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The Need for Energy Transition to Build Sustainable Societies

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Abstract

The energy transition from the use of fossil fuels to the use of renewable sources is a necessity for all economies on the planet we inhabit. Every day, more thermal, moving and electrical energy is consumed, and greenhouse gases and electromagnetic emissions degrade survival. The only solution is to migrate to a modern electrical system as a complex interconnected network that efficiently generates, transmits and distributes electricity from various sources to consumers. It includes a combination of traditional power generation, such as steam and hydraulic turbines, along with emerging technologies, such as renewable energy sources, energy storage and advanced communication systems. Modern electrical systems also incorporate power electronics for efficient energy transfer and smart grid technologies for improved control and monitoring. In this paper, the authors hope that readers will be able to recognize the key aspects in just a few paragraphs and that those who wish to do so will have a guideline for further exploration.

Keywords: Energy transition; Climate change; Power and energy system; Power electronics and energy systems; Renewable energy and smart grid; Modern electrical systems

Introduction

This contribution is inspired by the meaning of the following two memorable quotes: by Albert Einstein: "You do not really understand something unless you can explain it to your grandmother" [1] and novelist Samuel Lover "better safe than sorry" [2,3]. In a didactic way, assuming readers who do not have the required basic knowledge, that, for the current moment of life in the 25th century, characterized by the productive sectors, goods and services, as well as the residential sector, demand high volumes of energy, energy consumption and Greenhouse Gas Emissions (GHG) are closely related and are the cause of accelerated climate change [4] towards worse survival conditions. Throughout history, there have been several industrial revolutions [5], each characterized by technological advances and significant economic and social transformations. The first industrial revolution (18th-19th century) focused on mechanization and the use of steam power. The second (second half of the 19th century-1914) focused on mass production and electricity. The third (mid-20th century-present) focused on automation and electronics. The fourth (21st century) focused on digitalization and renewable energy. These industrial revolutions have had a profound impact on society, the economy and technology and continue to shape the world we live in.

By the current year, 2025, energy consumption can be broadly classified as thermal, electrical and motion energy. Using the term "energy services" [6] to refer to those functions that are performed using energy and that constitute a means to obtain or facilitate desired services or end states, the most common examples of energy services are lighting, cooking, space heating, water heating and cooling. Thermal energy is used for heating and other purposes not related to transportation. Electrical energy, or electricity, is used for a wide range of applications, such as powering devices, lighting and industrial processes. Motion energy encompasses the energy required for locomotion, whether human movement or the operation of machinery. The rapid development of industry, which is a sector with high energy consumption, leads to a significant increase in energy consumption [7]. Decoupling energy consumption from economic growth is one of the requirements for achieving sustainable development. This study performed a decoupling analysis between industrial energy consumption and industrial economic growth to identify their relationship. Since the Second Industrial Revolution, the final stage of a power generation plant has been through electromechanical converters. These deliver to the centralized electrical power system a sinusoidal waveform of 60Hz in America and Japan and 50Hz in Europe. Typical technologies: centralized power systems without power electronics have as their essential elements rotating machines, transformers, switching devices and protection devices [8,9].

The role of electricity in the transition to renewable energy to mitigate climate change is crucial [10]. Renewable electricity offers opportunities to achieve sustainable development goals, climate stabilization, job creation, a green economy, and energy security with careful planning. Power electronics [11,12], which involves the conversion, control and conditioning of electric power, plays a critical role in addressing challenges such as the integration of renewable energy systems into the global power grid. The intermittent and variable nature of renewable energy sources such as solar and wind presents significant challenges to maintain efficiency and reliability. Power electronics in propelling the increase of renewables and increasing the efficiency of contemporary electrical grids is important [13]. The interaction between power electronics, DG, microgrids and smart grids happens [14]. Microgrids and Smart Grids are modern power system technologies [15] that utilize distributed energy resources and advanced control systems to enhance reliability, efficiency and sustainability. Microgrids are localized power grids that can operate independently or in parallel with the main grid, while Smart Grids are a broader concept of modernizing the entire electricity network. The large-scale integration of power electronic based systems poses new challenges to the stability and power quality of modern power grids [16]. The wide timescale and frequency- coupling dynamics of electronic power converters tend to bring in harmonic instability in the form of resonances or abnormal harmonics in a wide frequency range.

The evolution of electrical grid systems from centralized to decentralized networks [8,17] marks a significant transformation in the energy sector. Traditionally, centralized grids, with power generated at large facilities and transmitted over long distances, have been the norm. However, the increasing demand for sustainable, resilient and flexible energy solutions has spurred a shift toward decentralized networks. These decentralized grids distribute electricity generation across multiple, often renewable, sources closer to the point of use, reducing transmission losses and enhancing grid reliability. Switched converters, commonly used in electronic devices, can generate Electromagnetic Radiation (EMR) or Electromagnetic Interference (EMI) [18], due to their high frequency switching operations. This radiation can disrupt the performance of other nearby electronic devices and potentially pose health risks. Therefore, understanding and mitigating EMI from switched converters is crucial for ensuring reliable and safe operation.

Educational Contribution: A Conceptual Demonstration that the Only Solution to Transforming Current Societies into Sustainable Ones Is Through Migration to a Modern Electrical System

Why sustainable societies are strongly preservation of life?

Sustainable societies prioritize the preservation of life by focusing on ecological integrity, social equity and economic viability. This holistic approach ensures the well-being of both present and future generations by managing resources responsibly, minimizing environmental impact and fostering healthy ecosystems. Essentially, sustainability aims to create a world where humans and nature can thrive together, minimizing harm and maximizing long-term benefits.

How sustainable societies and energy transition are linked?

Sustainable societies and the energy transition are fundamentally linked, with the latter being a crucial component of the former. The energy transition, shifting from fossil fuels to renewable energy sources, is essential for achieving sustainable development goals by reducing environmental damage and promoting a more equitable and resilient future.

How sustainable societies and modern electrical system are linked?

Modern electrical systems are crucial for building sustainable societies by enabling the widespread adoption of renewable energy sources, reducing reliance on fossil fuels and promoting energy efficiency. Electrification, especially when powered by renewables, offers a pathway to decarbonization, cleaner air and improved connectivity. Sustainable electrical systems also contribute to achieving Sustainable Development Goals, like affordable and clean energy.

Conclusion

Promoting energy transition in every region of the planet, whether country or community, with the goal of building sustainable societies, will require the following three key aspects to be taken into account:

Why is electrical energy the optimal energy for establishing power systems in a society?

A. Electrical energy is widely preferred over thermal and mechanical (movement) energy due to its versatility, ease of transport, and efficiency in conversion and use. It can be readily converted into other forms of energy (light, heat, motion) and easily transmitted over long distances. In essence, electricity's ability to be easily transformed, transported and controlled makes it the most convenient and widely used form of energy in modern society.

Regarding topology, what are the current technologies for power systems to improve reliability, efficiency and sustainability?

B. Microgrids and Smart Grids are Modern Power System technologies that utilize distributed energy resources and advanced control systems to enhance reliability, efficiency and sustainability. Microgrids are localized power grids that can operate independently or in parallel with the main grid, while Smart Grids are a broader concept of modernizing the entire electricity network.

In addition to the changes in electrical system topologies indicated in the previous item, what are the new emerging technologies for each society to migrate from Traditional Power Systems to Modern Power Systems?

C. The evolution of power systems, from Traditional Power Systems to Modern Power System requires exploring the multifaceted components of smart grids, encompassing smart sensing, communication technologies, home energy management systems, demand-side management, smart metering, smart EV charging, smart lighting, the Internet of Things and big data integration, while investigating their role in enhancing the power grid in an intelligent and digitally integrated manner.

Authors

Luis Vazquez-Seisdedos Ph.D. in technical science. His research interests included both fossil fuel sources and renewable energy resources (RES), electric vehicles (EV), energy storage subsystems and hybridization, electric drives, electrical traction systems, and RES's and EV's integration into electrical power systems. He is a member of TC 6.3. Power and Energy Systems Committee of IFAC.

Rahimil Vazquez-Gomez is a seasoned computer engineer with a passion for cloud computing and renewable energy from Florida international University (FIU). He is currently working as Principal IT Programmer Analyst for Florida Power and Light (FPL), located at Miami, Florida, US. His technical prowess extends to renewable energy.

Eberto Sedano-Herrera is a seasoned computer engineer. He worked with POTEVIO-ATMs. They are powered by photovoltaic systems with battery storage backup. He was involved in technical solutions to longer energy autonomy but also to do more robust under use of aggressive environmental conditions such as areas of high salinity and relative humidity greater than 80%.

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