Summary of Ph.D. thesis Scientific contributions

Title of Thesis: "Distributed Microgrid System Design and Control Algorithms for Oil and Gas fields"

Gas flaring is an issue of serious environmental concern worldwide. Globally approximately 100 BCM (Billion Cubic Metres) of natural gas is flared every year, which leads to 400 million tons of CO_2 (Carbon Dioxide) emissions and wastage of nearly 20 million dollars annually. The burning of expensive natural gas is not just an economical loss, it also poses a severe environmental threat to the flora and fauna and a risk of health abnormalities for human settlements around oil and gas fields, petroleum refineries, and petrochemical plants. Almost all the gas flaring sites are situated at remote locations because of which unreliable electricity is another major issue faced in the region.

This thesis proposes a complete solution for converting the power-consuming and emission-causing oil and gas fields to power-generating - reduced emission systems. The proposed solution can be a role model for carbon transition and achieving the Intended Nationally Determined Contributions (INDC) set by India to meet the Sustainable Development Goals (SDG).

1. While installing the hybrid renewable energy systems at oil and gas fields, one of the critical concerns is the selection of the right location as it ensures high productivity and efficiency of the system throughout the system life-cycle. The existing site selection algorithms were insufficient to deal with the uncertainties of the oil and gas field region. Therefore, a novel Multi-Criteria-Decision Making (MCDM) algorithm was developed picking up selective features from the existing MCDM algorithms to suit the requirements of oil and gas field regions. The results proved the efficacy of the new algorithm over the existing algorithms viz. Analytical Hierarchy Process (AHP) or technique for order of preference by similarity to ideal solution (TOPSIS).
2. After site selection, the natural next step is designing a minimal power loss transmission and distribution network, which could select the right capacity of gas microturbine to be installed at the gas flaring site and choose the best possible electricity distribution path such that the network power loss is minimized, and load demand is met without much dependency on the main power grid. To solve this objective, a Mixed Integer Linear Programming (MILP) problem was formulated which was solved in MATLAB using Tomlab solver.
3. To make the oil and gas well power system more environmentally and economically efficient, other renewable energy sources like – solar, wind, and hydro energy were clubbed with gas flare wastes to produce power. Accurate prediction of the available renewable energy resource plays a significant role in the further scheduling optimization of a microgrid system. Therefore, various boosting (XgBoost, AdaBoost) and regression (Multiple linear regression) algorithms were used to predict the renewable sources in the area.
4. Load Following (LF) and Cycle Charging (CC) dispatch strategies are used by default for scheduling various Distributed Energy Resources (DERs) in a microgrid system. These dispatch strategies are not efficient for oil and gas field power systems where the gas flare wastes are utilized to generate power. Therefore, a novel dispatch strategy is developed for scheduling the microgrid power generation at oil and gas fields. The entire oil and gas field power system was modeled on Digsilent Powerfactory software and load flow studies were conducted to test the efficacy of the control strategies.
5. As there are multiple gas flare locations, there is a possibility of multiple gas well-based microgrid systems located in the vicinity of each other. Therefore, algorithms for power and energy management between multiple microgrid systems were developed. To achieve this objective again Mixed Integer Linear Programming optimization was used, which was solved in MATLAB.