Machine Learning Algorithms for Remote Control of the VSLLIM Microreactor

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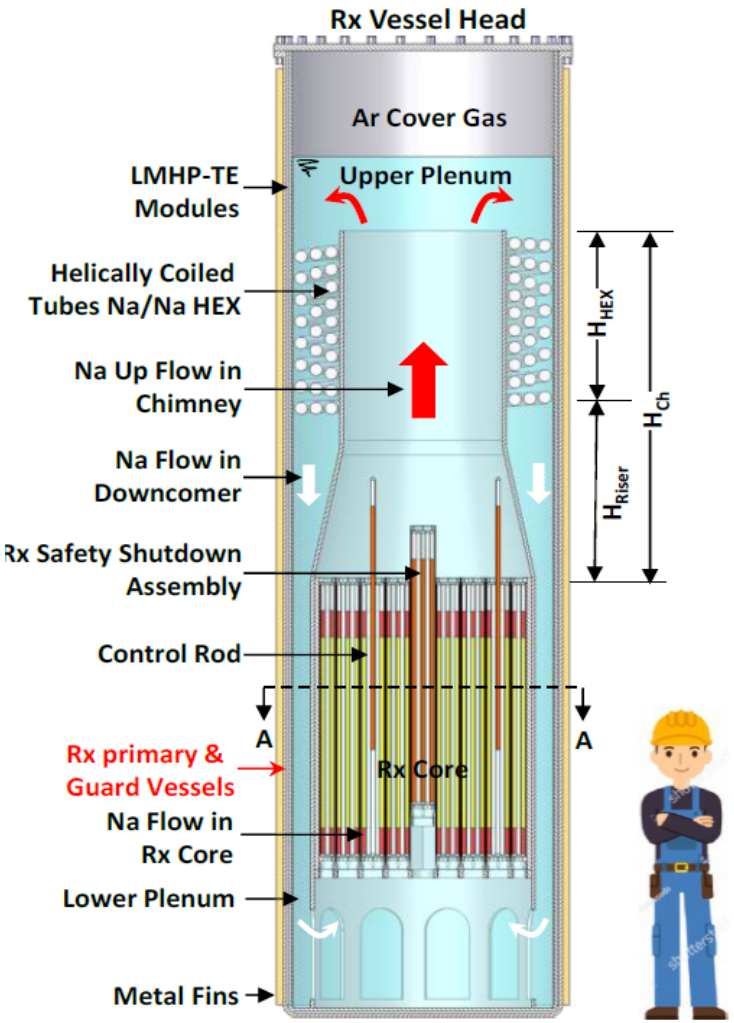
Project Objectives

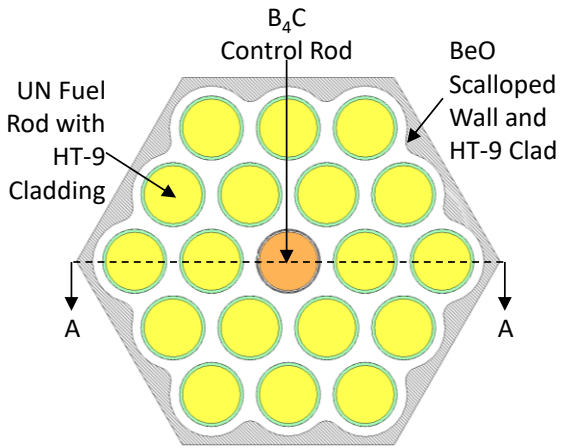
- **Train** two ML algorithms for performing transient reactor startup of the Very Small, Long-Life Modular (VSLLIM) microreactor.
  - **Supervised Learning (SL) paradigm** with Long Short-Term Memory (LSTM) neural networks. (completed)
  - **Reinforcement Learning (RL) paradigm** using Soft-Actor Critic algorithm. (completed)
- **Implement** trained neural networks into a real time Programmable Logic Controller (PLC) and **test it while coupled** to the dynamic Simulink model of the VSLLIM microreactor. (partially complete)
- **Develop and demonstrate** a secure, remote, control testbed of VSLLIM microreactor using two-step communication encryption. (planned)
- **Demonstrate remote control** of VSLLIM microreactor from Purdue University. (Planned)



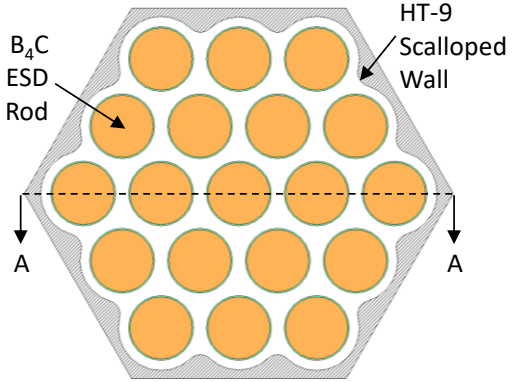
VSLIMM Microreactor

VSLLIM Microreactor Control

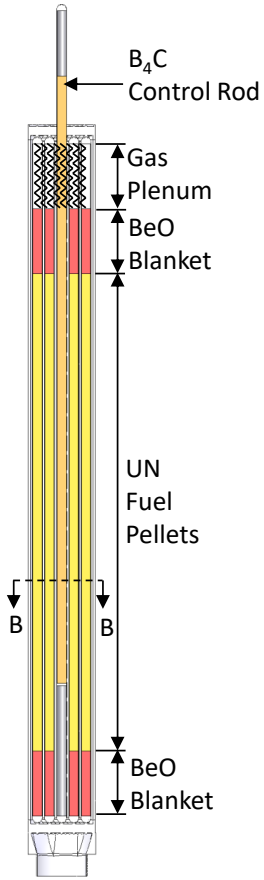
- A walk away safe microreactor design for generating 1.0 -10 MW(t)



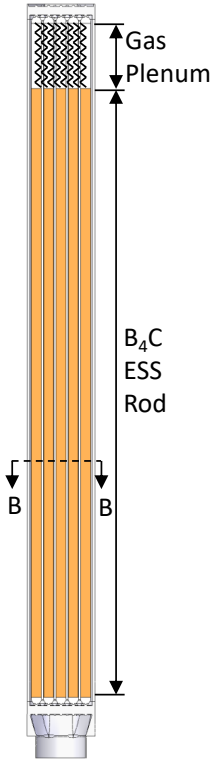
(a) RC Cross-Section View B-B



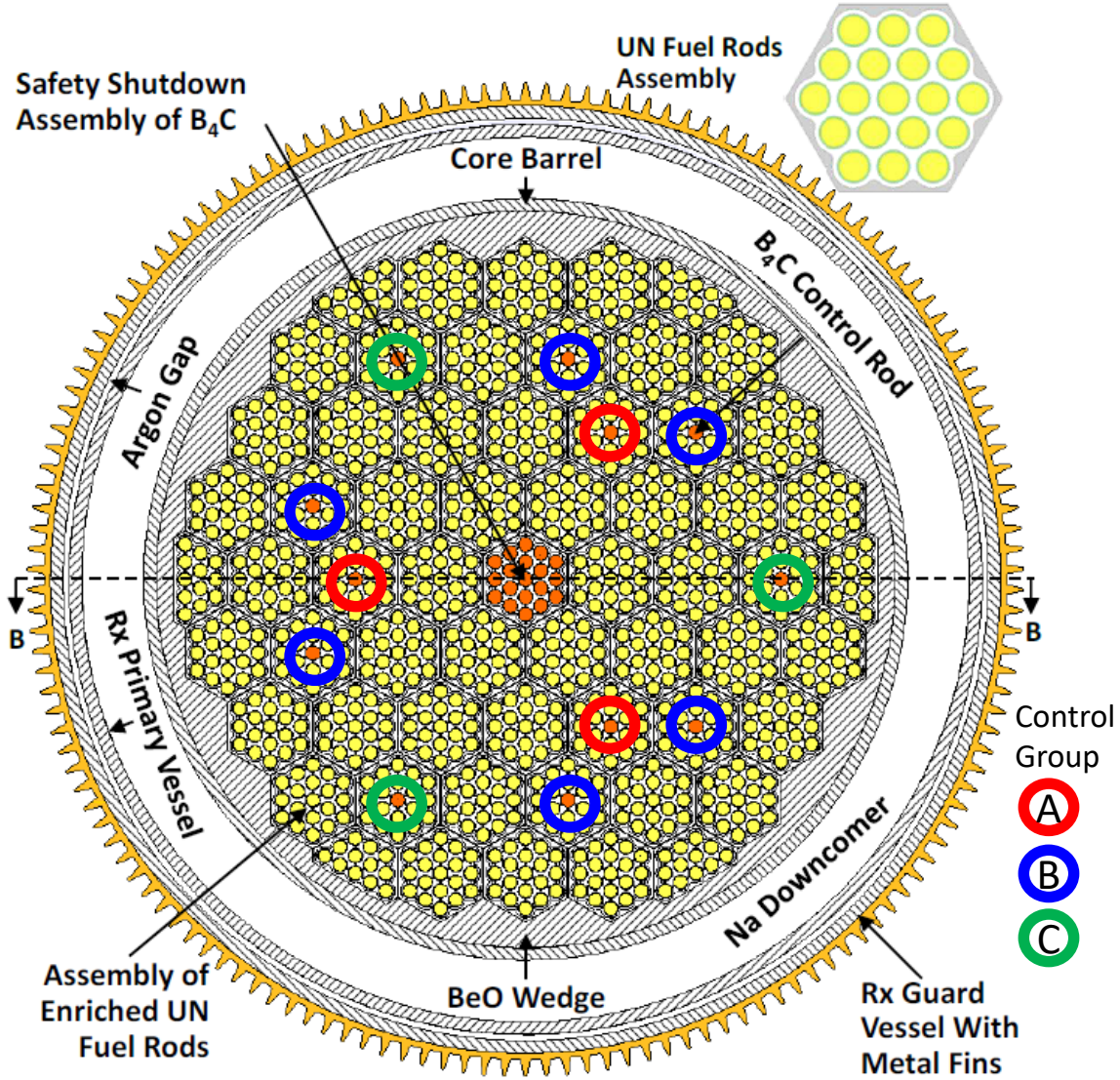
(b) ESD Cross-Section View B-B



(c) RC Cross-Section View A-A

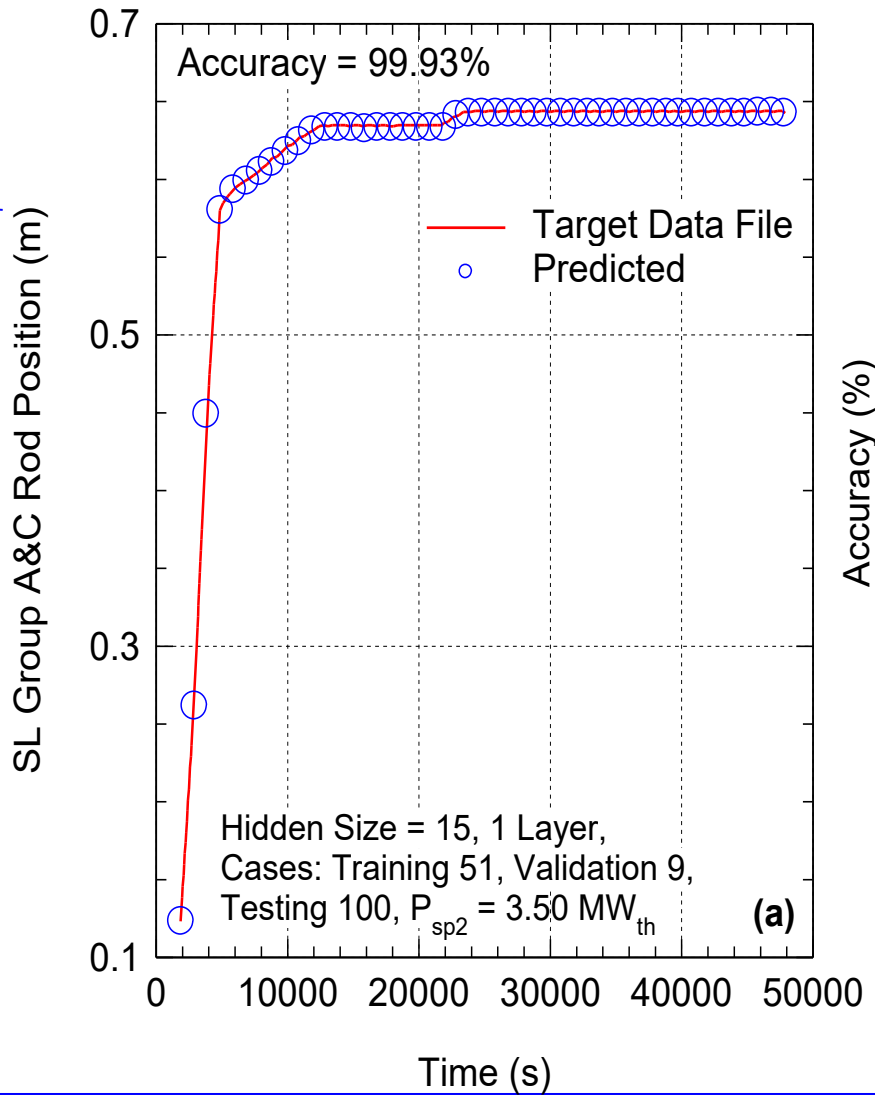


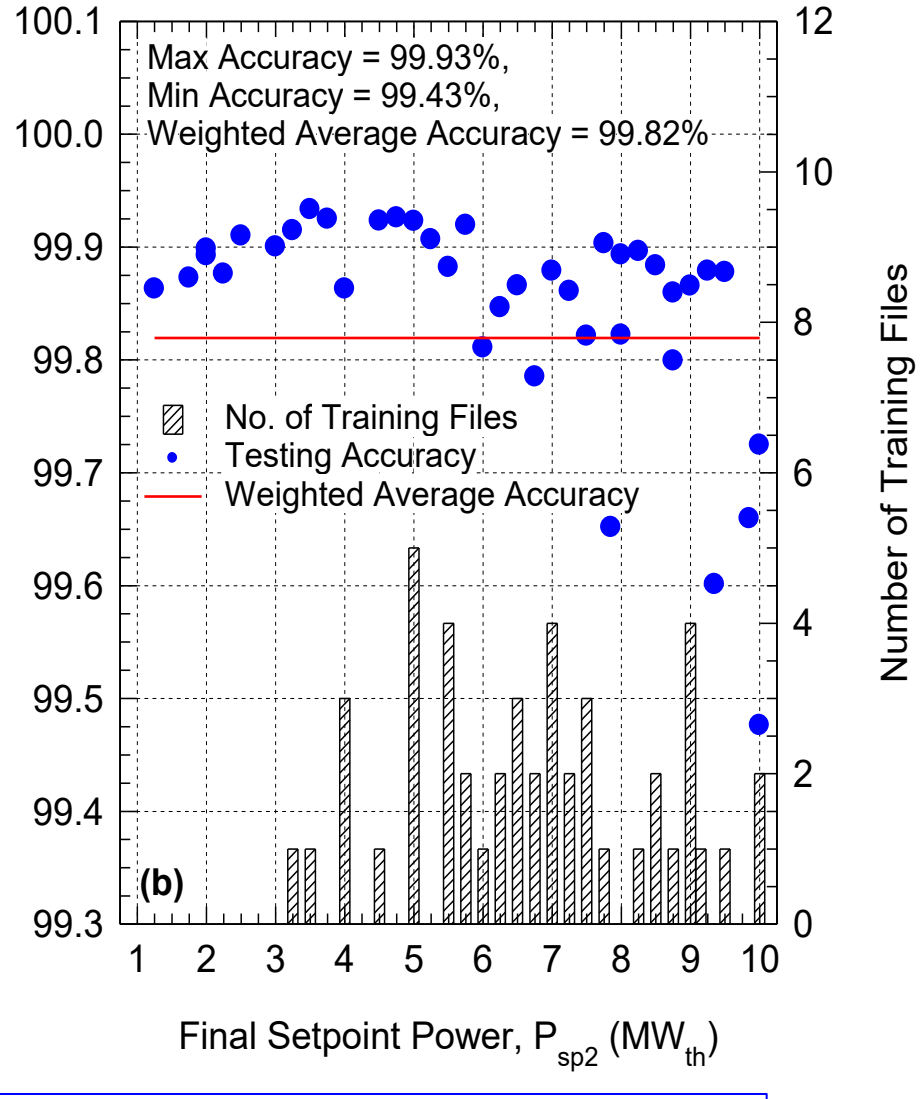
(d) ESD Cross-Section View A-A



Supervised Learning Paradigm: Training Results

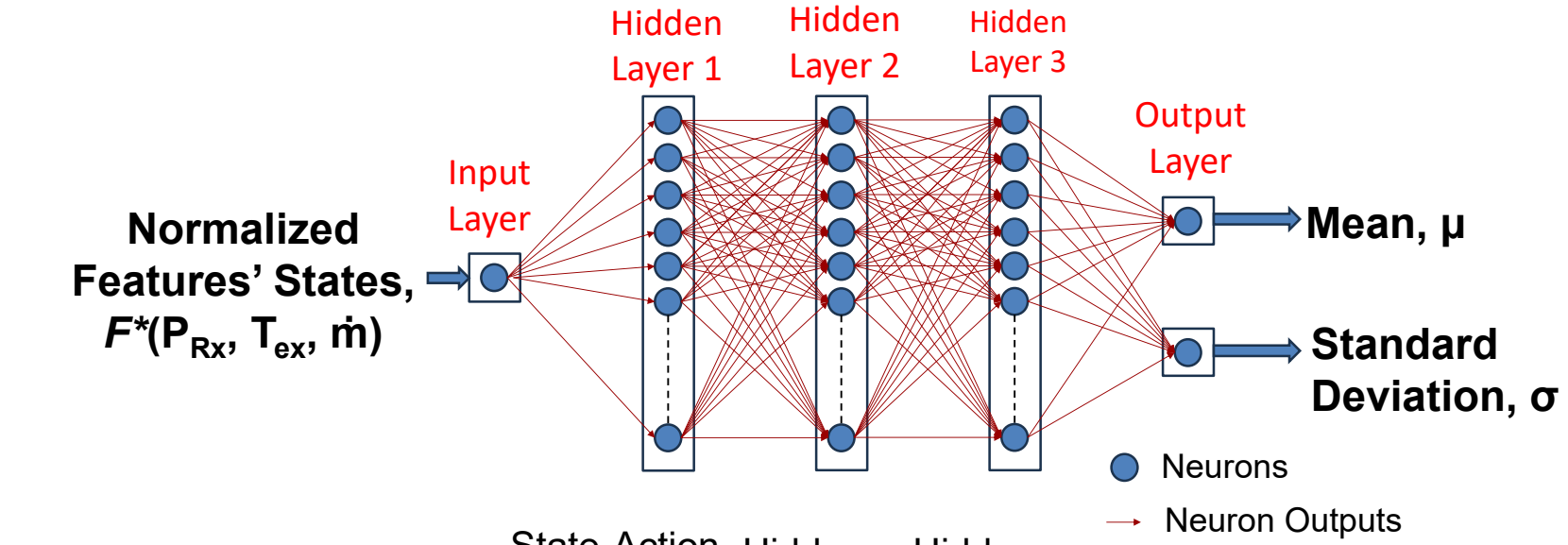
- Used 797 training data sets with 956 m data points generated by VSLLIM MATLAB Simulink model
- Demonstrated prediction accuracy up to 99.95%



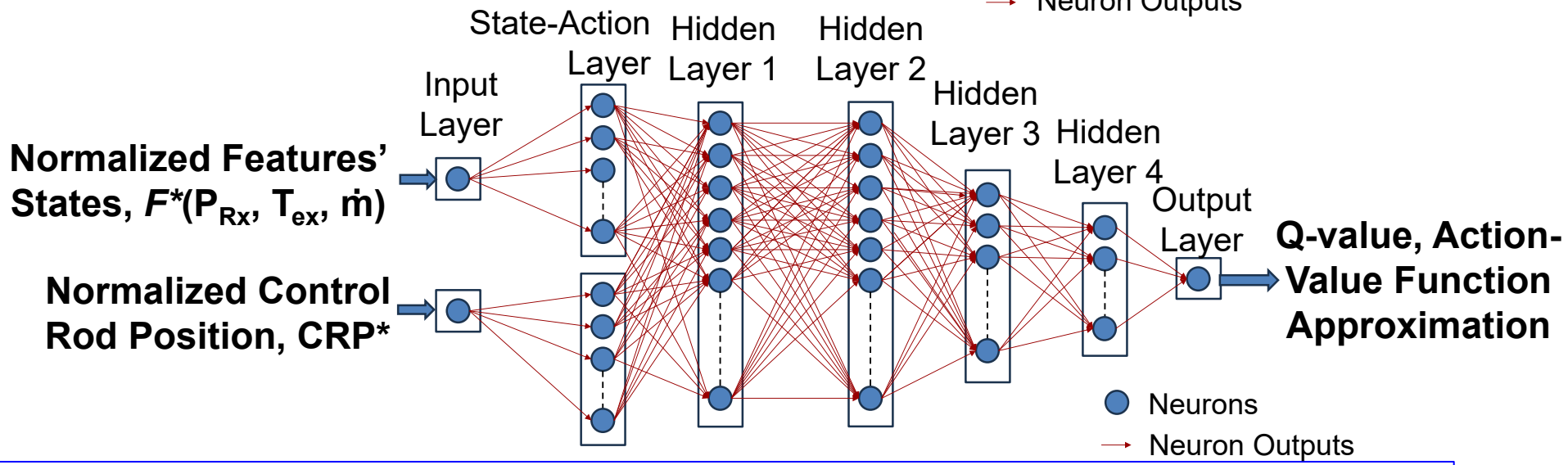


Reinforcement Learning Paradigm: Soft Actor-Critic (SAC)

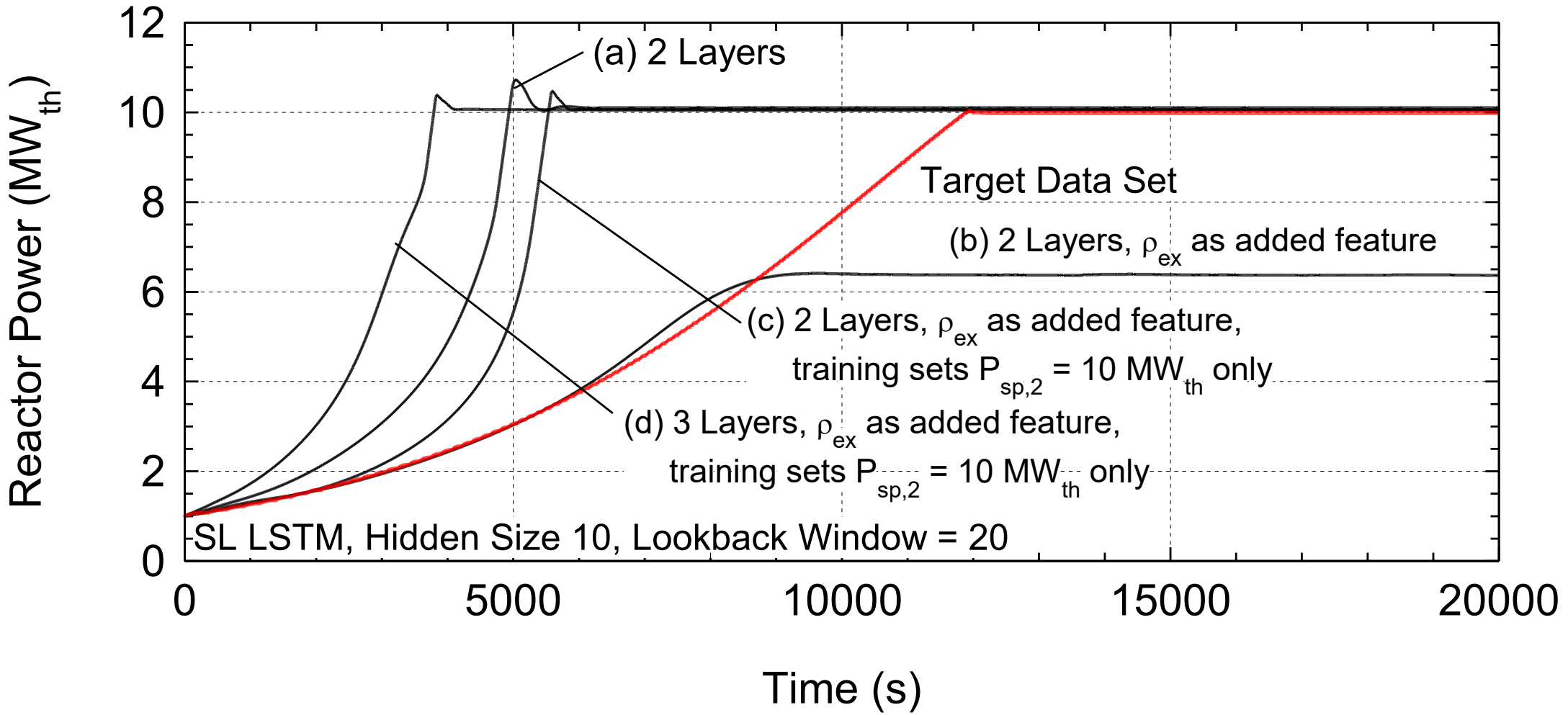
SAC Actor Feedforward Neural Network



SAC Critic Feedforward Neural Network

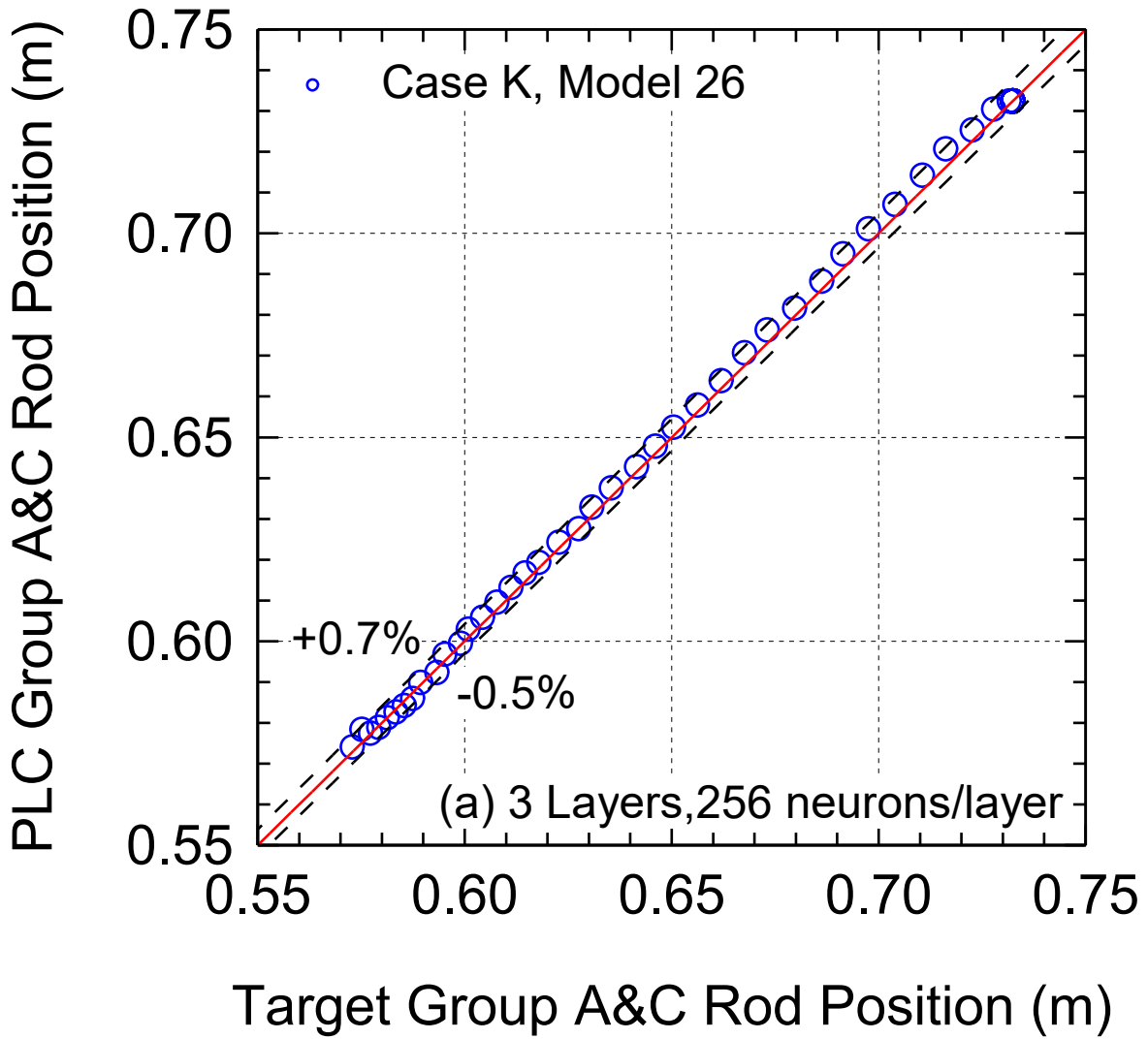


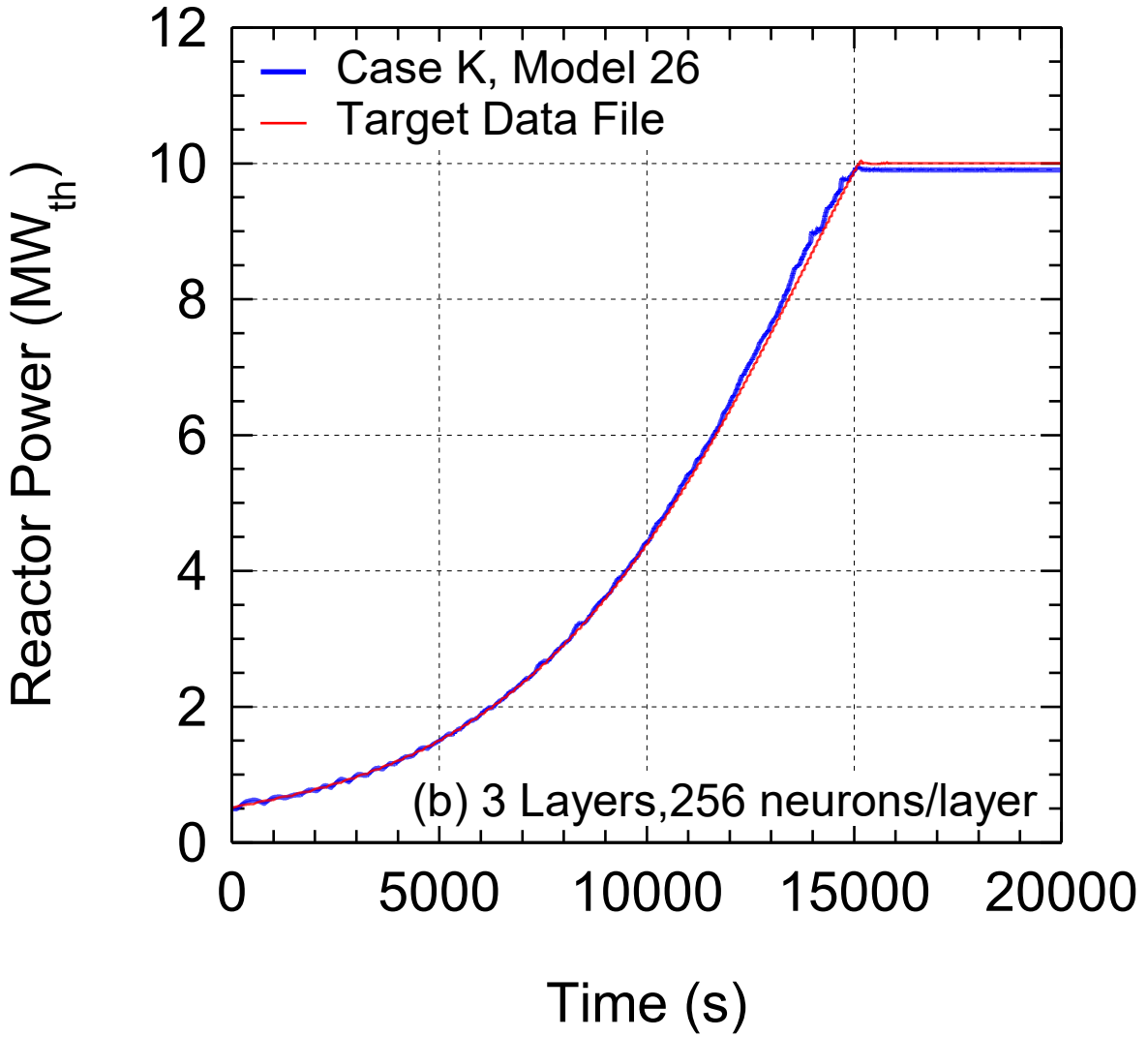
Testing Results: PLC with SL LSTM



PLC with Supervised Learning LSTM

Testing Results: PLC with SAC Feedforward Network

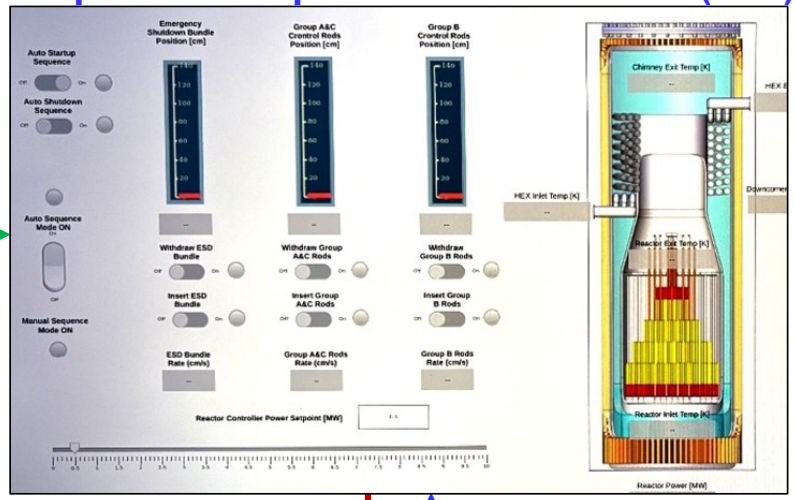




Testing Setup: Real Time Controller

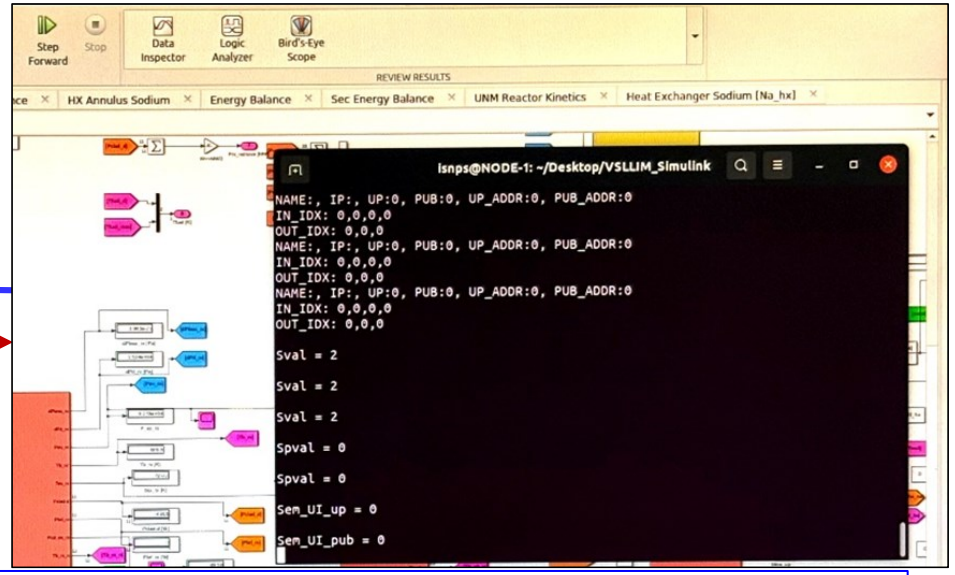
Remote Operator Graphical User Interface (GUI)

Human Remote Operator



Ethernet Testing Network Managed Switch

VSLLIM Simulink Model and LOBO NCS Platform Server



Operator Commands TCP/IP Communication

PLC Monitoring Data TCP/IP Communication

Reactor Control PLC Program Server

Modbus Operation Variables

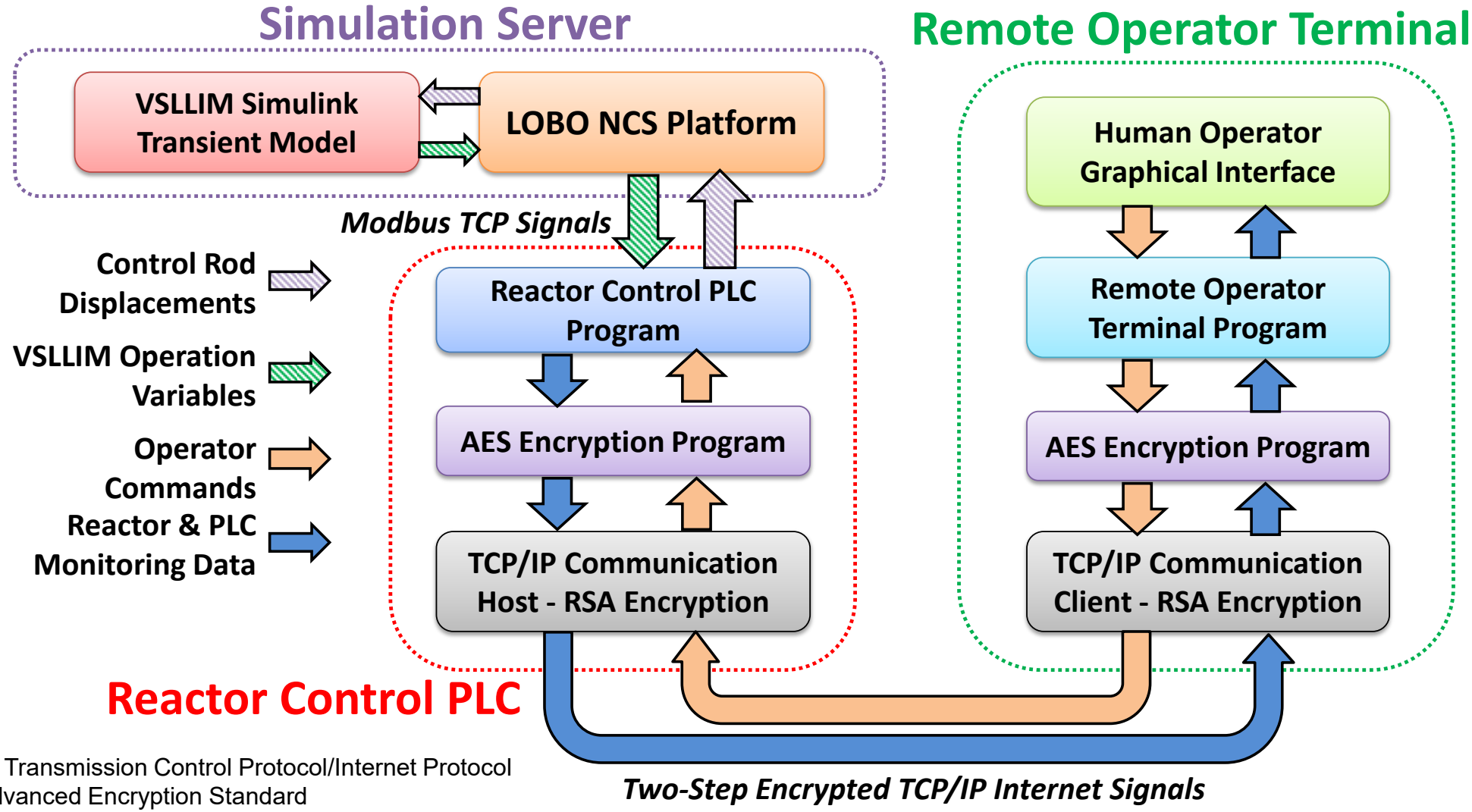
Modbus Control Signals

TCP/IP = Transmission Control Protocol/Internet Protocol

Summary and Work in Progress

- **Trained** artificial neural networks for programmable logic controller (PLC) of VSLLIM microreactor using SL and SAC algorithms:
  - **SAC networks performed well for real time transient startup of VSLLIM reactor.**
  - SL networks displayed mediocre performance due to lack of feedback during training.
- **Conducted** real time testing of PLC with trained neural networks coupled to VSLLIM physics-based Simulink model.
- **Developing** encrypted communications with remote operator.

VSLLIM Secure Remote-Control Scheme



TCP/IP = Transmission Control Protocol/Internet Protocol
AES = Advanced Encryption Standard
RSA = Rivest–Shamir–Adleman

Thanks for Listening: Discussion and Questions!