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EDITORIAL

Rural electrification using hybrid solar-wind energy systems

The Intergovernmental Panel on Climate Change (IPCC) assessment reports have warned us about the impact of climate change. This is highlighted by the rise in greenhouse gas concentrations over the past 50 years, which has led to an observed increase in global mean temperature. Warming of the atmosphere and oceans, diminishing amounts of snow and ice, increase in sea level, and increase in the concentrations of greenhouse gases have been observed. Observed temperature during each of the last three decades has been successively higher than previous decades. IPCC reports indicate that surface temperature change by the end of the 21st century will likely exceed 1.5 to 2°C relative to pre-industrial times. If the emissions of greenhouse gases continue, it can lead to further increase in temperature with consequent changes in most of the components of the climate system. Intergovernmental Panel on Climate Change has predicted many consequences. Increasingly rapid sea level rise, melting of glaciers, increase in the number of extreme weather events, adverse impacts on biodiversity are some examples. Reducing the consequences of climate change demand significant reductions of greenhouse gas emissions. For India, climate change is not just a science issue but involves several other factors such as economics, water-energy-food security, health, insurance, law, international policy and so on.

Using fossil fuels has resulted in rapid economic growth during the past hundred years, but climate change is a serious consequence. Hence, it is essential to replace them with sustainable, renewable or alternative energy sources to reduce the impact on climate. This is essential, as the global energy needs, in general, and of India in particular, will continue to increase, driven by population growth and development. There is also the concern about the shortfall of fossil fuels in the near future. So, alternate and renewable energy is going to gain increased attention. Solar and Wind energies are two main components of renewable energy that India can bank upon. India has invested heavily in solar power, and the installed capacity of solar power plants has exceeded 70,000 MW by June 2023. In India, winds are high, mainly during the monsoon season. The main advantage of wind power in India is that it can provide power at night, which solar cannot. Around 80 to 90 countries are tapping wind power to supplement the electricity grid. Though not so popular and viable, ocean wave power is also an option for renewable energy, considering the long coastline of our country. Some feasibility tests have already been carried out. In any case, there is a need for considerable investment in renewable energy generation and low-carbon technology for sustained development.

The main objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to prevent human interference with the climate. The Conference of the Parties (COP) include all countries that are parties to the Convention and are represented at the COP. Decisions are necessary to promote the effective implementation of the objectives of the Convention. The 20th annual meeting of the Conference of the Parties (COP20) in Lima in 2014 reached a consensus to develop plans for their national contributions to reduce emissions, called Intended Nationally Determined Contributions (INDCs) to determine future mitigation strategies. In a historic agreement in Paris, 195 nations set a path forward to limit the increase in global average temperature to well below 2°C. To limit global warming to less than 1.5 degrees, a target to stabilize the concentrations of atmospheric CO_2 at around 400 ppm was necessary. But unfortunately, it has already crossed this level. Realising this reality has resulted in a new target of 450 ppm, which is the concentration target limiting the warming to 2°C or less.

India has made several commitments in Paris (during COP21); the important ones being (a) Reduction of the country's emissions intensity per unit GDP by 33 to 35% below the 2005 level by 2030, (b) Plans to derive 40% of its electricity from renewable sources of energy (solar and wind) and other low-carbon-emitting sources by 2030 and (c) Create an additional carbon sink of 2.5 to 3 billion tonnes of carbon-dioxide through the extra forest and tree cover by 2030. Consequently, solar power generation is fast developing in India. Currently, the solar installed capacity in the country stands at 72 GW. However, with the rapidly growing population and overall development, the energy demand is increasing faster. As a result, the consumption

of fossil fuels is also rising, leading to a global, national, and regional crisis due to the uncontrolled utilization of natural resources.

The Government of India has given a strong thrust to rural electrification, and as a result, India is close to achieving universal electrification. However, the situation remains grim; nearly 10% of the global population does not have access to electricity. The solution in this direction is using renewable energy in rural and remote areas. Remote regions with difficult terrain pose difficulties for rural electrification through the main power grid. Transportation of conventional energy supplies (coal, petroleum-derived fuels, natural gas, nuclear fuel) is difficult. Extending a standard transmission grid will involve a high cost of capital because of uneven landforms. Rural areas generally have small power requirements (~20 kW) and lower power loads.

As such, options for sources of electricity in rural areas include hydro-electric power stations, solar power plants, biomass-based electricity generation systems, and so on. Photovoltaic solar cell panels are electronic power generators based on semiconductors that produce electricity from exposure to direct sunlight. These silicon-based cells have efficiencies of around 20%. Wind turbine modules use wind blades to operate on the wind circulation in the atmosphere. There are two types of wind turbines. Two-blade turbines operate downwind (blades facing away from the wind), while three-blade turbines operate upwind (blades facing into the wind).

PV-wind energy systems with battery storage are well suited for remote and rural locations. A PV array requires a terrain without any obstacles to direct sunlight. Wind speed and direction are essential for wind turbine design. The turbines must be installed above the tree level with non-turbulent wind flow. The installation site requires sufficient space for the array and turbines, along with tension cables for the stability of the structure.

However, storing the power generated and making it available as needed (during off-generation periods) remains a big hurdle. This is because electricity consumption typically rises after sunset, while the high proportion of solar energy in the grid can affect its stability. Wind, on the other hand, does not completely stop at any point. Wind speeds are often higher at night and early morning when solar power is either absent or minimal. As a result, hybrid solar-wind power is seen as an ideal solution that strikes a balance between the two.

Multiple methods exist to integrate renewable energy technologies to build a hybrid energy system such as AC-coupled, DC-coupled and hybrid-coupled. In hybrid energy systems, AC-coupled method is used, where the renewable energy is connected to an AC busbar. PV and wind turbines provide DC power, which is converted into AC power using a semiconductor-based device called a power inverter. Inverters should ideally have at most 4% harmonic distortion for good power regulation. Power circuits connect primary loads to the AC busbar, as well as the utility grid. The utility grid supplies power to the primary loads and charges energy storage units. In case of power generation outages, the energy storage units provide backup power. Safety equipment is necessary to prevent damage to the circuitry and protect consumers. These include over-current protectors (fuses) and lightning protection components. Lightning arrestors are needed for wind turbines as they are the highest structures in remote locations. Power management systems provide information about usage and individual component status of the system as a whole.

With improved technologies in these directions, it is expected that the rural areas will be able to meet their energy needs with lesser impact on climate.

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