Multi-variable PID Fuzzy Neural Network Control for a 20K Large-scale Helium Refrigerator

L. L. Lei[a,b], L.B.Chen[a], N. Peng[a], L. Y. Xiong[a], J. C. Tang[a,b], B. Dong[a] and L. Q. Liu[a]
[a] Technical Institute of Physics and Chemistry, CAS, Beijing, 100190 China
[b] University of Chinese Academy of Sciences, Beijing, 100190 China

Technical Institute of Physics and Chemistry (TIPC)
Chinese Academy of Sciences (CAS), Beijing

Introduction

Large-scale helium refrigerators at 20K are used for cooling neutron sources systems, nuclear-energy and high-energy physics. These systems generate heat load which is pulsed, and helium refrigerators have to handle such heat loads. For example, modern neutron sources systems can generate a high-level pulsed neutron flux in a small volume, and this pulsed neutron flux will lead to a pulsed heat load for the refrigerator. The proposed control scheme can be used to have precise control of every pressure in normal operation or to stabilize and control the cryoplant under high variation of thermal loads. The strategy intends to optimize the control loops of the GMP and turbine inlet valve, by fuzzy neural network PID controller.

The controller contains three modules: fuzzy module, neural network and normal PID controller. Fuzzy control has strong robustness, and the neural network control is good at self-tuning. They were combined for their advantages, and fuzzification can avoid that the output is not sensitive with the input when the input of NN control is too big. In this new controller, the V2 and V3 will be considered as one regulator.

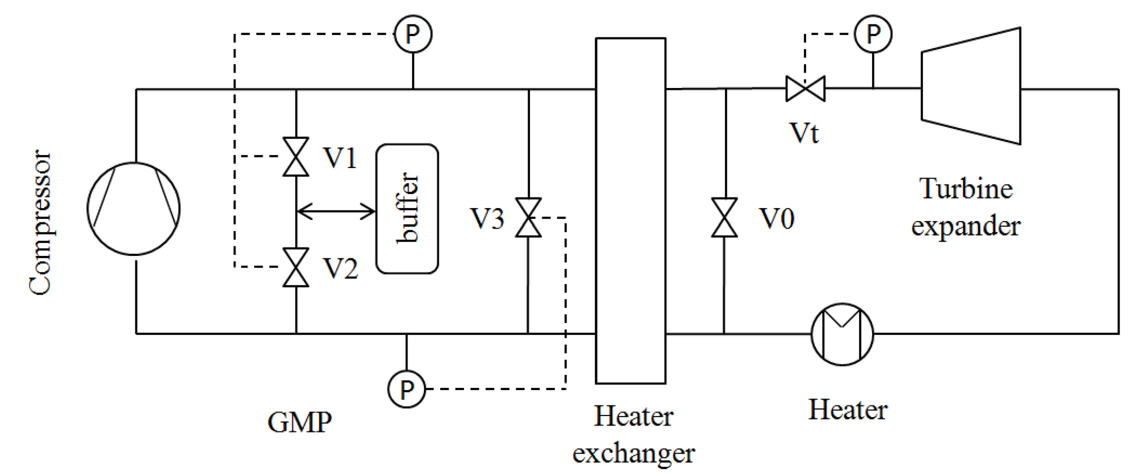
Conclusion

A fuzzy neural network PID controller, which is a method for adaptively adjusting the PID gains using a BP neural network, are introduced to GMP of the large-scale helium refrigerator. The neural network PID control has self-learning and self-adapting abilities and fuzzy control has strong robustness. The fuzzy neural network PID control and traditional PID control are both applied to a simulation model of a reverse Brayton refrigerator. The simulation results indicate that the fuzzy neural network control system has better robustness and higher precise than traditional PID control. For future work, the fuzzy neural network PID controller will be compared with the other control methods on simulation model and the real helium refrigerator.

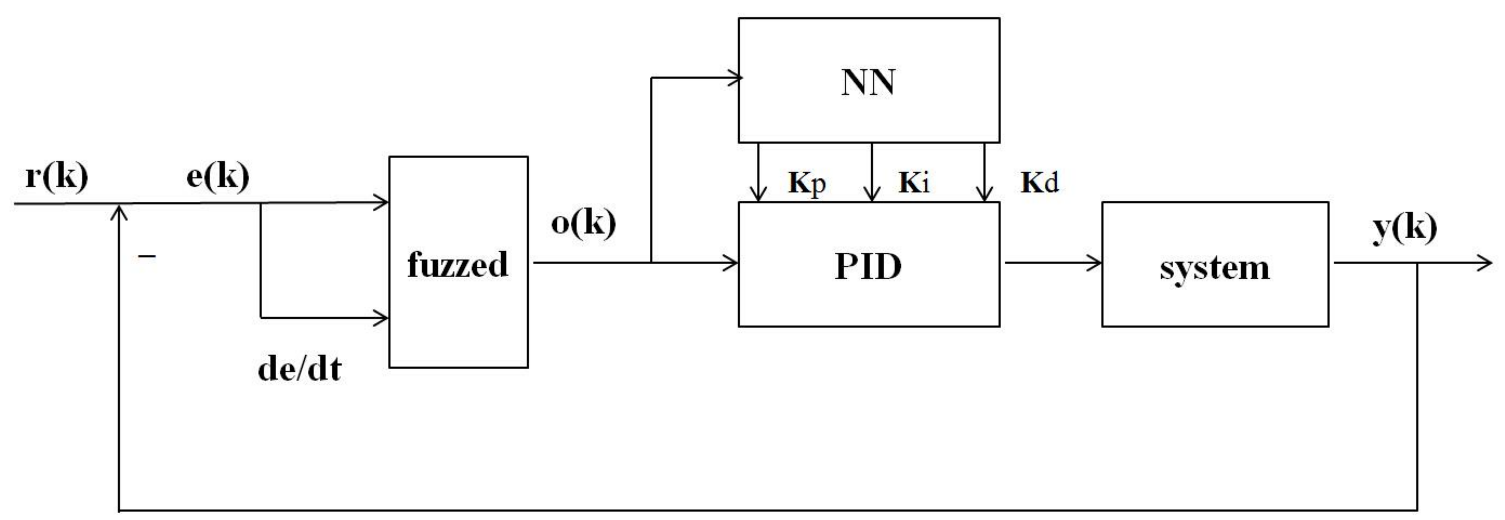
Methods

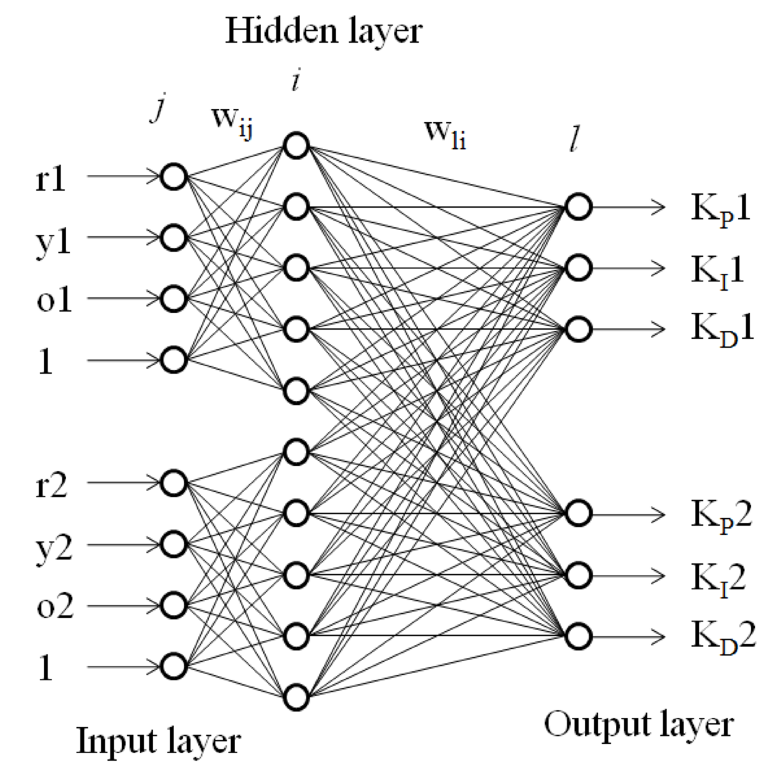
Flow scheme of the refrigerator

A refrigerator based on modified reverse Brayton cycle has been developed recently. This refrigeration cycle consists of an oil lubricated screw compressor, a GMP, a buffer tank, a counter-flow heat exchanger, a heater and a turbine expander.



Multivariable FNN-PID controller structure





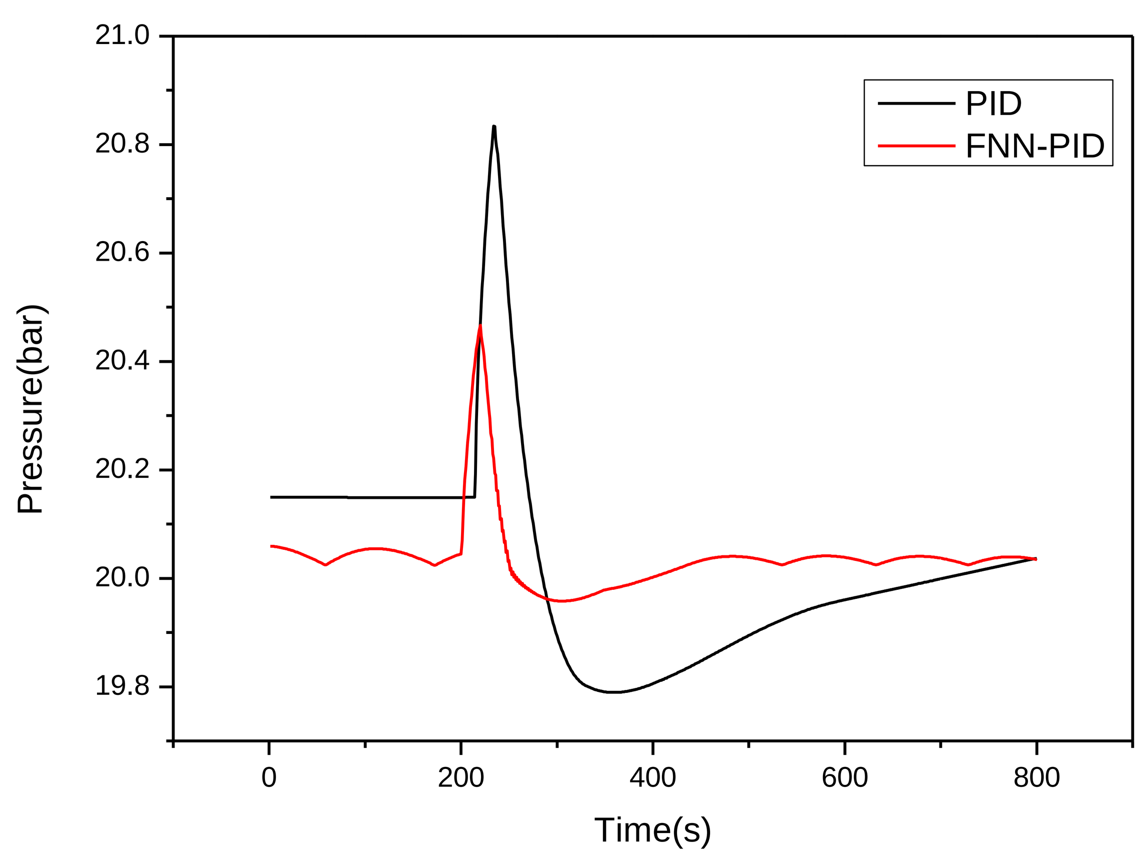
Details

The error and the change rate of error were fuzzed to 13 linguistic variables, and the output O(k) can be calculated by the right table.

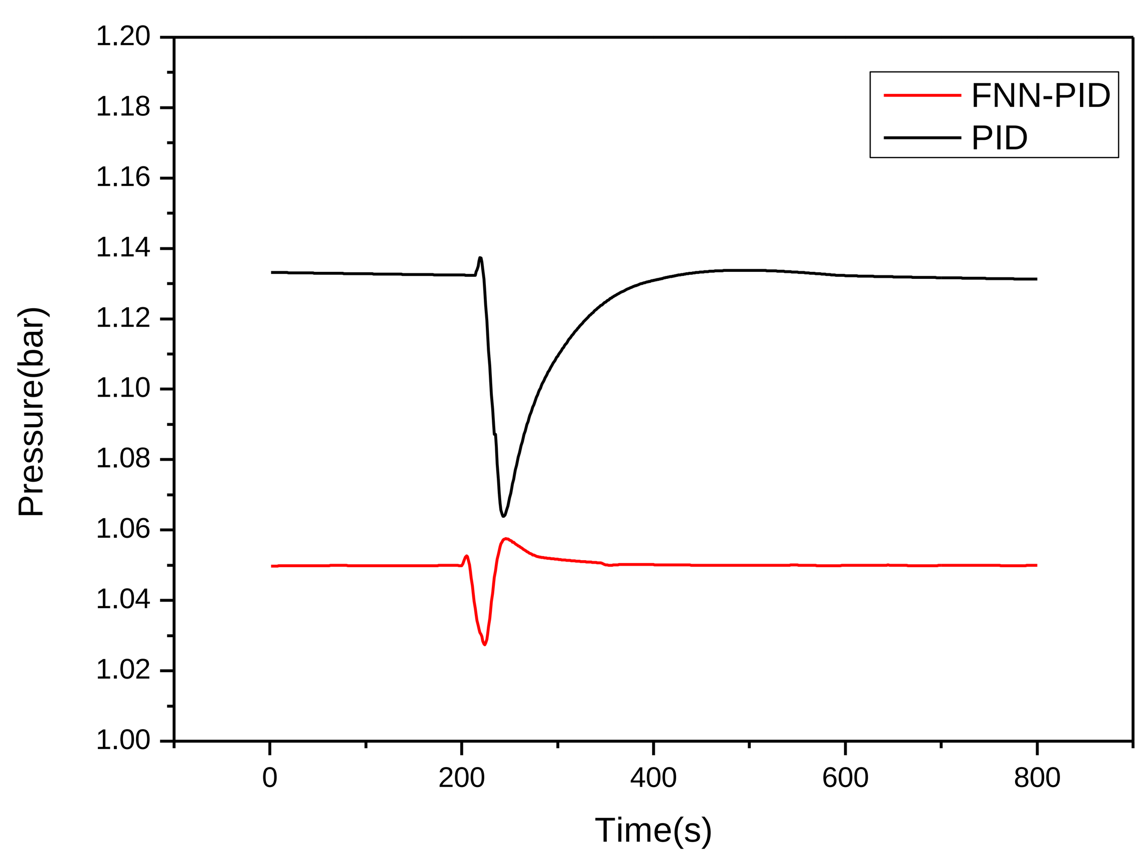
The part of a NN block is build in order to adjust the gains of PID controllers adaptively by using the back propagation (BP) method with measurement data of u(t), y(t) and r(t).The BP is a multilayered network which consists of an input layer, an output layer and several hidden layers of nonlinear processing elements as shown on the left.

O(k)		EC（k）												
		6	5	4	3	2	1	0	-1	-2	-3	-4	-5	-6
E(k)	6	6	6	6	6	6	5	5	4	3	2	1	0	0
	5	6	6	6	6	5	5	5	4	3	2	1	0	0
	4	6	6	6	5	5	5	5	4	3	2	1	0	0
	3	5	5	5	5	4	4	4	3	2	1	0	-1	-1
	2	4	4	4	4	4	4	4	2	1	0	0	-2	-2
	1	4	4	4	3	3	3	3	1	-2	-2	-3	-3	-3
	0	4	4	4	3	3	1	0	-1	-3	-3	-4	-4	-4
	-1	3	3	3	2	2	-1	-3	-3	-3	-3	-4	-4	-4
	-2	2	2	2	0	-1	-2	-4	-4	-4	-4	-4	-4	-4
	-3	1	1	1	-1	-2	-3	-4	-4	-4	-5	-5	-5	-5
	-4	0	0	0	-2	-3	-3	-5	-5	-5	-5	-6	-6	-6
	-5	0	0	0	-2	-3	-4	-5	-5	-5	-6	-6	-6	-6
	-6	0	0	0	-2	-3	-4	-5	-5	-6	-6	-6	-6	-6

Results



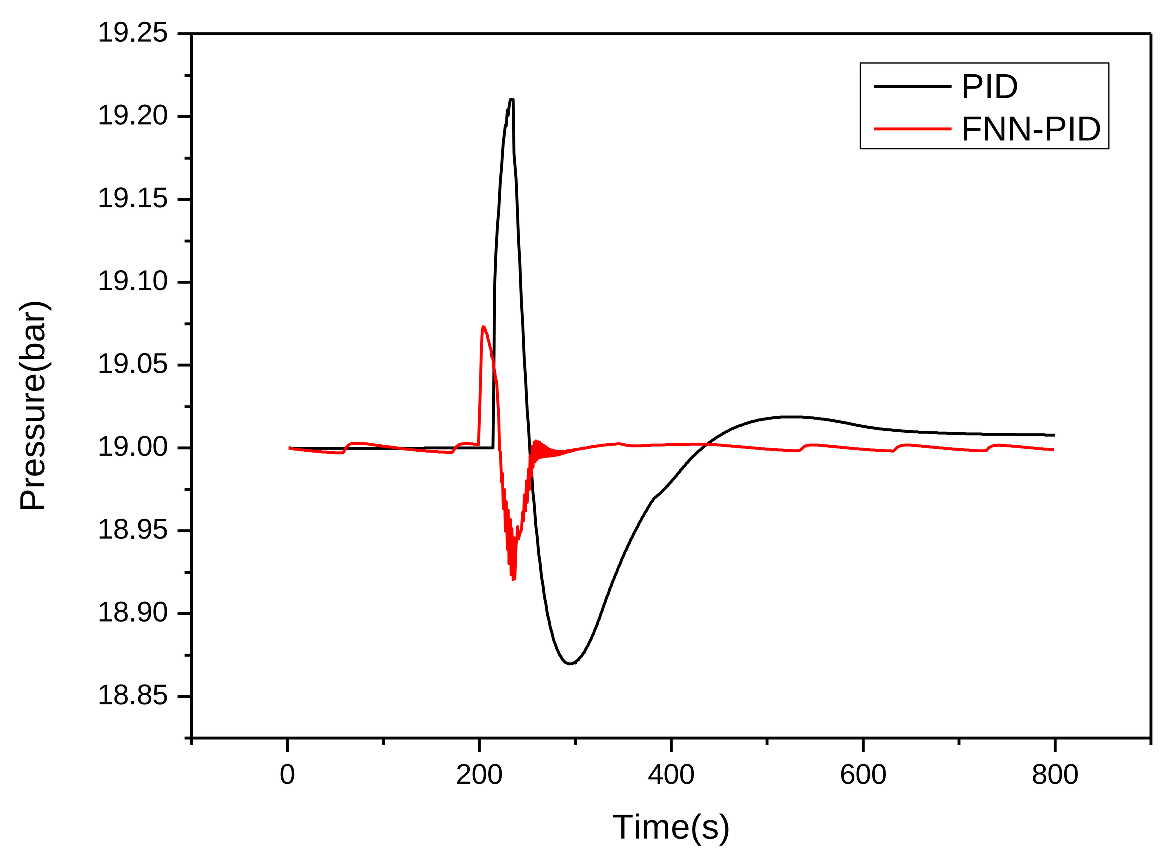
Compressor outlet pressure



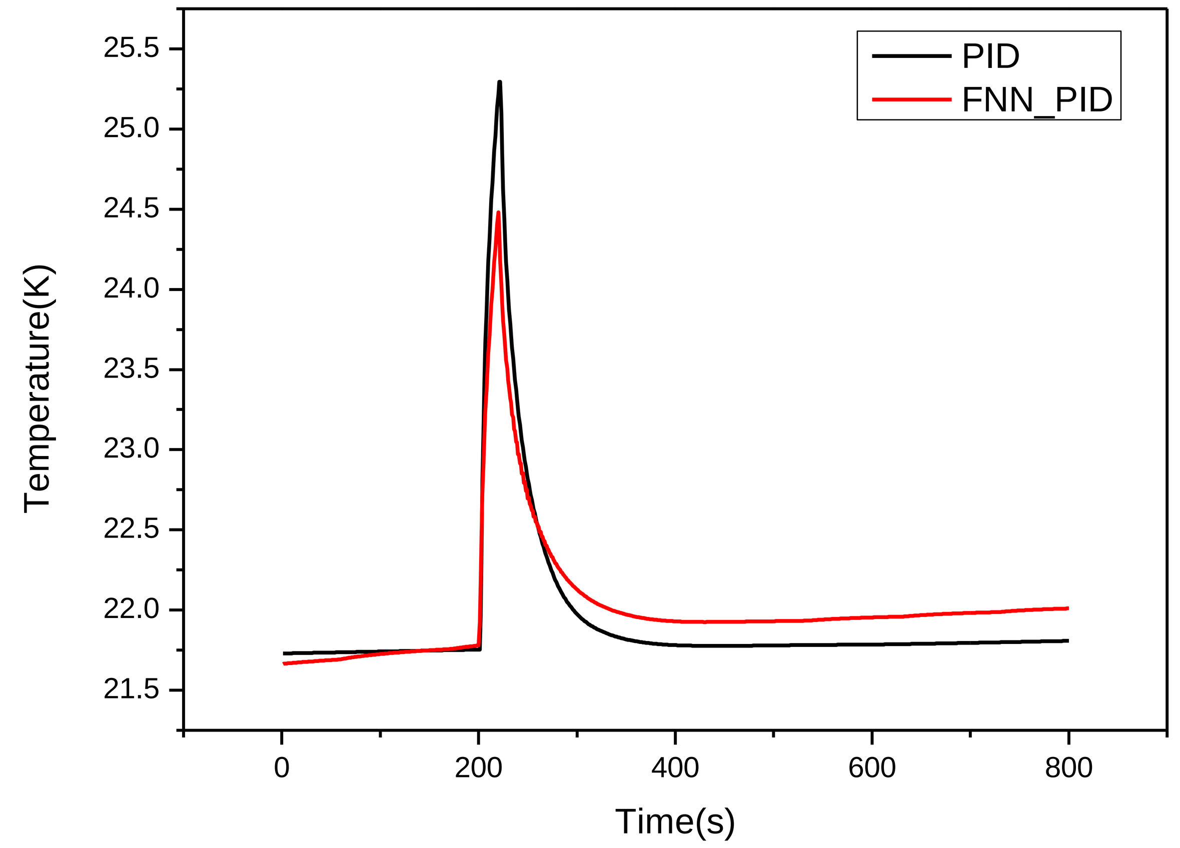
Compressor suction pressure

The setting pressure of high pressure is 2.0 MPa and that of low pressure is 0.105 MPa. The traditional PID parameters for V1 are K_P = 2.0, K_I = 20, K_D = 0; those for V2 and V3 are K_P = 1.0, K_I = 30, K_D = 0. For fuzzy neural network PID in the simulation, the learning rate is 0.1 and the smoothing coefficient is 0.2 and the initial weights is the random number in the extent (-1,1).

When system remains stable, excess 25% pulse heat load was given and lasted for 20s.



Turbine inlet pressure



Turbine outlet temperature

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