Machine learning enabled operational excellence of large industrial complexes supporting the net-zero goal

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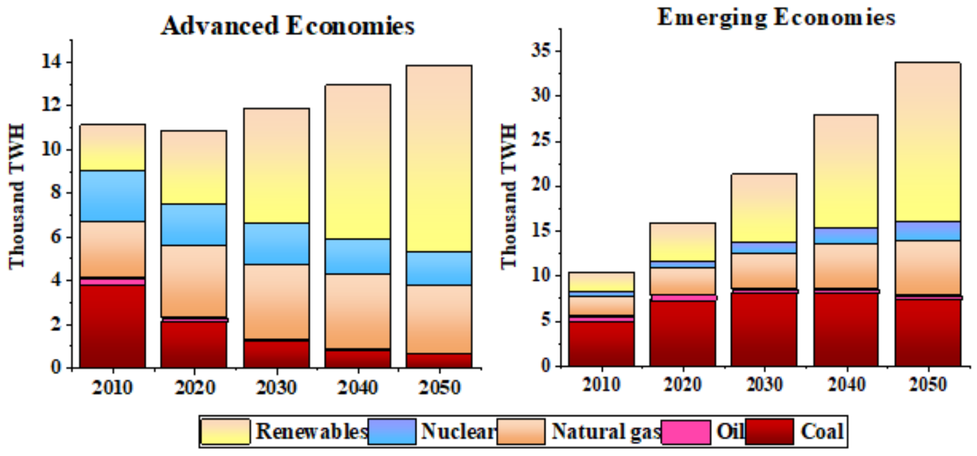
Introduction

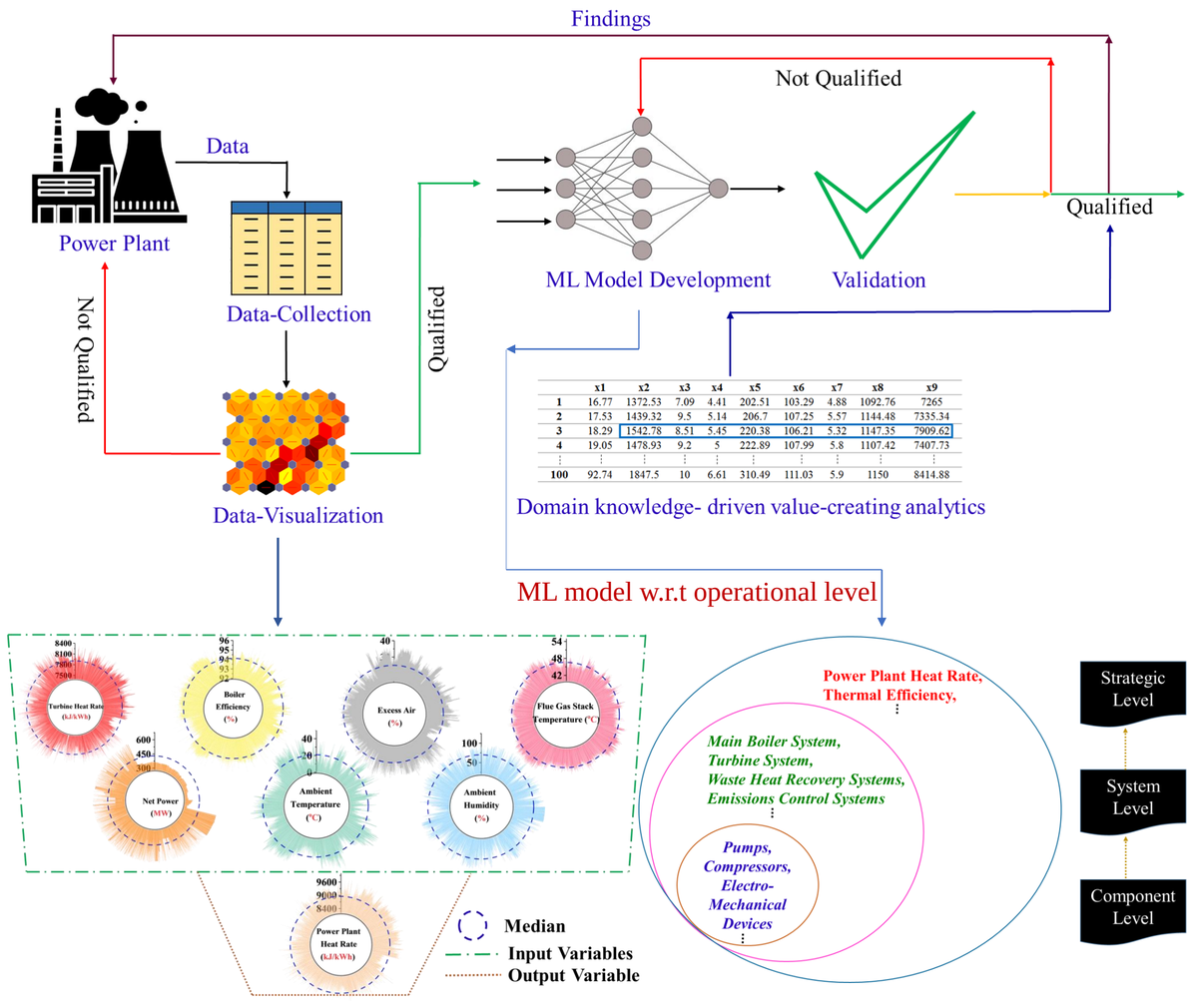
- Large industrial complexes store heaps of valuable operational data that is severely under-utilized to enhance their operational excellence
- Data is the fuel to maintain smart operation of complex industrial processes which are controlled on hyperdimensional input space
- The operation of large industrial complexes is categorized into component, system and strategic level and the performance indicators are either of quantitative or qualitative nature
- The choice of machine learning (ML) model is critical and should be relevant to the nature of problem (quantitative or qualitative)
- A systematic and generic methodology demonstrating the step-wise procedure for reliable implementation of machine learning based analytics is lacking
- Supporting energy efficient operations is critical to contribute to net-zero from the electrical power generation sector which is dominated by fossil fuels for emerging economies (coal causes 40% of global CO_2 emissions [1])



Objective

- To exploit the true potential of machine learning algorithms for the operational excellence of large-scale industrial complexes including power generation systems
- To contribute to net-zero goal from the energy sector by machine learning

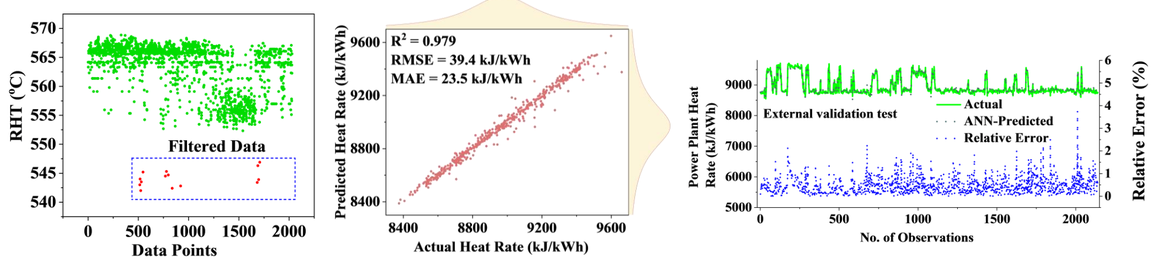
Methodology



	x1	x2	x3	x4	x5	x6	x7	x8	x9
1	16.77	1372.53	7.09	4.41	202.51	103.29	4.88	1092.76	7265
2	17.53	1439.32	9.5	5.14	206.7	107.25	5.57	1144.48	7335.34
3	18.29	1542.78	8.51	5.45	220.38	106.21	5.32	1147.35	7909.62
4	19.05	1478.93	9.2	5	222.89	107.99	5.8	1107.42	7407.73
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
100	92.74	1847.5	10	6.61	310.49	111.03	5.9	1150	8414.88

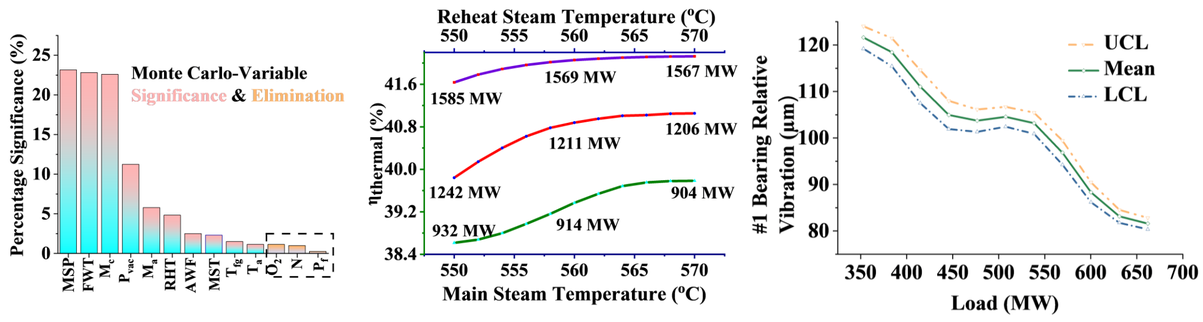
Results

- Deployment of extensive data-cleaning and various pre-processing techniques to enhance data quality
- Development of problem-specific (qualitative or quantitative nature) ML models, i.e., ANN, SVM, ELM

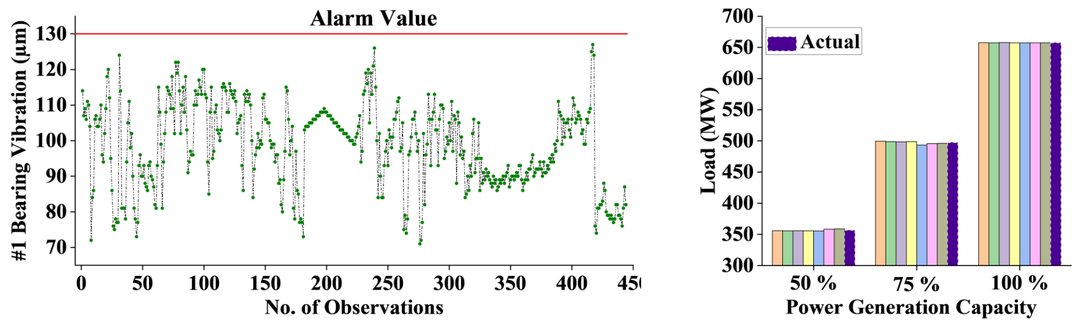


Results

Variables significance analysis and parametric study corresponding to different operational nature problem (component – strategic)

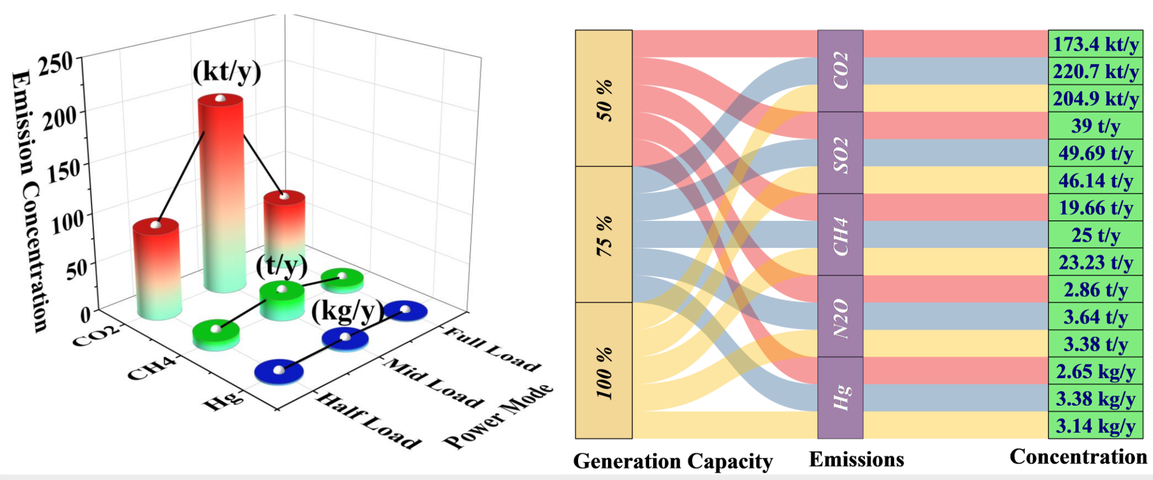


Validation of simulated results of different operational nature problem (component – strategic) on the power plant operation



Energy efficiency enhancement and emissions reduction as the result of ML-driven operational excellence for the power generation [2,3]

Generation Capacity	State	$\dot{m}_f$ (t/h)	Thermal Efficiency (%)	Heat Rate (kJ/kWh)
50%	BAU	138	39.41	9135
	RSM-SV	134	40.70	8846
75%	BAU	195	38.97	9239
	RSM-SV	183	41.60	8653
100%	BAU	241	41.89	8594
	RSM-SV	235	42.83	8406



Conclusions & Future work

- ML models like ANN, SVM and ELM are trained under rigorous hyper-parameters tuning for modelling the operational performance parameters corresponding to component, system and strategic level of a 660 MW supercritical coal power plant
- Variables significance analysis and extensive parametric study are conducted, and the results are supported by the domain knowledge of the power plant
- The ML model-simulated findings are validated on the real-operation of the power plant and significant savings in fuel consumption, improvement in energy efficiency and significant reduction in emissions (210.2 kt/y) are achieved [2,3]
- The energy efficiency improvement and emissions reduction potential using machine learning enabled modelling and optimization of fossil-based global energy assets (coal, gas and oil), and quantifying the performance enhancement under uncertainty

References

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[3] Ashraf, W. M., Uddin, G. M., Ahmad, H. A., Jamil, M. A., Tariq, R., Shahzad, M. W., and Dua, V., 2022, "Artificial intelligence enabled efficient power generation and emissions reduction underpinning net-zero goal from the coal-based power plants," Energy Conversion and Management, 268, p. 116025.

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