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Resources, configurations, and soft computing techniques for power management and control of PV/wind hybrid system

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ABSTRACT

The technological advancement of renewable energy has created a significant need for research under the PV/wind based hybrid system. This article presents a detailed review of the integrated PV/wind hybrid power generation system with the primary focus on the energy crisis and its sustainability in the future. This paper highlights mainly imperative problems, disputes in the availability of resources and the importance of hybrid renewable systems. The structure of power electronic converters and their operation with integrated hybrid systems are discussed in detail. Energy management of PV/wind input sources along with the battery and their corresponding control technologies are dealt with. The recent statistics of the global status of successful PV/wind integrated projects, the future vision of an integrated power generation and important challenges facing the general deployment of PV/wind integrated power generation techniques are also presented.

1. Introduction

The increase of population of people by 2040 will be at a shocking rate with the addition of two billion people with existing inhabitants. The emerging nations like India and other African countries will show a significant part in this population outburst. Such increase in population in a rapid rate make profound effects on the necessities of infrastructures such as buildings for domestic needs and commercial purposes, transport services and other basic facilities. On the other hand, the evolving nations have a strong demand for energy and resources with respect to their booming economies. It is anticipated that energy demand increases with 30% by 2040 by overtaking conventional supply-demand ratio. The rapid industrialization and urbanization in the developing countries have attracted the rural people towards the industrialized cities by increasing the demands for the energy. Traditional energy, such as coal, hydro-electricity, nuclear energy, oil and natural gas, are no sufficient enough to meet the exponentially growing energy demand of people. In addition, the rural people have been progressively moving towards conventional energy sources from non-commercial sources.

To eradicate the above problems, at first readers should understand world energy consumption as well as world energy production which are presented in Section 1.1. Also, world governments have the second biggest challenge to diminish greenhouse radiations and added impurities rising from the boiling of fossil fuels that threaten universal climatic fluctuations and ecological inequality. The problem due to emissions and pollutants is discussed in Section 1.2. Renewable based power generation is the only option for world governments to solve the above large problems of power demand and emissions. Keeping this aspect in mind, this paper particularly focuses only on wind energy and solar energy based hybrid power generation. Power generation based on these sources is analyzed in sections1.3 and 1.4.

1.1. Energy consumption and energy production

Energy consumption has risen for all fuels except nuclear power; energy production has also increased for all fuels except coal. For oil and gas, global consumption development is more pathetic than energy production. Fig. 1 depicts world energy consumption in the year 2013 and Indian energy consumption in the same year. India's energy creation for 2013 is 3450 Mtoe although the demand has been documented as 5462 Mtoe. From this statistics, it is evident that India has an energy shortfall. Fig. 2 illustrates world primary energy making in the year 2013 and Indian energy primary production in the

Abbreviations: ANN, Artificial Neural Network; CSI, Current Source Inverter; DFIG, Doubly Fed Induction Generator; DG, Distributed Generations; DSP, Digital Signal Processor; FLC, Fuzzy Logic Control; FPGA, Field Programmable Gate Array; MAS, Multi-Agent System; MPPT, Maximum Power Point Tracking; NERL, National Renewable Energy Laboratory; NWTC, National Wind Technology Center; PWM, Pulse Width Modulation; SCADA, Supervisory Control and Data Acquisition System; SMES, Superconducting Magnetic Energy Storage; SOC, State of Charge; VSC, Voltage Source Converter; VSI, Voltage Source Inverter

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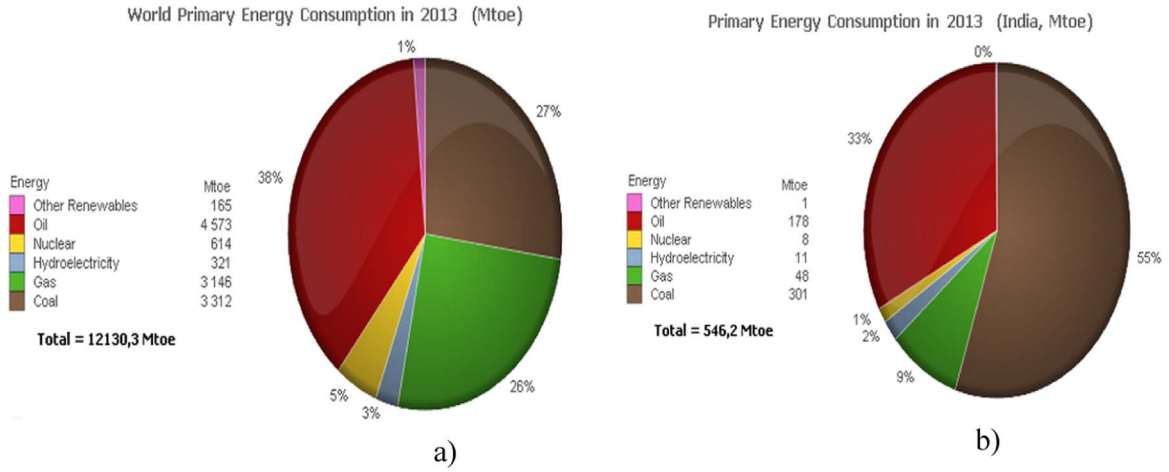

Fig. 1. a) World Energy Consumption b) India–Energy Consumption [3].

same year. It also proves that the contribution of fossil fuels to energy generation is more than the contribution of renewable-based generation.

According to the report of the International Energy Agency (IEA), the energy consumption of India will double by 2040. Meanwhile, global energy utilization has been predicted to grow by 25% by 2040 concerning oil and coal consumption in absolute growth rate. To satisfy the requirements in consonance with the new policies scenario, India needs $110 billion per year for supply projections with $0.8 trillion per year to improve energy efficiency. The required budget is 75% of the annual allotment of the power sector in India.

1.2. CO_2 emissions

Fig. 3 illustrates the top countries with the highest carbon dioxide emissions per capita. The report shows that from 2011 to 2013, the top carbon dioxide (CO_2) emitters were Singapore, Brunei, Darussalam and Australia. The figure also indicates that India is in 20th place for CO_2 emissions. In spite of the present regulations and policies, global carbon dioxide emissions from the utilization of numerous energy sources have been predicted to increase by 46% in 2040 to 45 billion metric tons [1]. The diminishing energy sources and the greenhouse emissions are penetratingly observed by most countries with fear to balance the environmental effects. With deep anxiety to save the global green environment, the government has framed regulations and policies to inspire the utilization of renewable energy sources over conventional energy.

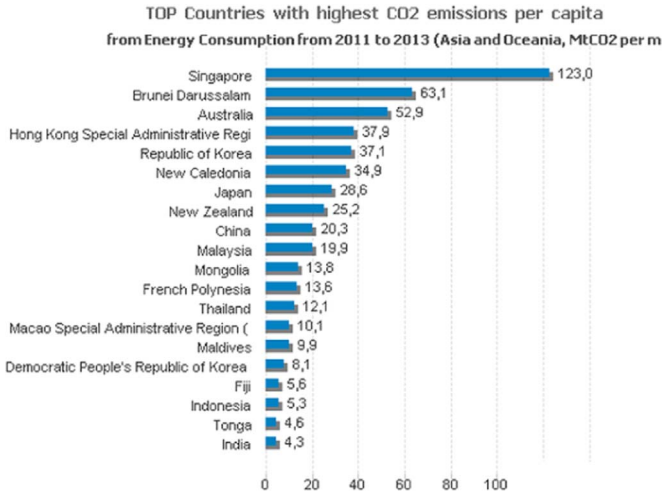

Fig. 3. Top Countries with highest CO_2 emissions per capita [3].

1.3. Renewable energy production and consumption

The generation electricity is achieved with various sources of energy. In conventional electricity generation models, hydropower plants use water resources and, thermal power plants utilize nuclear energy or fossil fuels to produce power. On the other hand, the alternative hybrid power generation models include biomass power plants, Fuel Cell (FC), Photovoltaic (PV), geothermal power stations and, wind turbine generators for the production of electricity. The

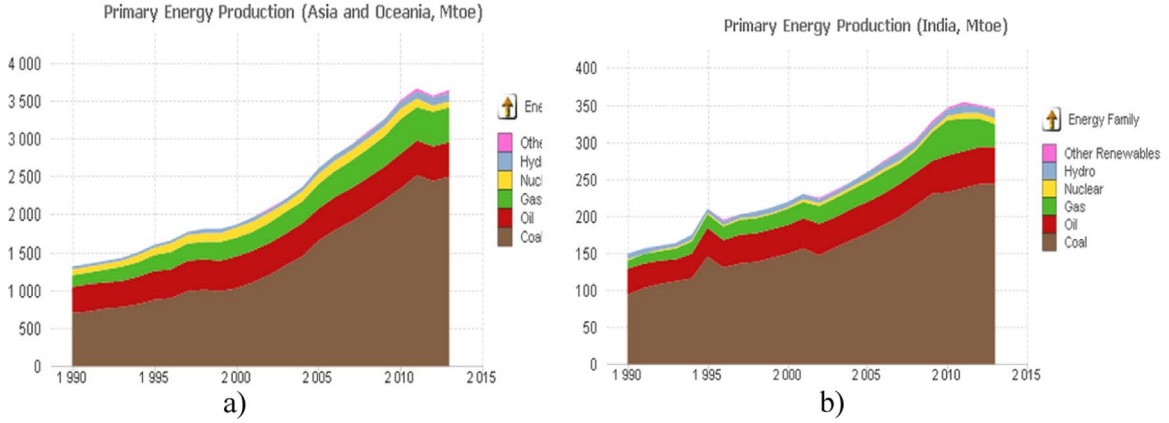

Fig. 2. a) World Energy Production b) India–Energy Production [3].