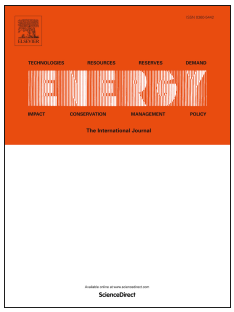
Accepted Manuscript



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PII: S0360-5442(18)30454-7

DOI: 10.1016/j.energy.2018.03.046

Reference: EGY 12504

To appear in: *Energy*

Received Date: 13 December 2017

Revised Date: 27 February 2018

Accepted Date: 9 March 2018

Please cite this article as: Dong Z, Zhang Z, Dong Y, Huang X, Multi-layer perception based model predictive control for the thermal power of nuclear superheated-steam supply systems, *Energy* (2018), doi: 10.1016/j.energy.2018.03.046.

Multi-Layer Perception Based Model Predictive Control for the Thermal Power of Nuclear Superheated-Steam Supply Systems

Zhe Dong, Zuoyi Zhang, Yujie Dong, Xiaojin Huang

Institute of Nuclear and New Energy Technology (INET), Collaborative Innovation Center of Advanced Nuclear Energy Technology of China, Key Laboratory of Advanced Reactor Engineering and Safety of Ministry of Education, Tsinghua University, Beijing 100084, China

ABSTRACT: Nuclear superheated-steam supply systems (Su-NSSS) produces superheated steam flow for electricity generation or process heat. Although the current Su-NSSS control law can guarantee satisfactory closed-loop stability, which regulates the neutron flux, primary coolant temperature and live steam temperature by adjusting the control rod speed as well as primary and secondary flowrates, however, the control performance needs to be further optimized. Motivated by the necessity of optimizing the thermal power response, a novel multi-layer perception (MLP) based model predictive control (MPC) is proposed in this paper, which is constituted by a MLP-based prediction model and the control input designed along the direction opposite to the gradient of a given performance index. It is proved theoretically that this MLP-based MPC guarantees globally-bounded closed-loop stability. Finally, this newly-built MLP-based MPC is applied to the thermal power control of a Su-NSSS, whose implementation is given by forming a cascaded feedback control loop with the currently existing Su-NSSS power-level control in the inner loop for stabilization and with this new MPC in the outer loop for optimization. Numerical simulation results verify the correctness of theoretical result, and show the satisfactory improvement in optimizing the thermal power response.

KEYWORDS: Nuclear energy; optimization; model predictive control; neural network

Nomenclature

Abbreviations

CARIMA	controlled auto-regressive and integrated moving average
FNN	fuzzy neural network
FS	fuzzy set
HES	hybrid energy system
HTR-PM	high temperature gas-cooled reactor pebble-bed module
MAC	model-free adaptive control
MHTGR	modular high temperature gas-cooled reactor
MLP	multi-layer perception
MPC	model predictive control
NC	nonlinear control
NN	neural network
NPP	nuclear power plant
NSSS	nuclear steam supply system
OTSG	once-through steam generator
PWR	pressurized water reactor
RFP	reactor full power
RNN	recurrent neural network
SMR	small modular reactor
Su-NSSS	nuclear superheated-steam supply systems

Symbols of Process Variables

$\mathrm{d}n_{\mathrm{r}01}$		revision to the setpoint of normalized nuclear power of 1# NSSS module
$n_{\mathrm{r}1}$		normalized nuclear power of 1# NSSS module
$v_{\mathrm{r}1}$	cm/s	control rod speed of 1# NSSS module
$G_{\mathrm{h}1}$	kg/s	primary helium flowrate of 1# NSSS module
$G_{\mathrm{s}1}$	kg/s	OTSG feedwater flowrate of 1# NSSS module
$P_{\mathrm{th}1}$	MW	thermal power of 1# NSSS module
$T_{\mathrm{cout}1}$	°C	reactor outlet helium temperature of 1# NSSS module
$T_{\mathrm{s}1}$	°C	live steam temperature of 1# NSSS module