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A STUDY OF SMART GRID DEVICES IN HIGH TEMPERATURE TOWARDS SUPERCONDUCTING STORAGE

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ABSTRACT

It is now a worldwide priority to build a reliable and sustainable energy system. Incorporating renewable energy sources and optimizing energy distribution rely heavily on smart grids, which are distinguished by increased efficiency and adaptability. At the same time, systems based on superconducting magnetic energy storage (SMES) provide a viable answer to the problem of efficient and high-capacity energy storage. However, a thorough comprehension of SMES performance in various temperature conditions and the compatibility of smart grid devices is necessary for their effective integration into smart grid networks. The purpose of this study is to compare the operational performance of smart grid devices in high-temperature conditions and via thermal analysis when integrated with SMES systems. This research looks at how temperature swings affect SMES devices and how well they can maintain a steady energy supply even in the harshest of climates. Additionally, SMES system compatibility and interoperability with advanced metering infrastructure (AMI), distribution management systems (DMS), and demand response methods are examined.

KEYWORDS: Smart Grid Devices, High Temperature, Superconducting Storage, magnetic energy storage, SMES systems

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INTRODUCTION

Only energy storage systems, many of which have been compared in terms of energy/power density, reaction time, efficiency, and disposal impacts, would be able to handle such outages. It has been determined that one of the best technologies to deal with the aforementioned issues with power networks is superconducting magnetic energy storage.

BASIC INTRODUCTION TO ENERGY

Although energy cannot be generated or destroyed, it may be stored in a number of different ways. Energy is a fundamental need of existence and a crucial resource for the progress of the contemporary world. Although there are several methods to categorize energy, main and secondary categories provide the most useful framework. Coal, biomass, crude oil, the sun, the tides, the wind, geothermal energy, water springs, uranium, natural gas, and so on are all examples of primary energy sources. However, numerous energy conversion methods are often used to extract secondary energy sources from main ones. The connection between main and secondary energy sources is shown in a flow diagram in Figure 1.

Diesel, gasoline, electricity, butanol, ethanol, hydrogen, and heat are all examples of secondary sources of energy that are widely used because of their accessibility. The many kinds of secondary energy that may be derived from primary energy sources are shown in Table 1, along with the respective conversion technologies.

Energy consumption, as well as energy production, has skyrocketed as the world's population has expanded. According to the International Energy Agency (IEA), 2018 had the largest annual rise in energy consumption in the recent few decades, at 2.3% [1]. Global energy consumption may be traced down to only three countries: India, China, and the United States. Global energy consumption is up across the board, but the demand for fossil fuels in particular has surged by 70 percent annually since 2017. Solar power production has grown by 31%, while wind power generation has climbed by double digits. While encouraging, these increases still fall short of meeting global demand for energy, which is why the world as a whole has raised its consumption of coal by 0.3%, with the majority of this rise coming from emerging regions like the Asian continental region. As a consequence, the amount of carbon dioxide released into the atmosphere has risen by 1.7% to 33 Gigatonnes. As can be seen in Figure 2, which displays global figures on CO2 emissions from 1990 to 2017, the largest contributors to CO2 emissions are the power and heat generation industries, followed by the transportation sector and the industrial sector.

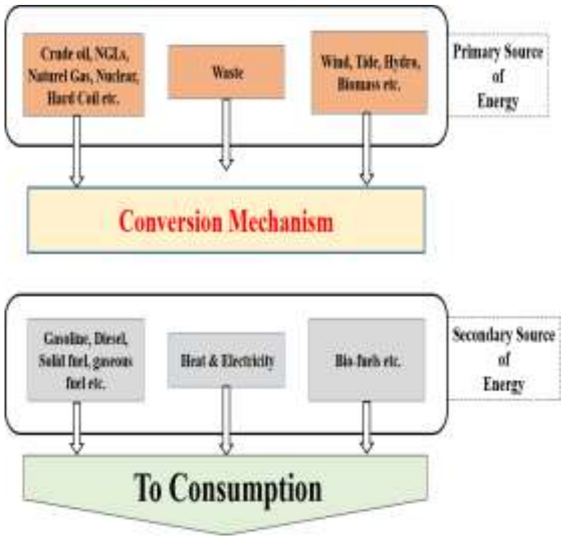

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Figure 1 Association among the primary and secondary energy sources

Table 1 Conversion from Primary energy sources

Primary Energy Sources	Conversion Process	Secondary Energy Sources
Coal	Thermal Power Plant	Work, Heat, Electricity
Natural Uranium	Nuclear Power Plant	Work, Heat, Electricity
Crude Oil	Oil Refinery	Diesel, Gasoline
Wind Energy	Wind Turbine Farm	Work, Electricity
Tidal Energy	Tidal Power Plant	Work, Electricity
Solar Energy	Photovoltaic Plant	Heat, Electricity
Falling or Flowing Water	Hydro-power plant	Work, Electricity
Solar Energy	Solar Power Plant	Work, Heat, Electricity
Geothermal Energy	Geothermal Power Plant	Work, Heat, Electricity
Biomass	Bio-refinery	Work, Heat, Electricity biofuel

The majorities of these emissions come from emerging Asian nations and are caused by the use of coal and oil in energy supply. Coal and oil products make up the bulk of India's main energy supply (1990–2017) in the IEA's World Energy Balances 2019 report, both of which contribute to pollution, global warming, and climate change as a result of their CO2 emissions.

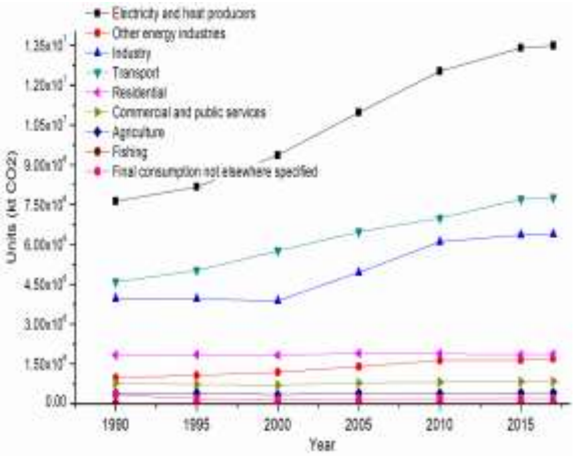

Figure 2 CO2 emissions by sector, World 1990-2017

The International Energy Agency (IEA) says that coal and oil use account for a growing share of India's total CO2 emissions. The IEA's study on CO2 emissions in India's various sectors shows that the power and heat generation sector accounts for the largest share, followed by the industrial sector and the transportation sector. Therefore, there are two solutions to pollution problems: either increasing renewable energy resources so that electrical energy can be produced through green innovative technologies like wind, solar, etc., or implementing electric vehicles for the transportation sector, which adds to electrical energy consumption and automatically lowers emissions.

Electrical energy generation from renewable sources might be viewed as a means to reduce pollution and satisfy energy needs. Using electric cars as a means of mobility and reducing our reliance on fossil fuels would help with pollution management. The Indian government is now making significant efforts to address this problem; as part of its Zero Emission Vehicles (ZEVs) initiative, electric motorcycles and vehicles have just been introduced to the Indian market. However, wind and solar power plants' output is very variable depending on weather conditions, and the energy they provide is intermittent overall. The second problem is that wind power facilities are most efficient along the shore, making it difficult to transfer or distribute electricity generated by these plants to other systems. In Denmark, a 3.6 MW superconducting wind turbine generator was recently erected, and it was stated that this machine generated the same power as traditional wind turbine generators but being half the size and weight.

POWER BLACKOUTS

Power outages are another major issue that people all around the globe have to deal with. In today's information-based economies, power outages may have a devastating effect on GDP and cause enormous monetary losses for any nation.

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Both natural climatic catastrophes like tsunamis and earthquakes and man-made ones like power outages caused by peak-hour electricity demand, voltage variations, and technical or human error are possible causes. The destruction caused by natural disasters is sometimes irreparable and requires significant time and effort to restore normality. However, since blackouts only last for a matter of minutes or hours, they are a natural truth that may be avoided. The majority of power outages have occurred in South Asia, with the largest contributions coming from India. The ultimate answer for managing such occurrences is to have an effective, cheap, and environmentally friendly energy storage backup that can be utilized in such times, hence preventing economic losses from occurring, since the average length of a blackout is found to be approximately 2.5 hours.

POWER SUPPLY AS POTENTIAL TERRORISM AND MILITARY TARGET

The military relies on the power supply sector to maintain social order and stability. Nowadays, all military sites are linked together by wireless connection, allowing for quick and precise data or information transmission thanks to digitization. Scarcity in border areas, maybe as a result of geography or climate change, has led to an increase in the use of surveillance cameras. Satellite communication systems, such as Global Positioning System (GPS), Radar, etc., are crucial to the success of any country's land, sea, or air forces, and as such, they must have a steady supply of electricity at all times. Even a temporary breakdown in such systems might cause widespread fear and force countries to take emergency measures.

For these reasons, electricity grids are a prime target for terrorists during times of conflict, and it is always preferable to keep them safe. Dams, thermal power reactors, high voltage transmission lines, and substations have all been reported damaged by terrorist organizations or states at war. A few are summarized in further detail below:

- In the Korean War between the United States and North Korea in 1952, the United States forces destroyed 90% of the country's power plants and dams.
- In 2005, in Georgia, terrorists have damaged the high voltage transmission line.
- Since September 11, various terrorist organizations have threatened the United States by saying they would destroy their dams unless the United States increases security on certain prone dams and closes others.
- In the past two decades, as computing and internet infrastructure have developed, the number of cyber-attacks in which hackers target electrical infrastructure has grown. In 2007, hackers remotely compromised and destroyed a USD 1 million diesel-electric generator at the Idaho National Laboratory.
- The development of new technologies has led to the emergence of new types of dangers. Since the voltage produced by a high-altitude electromagnetic pulse (HEMP) or an international electro-magnetic interference (IEMI) attack may range from the hundreds to the thousands of volts, it has the ability to damage all electronic chips and cause the whole power supply system to collapse.

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IMPORTANCE OF ENERGY STORAGE SYSTEMS

Electrical appliances, communication systems, data servers, and many more modern conveniences are all dependent on a constant supply of electricity for their operation. The power grid is the principal energy provider since it transmits electricity from power plants to homes and businesses. Achieving the smart city idea in India, preventing power blackout losses, and keeping up with the rising power demand all need that the modern electrical power production, transmission, and distribution industries provide a continuous/uninterrupted power supply. In the event of grid failure, a backup power source that can handle a sudden increase in demand is necessary to ensure a steady supply of electricity is maintained. Also, without high density energy storage systems, electricity from renewable sources like solar, wind, etc. might be disrupted at inopportune times since their output is dependent on weather. Therefore, a secondary power system is necessary to achieve uninterruptible power supply, since it is unable to provide continuous power to the grid. The "Superconducting Magnetic Energy Storage (SMES) Systems" study discussed here is an intermediate step in developing such a system in India.

NEED OF ENERGY STORAGE IN OTHER MAJOR DISCIPLINES

Hydro-electrical grids are generally connected with the domestic power grids where power distribution to the public is done using step transformers and due to two-way communication, the electricity production will be done as per the requirement only. Sometimes, excess electrical power is distributed among the other grids synchronized with the parent grid. However, there are some situations where production can be increased to peak level during the rainy seasons and the excess energy can be stored using power banks that can store energy without or minimal losses. Such power banks can be used in remote areas where transmission lines cannot install like military areas. Also, such power banks can be installed for the electrical vehicle charging MagLev trains where such systems can be embedded with high temperature superconducting motors to achieve required traction force or can be used for electric aircraft take-off or landing situations.

CONCLUSION

The purpose of this research was to investigate the influence of operating current, solenoid thickness, and operating temperature on the magnet topology, as well as other mechanical design features of the solenoid magnet. It may be deduced from the research that less superconducting tape is needed for energy storage if the operating temperatures are low since greater currents have a major influence on the length of the superconductor utilized for energy storage. Second, given the same total number of turns, it has been observed that the overall height and bore diameter may be reduced if greater solenoid thicknesses are employed for magnet design. For the magnet coils, the effects of the self-field on the critical current have been examined, albeit several approximations have been made to get around the computational modeling challenges. Using the Kim model and a parameter P, we can guarantee the presence of the critical current on at least one tape out of 108 cassettes of a pancake coil, therefore identifying the self-field effects. The critical current of the coil is found to be significantly affected by the self-field, leading researchers to infer that the self-field may significantly affect the magnet topology. Therefore, this factor has to be taken into account throughout the superconducting magnet's development.

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