Policy Initiatives and Emerging Technologies for Sustainable Power Generation

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ABSTRACT
Climate change is one of the biggest challenges of 21st century. The primary cause of global warming is the increasing emission of greenhouse gases. As of today, the main source of power generation in India and many other countries is by burning of the fossil fuels which results in emission of green house gases. In India, more than 65% of electrical power is obtained by burning of fossil fuels. Hence, the use of conventional power ought to be minimized for long term sustainability. The paper suggests some policy initiatives and need of adopting emerging green technologies for sustainable power generation.

Index Terms—Supercritical technologies, hybrid power generation, gasification, fuel cell, repowering of windfarms, green technologies.

I INTRODUCTION

In Paris summit-2015, most of the countries agreed to make substantial reduction in emission of greenhouse gases (GHGs). However, there are considerable technological, economic, and political challenges in meeting the ambitious targets. The International Energy Agency has projected that coal-fired power generation will continue to rise globally over the next few decades. Using clean coal energy efficient technologies could be a significant step towards reducing carbon-emissions besides other measures.

II POLICY INITIATIVES

In order to meet the stringent targets to combat climate change, it is necessary to take some policy initiatives as suggested below:

(a) Energy Conservation - Energy conservation by Demand Side Management (DSM) is the most important. The latest example is the large scale distribution of 9 W LED bulbs by the Ministry of New and Renewable Energy (MNRE) at a very low cost. This is a great initiative which will substantially reduce the demand of power, mainly during peak hours after sunset.

(b) Inefficient Old Thermal Power Plants - Most of the coal based old thermal power units have low rated output but they deliver still lower output at poor efficiency, say below 30% with high emissions of Green House Gases. Policy initiative is required to replace such Turbine-Generator (TG) units rated below 200 MW with lesser number of high rating TG units based on super critical technology which operate at higher efficiency but emit less GHGs.

(c) New Thermal Power Plants - India has entered into an era of super critical technology with the commissioning of a 660 MW unit in 2011 at Sipat, Chhattisgarh. The supercritical boilers operate above 221 bars and 274° C at higher efficiency but with lower emissions. The ultra super critical boilers are being developed which will operate at still higher temperature and pressure at higher efficiency but at still lower emissions. In view of serious environmental concerns, no utility should be allowed to install sub-critical boilers any more, as a policy initiative.

(d) Repowering of Windfarms - India has come a long way from kW range wind turbines in 1980s to 3 MW units. At present, India stands 4th in the world in terms of installed wind power capacity. A large number of wind turbines have completed 20 years or more. These low rated turbines operate at low utilization factor. As a suggested policy initiative, wind turbines rated upto 500 kW and which have completed 20 years should be replaced by high rating technologically advanced wind turbines. It will enhance the power generation substantially.

(e) Wind-Solar PV Hybrid Power Plants -The wind turbines are sparsely located in a wind farm and so most of the space remains empty. As a policy initiative, the empty space must be utilized either for cultivation or for installation of solar photovoltaic power plant. The output of a wind-solar PV plant is more stable as wind and solar resources are reasonably complementary to each other. Ministry of New and Renewable Energy issued draft National Wind-Solar Hybrid Policy on 14 June 2016. The objective of the policy is to provide a framework for promotion of large grid connected wind-solar PV system for optimal and efficient utilization of land and transmission infrastructure, reducing the variability in renewable power generation and thus improving grid stability. The policy aims to reach wind-solar hybrid capacity of 10,000 MW by 2022.

(f) Captive Power Plants -The power generated in a captive power plant is utilized in the same premises which almost eliminates transmission and distribution losses. Hence, captive power plants, preferably based on renewable energy, must be encouraged more with proper policy support.

III EMERGING TECHNOLOGIES

Some technologies are emerging and are important from the consideration of climate change. These technologies are either based on renewable sources of energy or they are less polluting even though based on burning the fossil fuels.

(a) Integrated Gasification Combined Cycle (IGCC)- IGCC plant gasifies coal into synthetic gas and operates a gas turbine. The heat from the exhaust of gas turbine is used to generate steam to drive a steam turbine. IGCC operates at higher efficiency but emits less GHGs. However, this technology is undergoing development and has yet to be well established techno-economically.

(b) Coal Gasification-Fuel Cell Power Plant [1]- As per the research carried out at Massachusetts Institute of Technology (MIT), USA, electricity from coal can be generated with much higher efficiency with lower emissions by combining two well-known technologies, viz. coal gasification and fuel cells. First, hot steam is passed over pulverized coal. The chemical reaction between coal and steam releases carbon monoxide and hydrogen which can produce electricity in a solid oxide fuel cell which works around a temperature of 800° C. In fact, heat generated in fuel cell is enough for gasification of coal, thus eliminating the need for a separate heating source. In fuel cell, a membrane separates oxygen from carbon monoxide and hydrogen. In an electrochemical reaction, carbon dioxide is produced in a pure and uncontaminated form, from which carbon can be capturing and sequestration can be done easily. This coal gasification-fuel cell power plant could achieve efficiencies in the range of 55 to 60%.

(c) Hybrid Coal-Solar thermal Power Plants- In a thermal power plant, heat contained in the flue gases is recovered and used in heating of air and water before feeding to the boiler. If heat of solar energy is used to pre-heat air and water before supply to the boiler, overall thermal efficiency is increased. Overall thermal efficiency can be increased by 1% if feed water temperature is raised by 5 to 6° C. Similarly, overall thermal efficiency can be improved by 1% if air temperature is improved by about 20° C. [2]

(d) Thorium Based Fast Breeder Reactor - India is dependent on import of uranium for executing nuclear power program. For self sufficiency in nuclear fuel, it is necessary to develop fast breeder reactors based on thorium which is abundantly available in India. Hence, onus is on India to develop suitable fast breeder reactors. As a first step, India has developed a 500 MWe prototype of fast breeder reactor based on uranium. It is under commissioning at Bhavini project at Kalpakkam, Tamil Nadu. As a part of nuclear power development program in India, thorium fuel based fast breeder reactor is planned to be developed by 2030.

(e) Kite Wind Turbines [3] -The power output of a wind turbine increases as a cube of wind velocity. The wind velocity increases with the height above ground. This has given a concept of flying turbine thus eliminating the expensive tower, its foundation, yaw mechanism etc. In a flying wind turbine, the electrical generator can be flying or ground-mounted. When the generator is aloft, a conductive tether can transmit electrical energy to the ground or power can be beamed to receivers using microwave or laser. The challenges include safely suspending and maintaining turbines hundreds of meters above the ground in high winds and storms, transmitting the generated power to earth and interference with aviation etc.

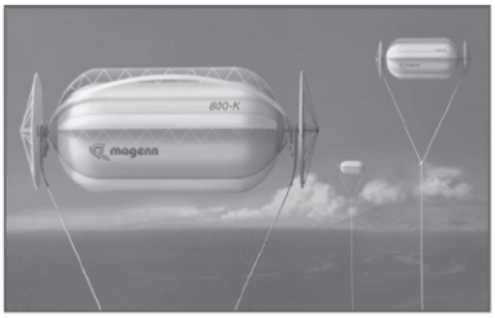

Fig. 1: Kite wind turbine

During insufficient wind or bad weather like lightning or thunderstorms, use of kite turbines could be temporarily suspended by bringing them down to the ground. So far, no commercial airborne wind turbines are in operation.

(f) Satellite Solar Power -The main disadvantage of solar energy is its non-availability in absence of sun light. This situation could be overcome if solar PV power plant is installed on a geo-stationary satellite and power is transmitted to earth. The idea for a satellite solar power was conceived by Dr. Peter Glaser in 1968. Solar Power Satellites placed in geosynchronous equatorial orbit, 35,800 km above earth would remain continuously illuminated. As a result of the orbit location, the amount of sunlight on the satellite during the year is about five times more. At geosynchronous orbit, satellites have the same rotational period as the earth and are therefore fixed over one location at all times, enabling the satellite to deliver almost uninterrupted power to ground. A successful ground test of a system designed to ultimately collect solar power from orbit and beam it to earth was conducted in Japan in 2016 by Mitsubishi Heavy Industries at Kobe works. In this project, 10 kW wireless power transmission was demonstrated using microwaves to a receiver at a distance of 500m. The testing proofed the performance of the control system that will regulate the microwave beam itself.

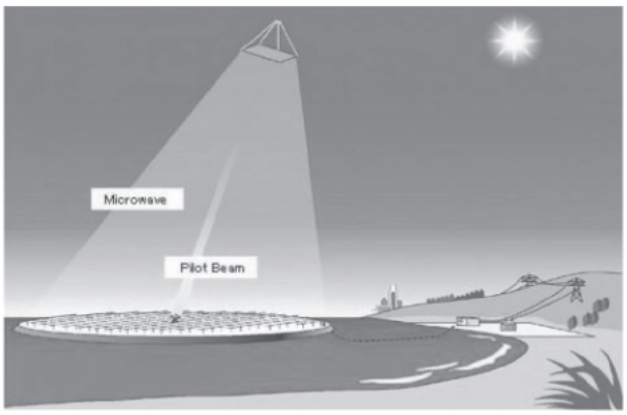

Fig. 2: Satellite solar power

It is still a long way to go. Some of the salient points are [4]

(i) Successful implementation of such a scheme is still not distinct
(ii) Intensive research and experimentation required for any realisation
(iii) This appears to be a promising technique
(iv) Few nations have started experimental projects

(g) Nuclear Fusion- Huge amount of energy is released in nuclear fission and fusion processes. At present, globally, atomic power generation is based on nuclear fission reaction. The main concern with nuclear fission process is the radiation hazard which becomes disastrous in the event of an accident. This problem can be overcome by nuclear fusion process where two atomic nuclei fuse together to form a single heavier nucleus and release energy. Nuclear fusion takes place in sun where temperature rises to lacs of degree Celsius. This is the biggest challenge as no material can sustain such high temperatures where fusion process could take place. A group of countries have joined to develop magnetic field called 'plasma' in which fusion will take place. International Thermonuclear Experimental Reactor (ITER) is an international nuclear fusion research and engineering megaproject, which will be the world's largest magnetic confinement plasma physics experiment. It is an experimental 'Tokamak' nuclear fusion reactor which is being built in Saint-Paul-lès-Durance, south of France. The ITER project aims to make the long-awaited transition from experimental studies of plasma physics to 500 MW fusion reactor.

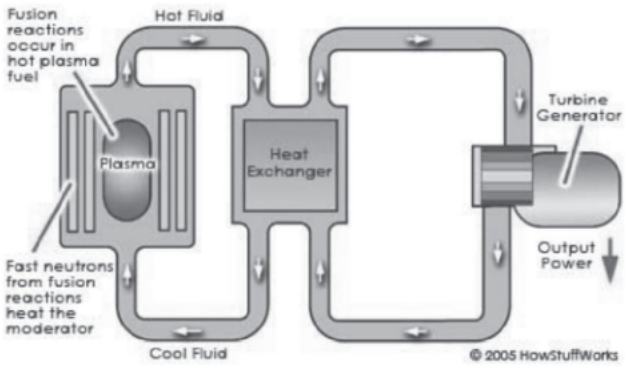

Fig. 3: Power generation from nuclear fusion

The ITER project is funded and run by seven nations—the European Union, India, Japan, China, Russia, South Korea, and the United States. The EU, as host party for the ITER complex, is contributing about 45% of the cost, with the other six parties contributing approximately 9% each. Construction of the ITER 'Tokamak' complex was started in 2013 and is expected to finish by 2019. It is planned to initiate plasma experiments in 2020 with full deuterium–tritium fusion experiments in 2027. The first commercial demonstration fusion power station, named DEMO, is planned to follow after successful completion of ITER project.

IV WATER CONSERVATION

The availability and acquisition of land are the major issues for building of a project. Hence, innovative ways are required in which minimum or no land is required for installation of a project. With the increasing population, per capita availability of water is reducing. Hence, conservation of water is becoming increasingly important. With the installation of floating solar PV power plants on canals, reservoirs and other water bodies, loss of water due to evaporation could be reduced.

(a) Solar PV system on canal top- In India, first Canal Solar Power Pilot Project was launched in Gujarat to utilize 19,000 km long network of Narmada canals across the state for setting up solar panels to generate electricity.

Fig. 4: Canal-top Solar PV Power Project (1MW)

A 1 MW pilot solar PV project on the 750m long stretch on Narmada branch canal near Chandrasan village of Kadi taluka in Mehsana district was commissioned on 24 April 2012. The pilot project was intended to prevent evaporation of 9,000 kilo litres of water annually. It is the first ever such project in India. This project has been commissioned by M/s SunEdison India. The Ministry of New & Renewable Energy (MNRE) had issued guidelines to set up 100 MW solar power capacities over and along the canals in the country. This approach tackles two major challenges simultaneously viz. water conservation and power generation.

(b) Floating Solar PV plants on reservoirs [5]-The floating solar power projects are coming-up in Japan, the UK, Brazil, the US and Australia. The floating plants are expected to be at least 50% more efficient than a ground mounted solar power plant due to lower constant temperature of solar panels. The water body has a cooling effect on the solar panels which results in longer life of the photovoltaic panels and their operation at higher efficiency.

Fig. 5: Floating solar panels

It is expected to reduce evaporation upto 90% from the water surface covered by solar panels. It also restricts algae blooms. In a dry climate of South Australia, about 2.5m depth of water can be saved from evaporation annually. The water thus conserved will be available for domestic use, irrigation, industries, power generation etc. India's first floating plant rated 10 kW was commissioned at Smritiban, New Town, Kolkata on 12th December 2014 by M/s Vikram Solar.

V CONCLUSION

For sustainable power, the paper suggests some policy initiatives for conventional as well as renewable power generation. Further, emerging technologies like kite turbine, satellite solar power, nuclear fusion etc. are described which need to be developed, established and adopted for future. They are important as they promise to mitigate the challenges posed by climate change.

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