Research Diary

KID: 20210305

Wind Energy harnessing @ GOKUL, IIT Hyderabad

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Even though state-of-the-art technologies are developed across the world to harness renewable energy, the efficiency remains low due to the uncertain and nonlinear nature of such resources. Though India is abundantly blessed with a potential wind resource, a large-scale profitable establishment for renewable energy conversion systems in India is rarely seen due to the uncertainty associated with it. Additionally, a common problem faced in the domain of windfarm modelling is the computational expense related to simulating the entire study. Thus, windfarm layout optimization, wake modelling, uncertainty handling, and control studies during energy harnessing from wind are still at inception with respect to the Indian subcontinent.

The development of a robust wind energy conversion system is need-of-the-hour to offset the energy crisis and drastic environmental issues India is facing in current times. At Global Optimization & Knowledge Unearthing Lab (GOKUL), we proposed novel methodologies to design optimal windfarms from the grassroots level by combining the fields of deep learning, CFD, combinatorial & evolutionary optimization, and uncertainty analysis. Further, we are working on new robust wind farm control strategies using reinforcement learning. Such a unique framework can resolve several issues faced by wind farm owners and ensure designs that can last for a long-term duration. The current status, scope for improvement, and novelties in the proposed work are presented below:

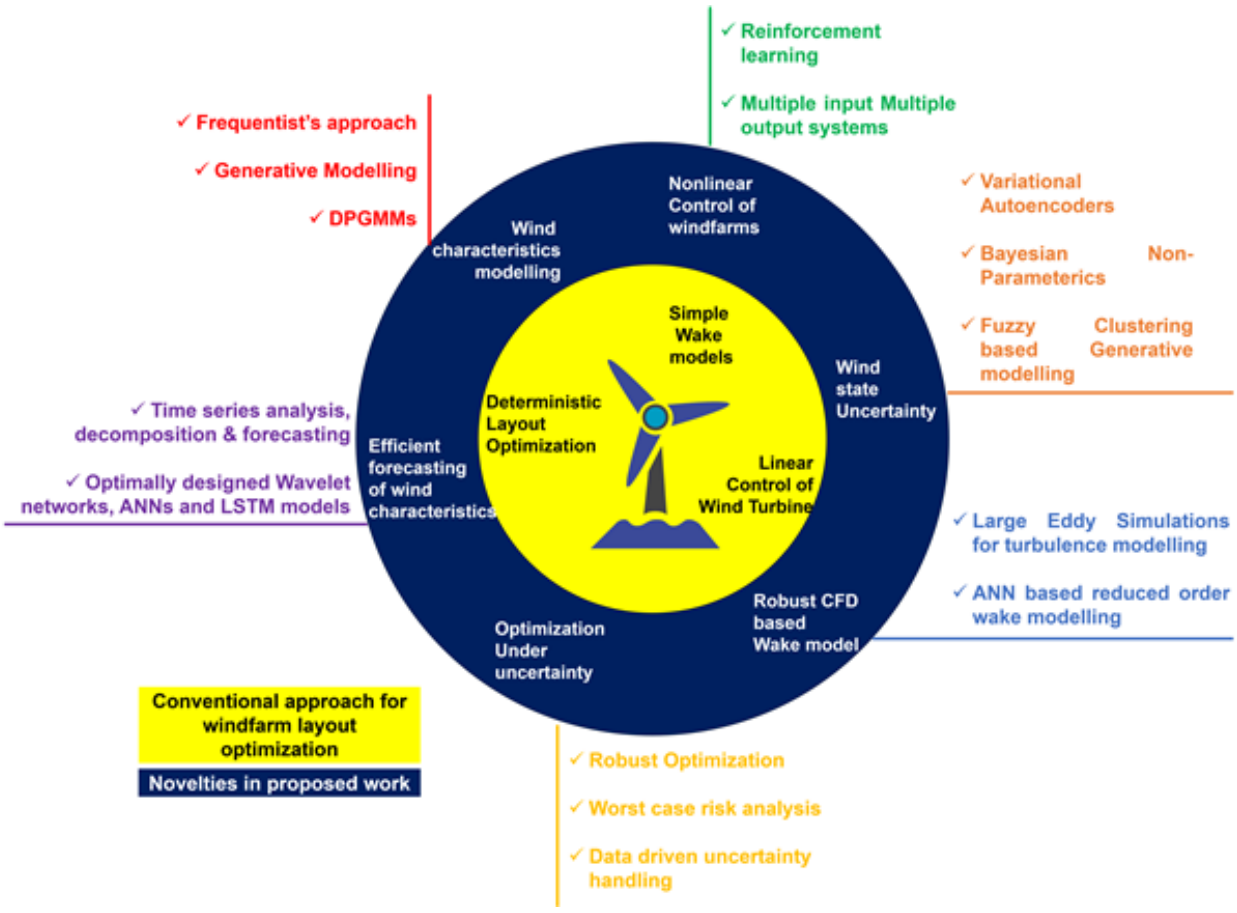

Fig. 7: Novel works being performed at GOKUL in the field of Wind Energy

- Realizing the need for forecasting wind characteristics data due to their limited availability, a novel heuristic-free optimal design algorithm for building nonlinear deep learning-based system-identification techniques has been proposed. Also, the abilities of generative models like Gaussian Processes and Variational Autoencoders are utilized in combination with a clustering-based generative model for accurately modelling the uncertain nature of wind.

- The novel ideas developed in the lab have led to 14 high-impact peer-reviewed publications of international repute and two high-value Government projects worth INR 1 crore with international collaboration for the establishment of large-scale efficient wind farms. The funding agencies include DST - National Supercomputing Mission, SPARC – MHRD, and special fund by British Council UKIERI through the international collaboration with the University of Exeter, UK (Department of Computer Science).

- Methods for modelling turbulent wake effects in wind farms are focused on next. Here, machine learning-driven accurate models are developed, which would be fast as compared to high fidelity CFD-based models.

- As a whole, the wind farm layout optimization problem turns out to be NP-hard MINLP formulation. To convert such a large-scale problem to a small scale, an auto-encoder-based strategy is proposed, which assists efficient usage of combinatorial, evolutionary, and hybrid optimization algorithms for micrositing.

- To make it realistic, wind state uncertainty in the micrositing formulation is considered and solved using Robust Optimization. Moreover, wind farm control studies using reinforcement learning are performed.

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Wind Energy Research at IIT Hyderabad

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Wind energy is one of the fastest-growing sources of renewable energy worldwide and in India. Per MNRE, the installed capacity in India exceeds 40 GW as of late-2020. Despite this, there are several issues that preclude the widespread penetration of wind into the Indian and global energy mix. The importance of harnessing energy in a clean and efficient manner leads to several exciting interdisciplinary research opportunities, targeted towards, e.g., making accurate wind forecasts; designing aerodynamically efficient, less noisy, and structurally robust wind turbines; & designing better wind-farm layouts and optimal control strategies that maximize energy generation and minimize maintenance/repair costs. Our group at IITH studies fluid dynamics associated with several of the challenges outlined above. The primary tools employed are high-fidelity large-eddy simulations (LES) of the turbulent flow over wind turbines and wind farms embedded in the atmospheric boundary layer (ABL). Due to the wide range of length and time scales involved, these simulations are extremely expensive, requiring extensive use of supercomputing resources (available in India via NSM-funded clusters at IITH, IISER Pune, etc., and internationally).