Design of a PID Controller for a Molten Salt Microreactor

A Thesis
Presented in Partial Fulfillment of the Requirements for the
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with a
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by
Sam J. Root

Major Professor: Michael McKellar, Ph.D.
Committee Members: Dakota Roberson, Ph.D.; Robert A. Borrelli, Ph.D.
Department Administrator: Indrajit Charit, Ph.D.

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Abstract

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Acknowledgements

This work and my coursework was completed under a Graduate Fellowship funded by Nuclear Regulatory Commission (NRC). I would like to thank Dr. McKellar...

Dedication

To my mother, Tammy, who planted and nurtured my love of science. To my father, Paul, who taught me how to design and build, and showed me that I am an engineer. To my cats, Babe and Bunyan, who stayed up with me all those late nights studying and writing. Thank you for your endless support.

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Acronyms

LWR Light Water Reactor.

MSNB Molten Salt Nuclear Battery.

NRC Nuclear Regulatory Commission.

PID Proportional-Integral-Derivative.

Chapter 1

Introduction

1.1 Background

The Molten Salt Nuclear Battery (MSNB) is a self contained design [1, 2]...

Micro Reactors

Molten Salt Reactors

Light Water Reactor (LWR)

1.2 Scope

Until now, little to no work has been done on the control system...

Chapter 2

Process Control Engineering

2.1 Feedback

2.2 Feedforward

The term 'Feedforward' can be used to refer to any element in the control block diagram that exists outside of the feedback loop.

Disturbance Feedforward

Not that useful since disturbance transport delay is on the order of minutes and disturbance dynamics are on the order of milliseconds

Pre-Filter

This could be electronic (less ideal) or physically realized by decoupling

2.3 Time Variance

Fissile depletion - time function parameters or look-up table to gain-schedule and turn the time variant system into a shift invariant system.

In addition to the relatively slow time variance of fissile fuel depletion during steady-state critical operation, there are specific times in a MSNB's expected operational life-cycle that exhibit a higher degree of time variance: 1. Start-up; 2. Shut-down; and 3. Re-start.

Start-up

Black-start may need to deal with thawing salt - main concern is fission product neutron poison build-up (discuss the burnable poison stuff)

Shut-down

Planned shut-down

Emergency Shutdown/SCRAM(must be passive)

Decay heat and keeping the salt liquid for restart

Re-start

^{135}Xe stripper

Chapter 3

Reactor Characterization

3.1 Reactor Design selection

3.2 Neutronics Modeling

3.3 Process Simulation

Chapter 4

Controller Design

4.1 Reactor Transfer Function

4.2 Tuning Methodology

Chapter 5

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6.1 Limitations

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References

[1] Carter, John P., 2022. Multi-Physics Investigation of a Natural Circulation Molten Salt Micro-Reactor that Utilizes an Experimental In-pile Device to Improve Core Physics and System Thermal-Hydraulic Performance. Ph.D. thesis, Univesity of Idaho.

[2] Peterson, John, 2019 8. An Analysis of the Nuclear Characteristics of a Molten Salt Microreactor. Master's thesis, University of Idaho.

Appendix A

Test

Code 1: Hello!

```
    print("Hello World") #comment
    try:
        a=2/x
    except ZeroDivisionError:
        print('undefined')
```

Inline codes like `import numpy`

Code 2: F strings

```
x = 4
print(f"The numeral four: {x}")
#comment
```

Appendix B

What

Straight Cash Homie