Parametric Uncertainty Estimation in DAB Converters Using Physics Informed Machine Learning

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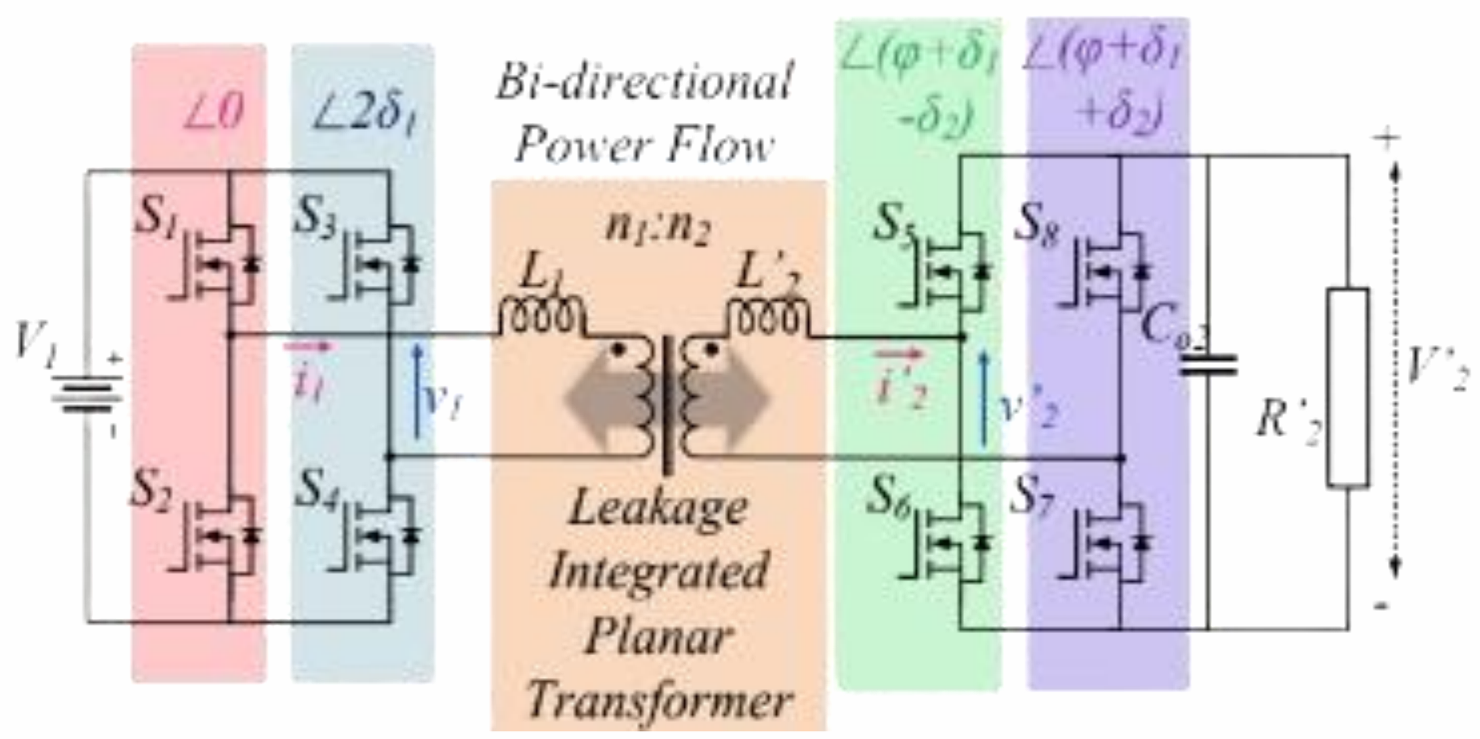
Objective and Research Question

The goal of the project is **to develop a machine learning-based approach for estimating parametric uncertainties and performing adaptive loss optimization in DAB DC-DC converters.**

Background Information

DAB DC-DC Converters: Essential in renewable energy systems, electric vehicles, and grid energy storage for high efficiency and bidirectional power transfer capabilities.



Challenges: Parametric Variations of passive and active components , such as Inductors (L) and On-State Resistances (R_{ON}) of MOSFET's, due to temperature changes and aging, lead to non-optimal operation of the converter and efficiency losses.

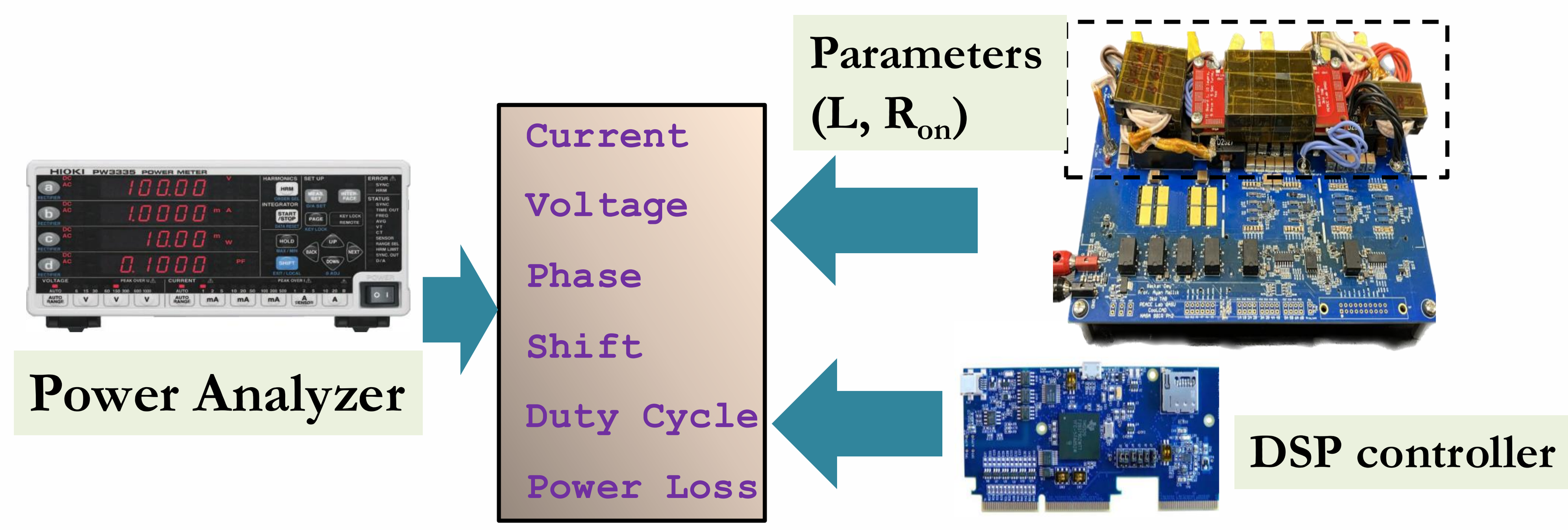
Solution: Implement real-time prediction of uncertain converter parameters using sensed voltages and Currents through an Intelligent Machine Learning Algorithm. This allows for on-the-fly adaptive, loss-optimal control implementation in DAB DC -DC converter based on ML model-estimated converter parameter

Methodology

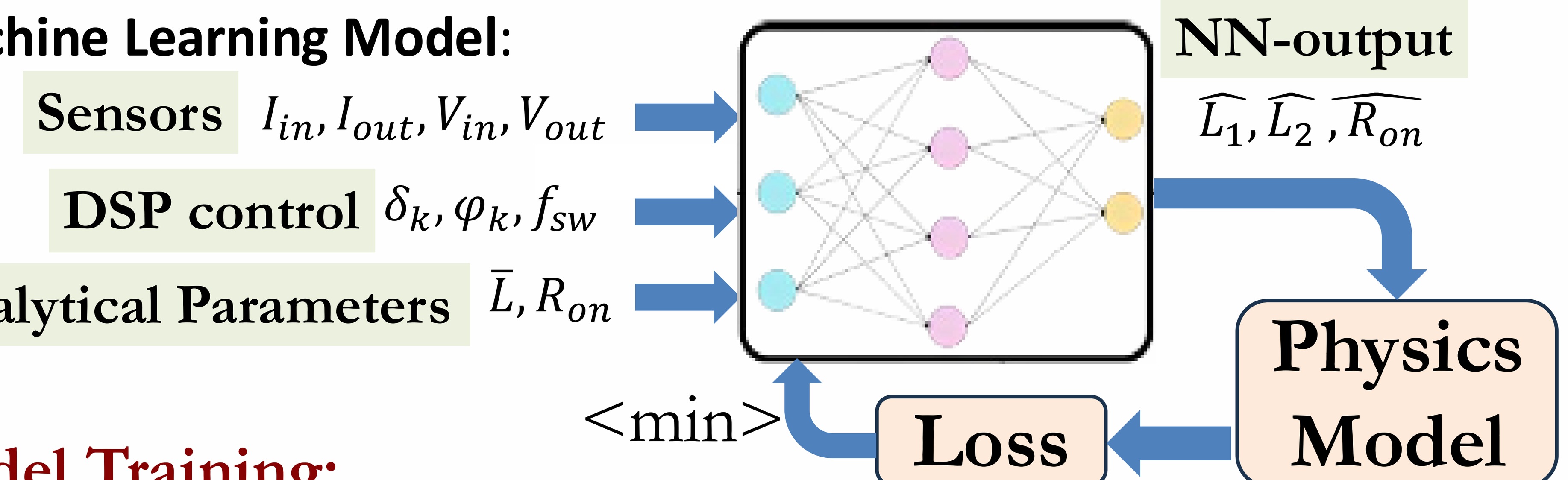
Data Collection:

Training: From an all-loss-inclusive mathematical model of DAB converter developed in MATLAB that precisely emulates the deployed real hardware .

Validation: From actual experimental hardware setup data.



Machine Learning Model:



Model Training:

- **Data Preprocessing**: Normalization and feature extraction.
- **Input Features:** Current, Voltage, Phase, Duty, Power Loss, $L_{analytical}$.
- $\boldsymbol{Loss = (L_{pred} - L_{actual})^2 + \alpha(P_{out} - P_{empirical})^2}$

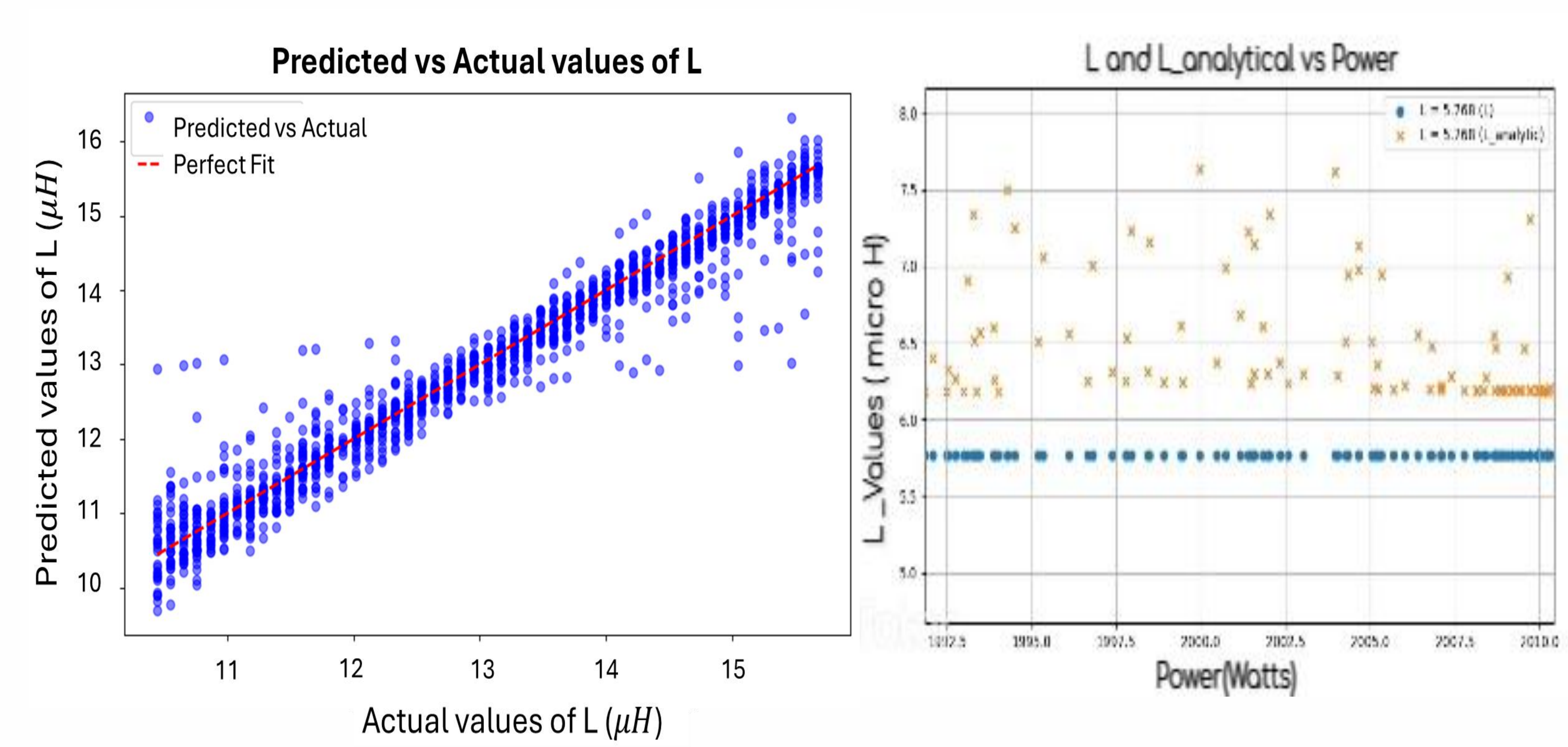
[α: hyperparameter]

- **Tools**: TensorFlow, Keras, Scikit-learn.
- **Training Process**: Split data into training and test sets; cross-validation for hyperparameter tuning.

Model Performance:

- **Metrics**: Accuracy, Root Mean Squared Error (RMSE), Mean Absolute Error
- **Visualization**: Graphs of predicted vs. actual parameter values.

Results



3 Layers, 16 Nodes , Sigmoid | **Average Error :** 0.5%

Conclusion and Future Research

Conclusion:

- The Model effectively estimate parameters and optimize losses, improving converter efficiency and reliability.

Future Research:

- **Implementation:** Implementing this Model on Actual Hardware and testing in real-world conditions.
- **Scalability**: Adapt approach for other DC-DC converters and broader applications.

Acknowledgement

The mathematical model development of the DAB converter and Testbed verification of this model using experimental setup was performed by **Mr. Saikat Dey** from Power Electronics lab, which is gratefully acknowledged.