Abstract

With fast rising energy demands and associated *Carbon Emissions*, the International Energy Agency (IEA) has projected a Renewable Energy (RE) technologies portfolio to reduce the emissions by the year 2050. It has been estimated that the global carbon emission can be reduced about 70% using the RE sources like Biomass, Solar, Wind, and Geothermal, directly for producing clean electricity or through their applications in various industries.

The RE based technologies have been emerging very fast but also demands higher initial investments and latest research innovation. As per IEA reports around 28% of carbon reduction could be achieved by using non-biomass (15%) and biomass (8%) systems. Hence, the motivation of multidisciplinary studies (*Solar Energy, Electricity Generation, and Bioenergy*) is the driving force for this thesis in the area of *Environmental Sustainability*.

ONGC, the flagship national oil company under Government of India, has over-arching objective of the strategic sustainability for energy security. *Carbon* with as center of the business and sighting the implications, ONGC has been pursuing a low *carbon high growth utilizing RE sources.* The author employed at ONGC has undertaken *multi-disciplinary research studies* on *PV technology, Concentrated Solar Power (CSP) and Microalgae Biomass* to cater the electricity needs, specific applications and finally to protect the environment. The three major aspects of this multidisciplinary research studies are as under:

[1] *Optimization of Solar Photovoltaic power* at Natural Gas fed Captive Power Plant and development of a MATLAB based Despatcher Control system.
[2] Utilizing Concentrated Solar Power technology for *Crude Oil heating* purpose and development of prototype hybrid model for real conditions.
[3] *Carbon Sequestration (Capture)* using microalgae based innovative 'State Of Art' hybrid approach at Gas processing complex at ONGC India.

In view of low carbon strategy a 'Hybrid model' has been conceptualized for oil and gas applications where the work has been outlined with two scenarios. *First* if carbon is emitted in the environment, the Carbon Capture approach has been thought and S*econd*, to restrict the carbon emission, alternate sustainable solutions of energy has been explored.

The thesis is spread over six chapters commencing with ***Chapter 1*** letting in the introduction, motivation, literature survey, thesis contribution and the road map to the thesis. ***Chapter 2*** reports the preliminaries required for understanding Solar PV system and its mathematical modeling, for a real industrial site and analyses the solar power compatibility with grid power. The 'Despatcher system' control methodology has been created utilizing MATLAB software which controls the essential power plant devices to optimize the energy balance between solar electricity and grid electricity. The control system is able to align solar electricity for the maximum use and reduce the use of generated turbine electricity. The MATLAB / SIMULINK model has been validated for an industrial site of gas based power plant at Assam, India. ***Chapter 3*** elaborates on another Solar technology, Concentrated Solar Power (CSP) for the 'Crude Oil Heating'. The study has been focused on the substitution of existing fuel of NG by Concentrated Solar heating based hybrid system. ***Chapter 4*** has been focused on the industrial site where the Carbon emissions are not able to be restricted due to industrial processes and the vent gas containing the Carbon-di-oxide. One live industrial site of ONGC has been targeted to capture utilizing the concept of Bio-Fixation using Micro-algae Bio-technology. Microalgae have been identified as third and latest generation energy source with an additionality of capturing Carbon emissions. The Microalgae carbon capture based pilot study has been performed at one of the largest Gas processing complex at ONGC Surat. ***Chapter 5*** has been focused on the model validations and results for three interdisciplinary research studies. The first model of PV system despatcher based control system resulted in decreases the usage of the grid power by 19% and increases the usage of own generated solar power by 34%. The second and third research work on hybrid model of CSP and Microalgae has been exhaustively explored and validated respectively. It has been also reported that Bio-methane (Biogas) is also a co-product of microalgae biomass in the process of the carbon capture of industrial vent gases. The potential of biogas has been evaluated for hybrid module for producing electricity or heat at site through combustion for the Crude Oil heating system. Accordingly the hybrid model termed as Algal-Solar (PV& CSP)-Natural Gas has been proposed and validated for with existing heater treater system. ***Chapter 6*** concludes that hybrid model is techno-commercially sustainable solution for crude oil heating and could be replicated in various other applications in different industries. This chapter also addresses few possible future works.