming more popular as these applications become more integrated with grid-based systems [7]. Power electronics has evolved rapidly over the last thirty years, and the number of applications has grown, owing primarily to advancements in semiconductor devices and microprocessor technology. In both cases, higher performance is consistently provided for the same area of silicon while the price is continuously reduced [8].

Objectives:

- Performance of Power Electronic System.
- Define Applications of Power Electronic System.
- Development of standard Power Electronics-Based Drives for the last decades.

Result and Discussion:

Some Applications of Power Electronics [9-11]

Wind energy is described as one of the most emerging renewable energy sources, which is transforming from a minor energy source to an important power source in the electrical network thanks to power electronics. Wind energy power electronics control in distributed power systems and computer simulation of wind power systems can be found. In the current development of power systems, there are two major trends. The first step is to make extensive use of renewable energy resources. The second is power generation decentralisation. [12-14] present some power electronics applications for power systems. Power electronics is used in many different residential, commercial, and industrial applications, such as computers, transportation, information processing, telecommunications, and power utilities. These applications can be divided into three types:

Electrical applications: Power electronics can be used to create regulated AC and DC power supplies for a wide range of electronic equipment, including consumer electronics, instrumentation devices, computers, and Uninterruptible Power Supply (UPS) applications. Power electronics is also used in the design of distributed power systems, the control of electric heating and lighting, power factor correction, and Static Var Compensation (SVC).

Electromechanical applications: Industrial, residential, and commercial applications all make extensive use of electromechanical conversion systems. AC and DC machine tools, robotic drives, pumps, textile and paper mills, peripheral drives, rolling mill drives, and induction heating are among the applications.

Electrochemical applications: Chemical processing, electroplating, welding, metal refining, chemical gas production, and fluorescent lamp ballasts are all electrochemical applications. Table (I) lists a variety of power electronics applications in the industrial, commercial, transportation, residential, utility systems, and telecommunications industries.

Power semiconductors are critical components of the vast majority of power electronics devices and systems. By far the most common semiconductor material is silicon. As power semiconductor devices improve, more and more power electronics systems are being used in high-power utility and industrial applications. As a key component in system topologies, power semiconductor devices have played an important role in the development of power electronics. Power semiconductor devices must withstand high voltages in the off state and carry high currents in the on state, which necessitates geometry differences from low-power devices. Power semiconductors are classified into two types based on their terminal numbers: two-terminal devices and three-terminal devices [15-16]. Figure 2 depicts a second classification based on device performance: majority carrier devices (Schottky Diode, MOSFET) and minority carrier devices (Thyristor, bipolar transistor, IGBT).

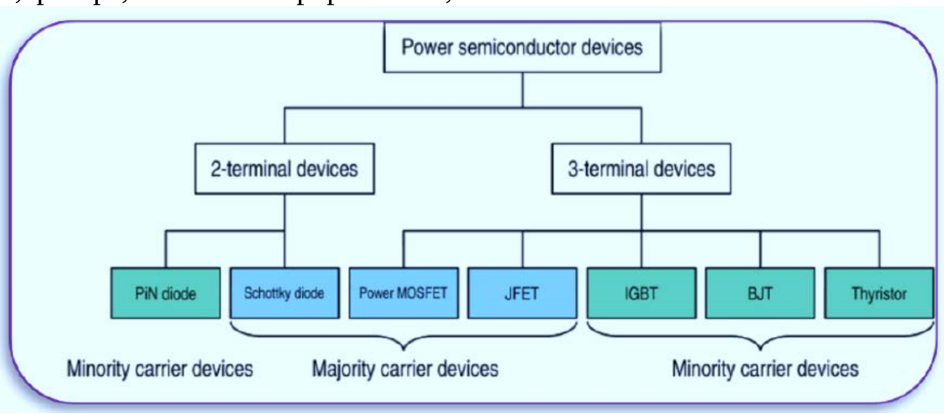

Figure 2:The Power Devices Family, with the Major Power Switches

Power semiconductors take advantage of the electronic properties of semiconductor materials such as silicon, germanium, and silicon carbide. The Silicon Controlled Rectifier (SCR) revolution in power semiconductor devices began in 1958, when General Electric Company (GE) began commercialising the first thyristors.

The power converter serves as the link between the renewable energy source and the electrical grid. Power flow is typically bidirectional. When using such a system, three major issues must be addressed: reliability, efficiency, and cost. Currently, the price of power electronics-based drives drops by 1-5% per year for the same output performance. Figure 3 depicts the weight, size, number of components, and functions of a standard Danfoss Drives A/S frequency converter. [17]

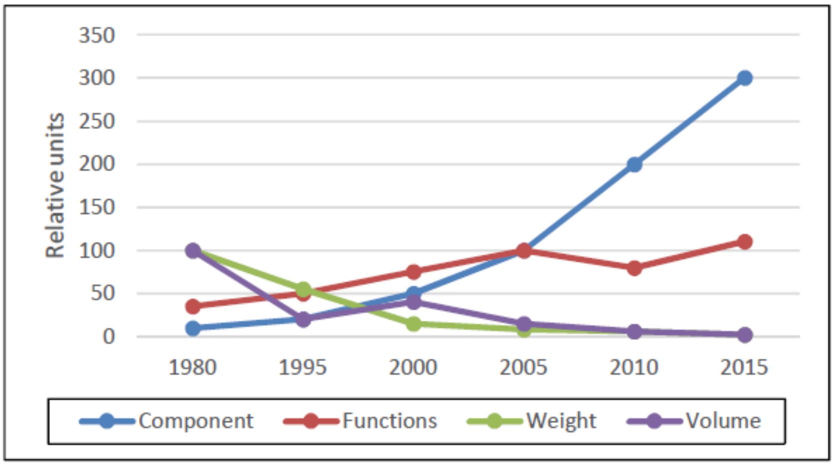

Figure 3:For decades, standard Power Electronics-Based Drives have been developed.

Most renewable energy system technologies use power electronics, with solar and wind energy systems being the most common. Over the last few years, there has been a continuous effort to improve each component of a photovoltaic and wind turbine application. Commercial photovoltaic module efficiency now exceeds 17%, inverters have reached nearly 99% European efficiency, and new topologies have been discovered that make wind turbine systems more efficient and flexible in their operation.

With new fields of application, the demands on power electronic solutions in terms of power density, functionality, reliability, and efficiency increase. To achieve the best results, the converter must be designed within the context of the entire power electronic system. Aside from the converter, this includes all system components (storage, cooling, electrical machines, cables, transformers, filters, and so on) as well as optimised control algorithms to ensure the converter's system-friendly operation. New applications frequently necessitate completely novel approaches, which can be thoroughly investigated using the ETI infrastructure for power electronic system modelling, simulation, and hardware validation. [18]

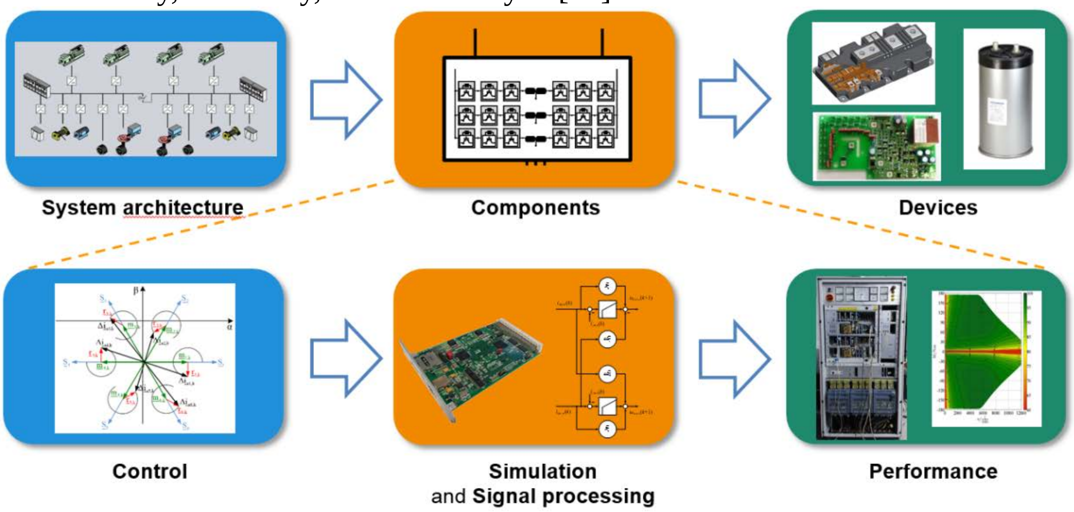

Figure 4: infrastructure for Power Electronic System

Conclusion:

This paper examined power electronic applications in power systems. Power semiconductor classification, devices, and applications are discussed. Power semiconductor device development is critical for modern electronics devices. This paper examines global energy and power electronics-based drives, as well as renewable energy resources and consumption. We discuss the role of power electronics in energy conservation and the importance of energy storage.

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