

Table of content

Chapter 1: Introduction.....	1
1.1. On our effect on the planet	1
1.2. Sustainability	2
1.3. Solar water heating	3
1.4. Policy optimization.....	4
1.5. Reinforcement Learning and Deep Reinforcement Learning.....	4
1.6. Objectives	5
1.6.1. General objective.....	6
1.6.2. Specific objectives.....	6
1.7. Structure of the Thesis.....	6
Chapter 2: Literature Review	8
2.1. Literature on solar water heating.....	8
2.2. Literature on policy optimization	8
2.3. Summary.....	10
Chapter 3: Theoretical framework.....	11
3.1. Dense Deep Neural Networks	11
3.1.1. Gradient Descent	12
3.1.2. Momentum	13
3.1.3. Backpropagation.....	14
3.1.4. Softmax activation.....	17
3.1.5. DNN initialization	19
3.2. Deep Reinforcement Learning Algorithms	19
3.2.1. Basic Concepts	20
3.2.2. Policy gradient methods and value methods	21
3.2.3. REINFORCE algorithm	22
3.2.4. Actor-Critic Algorithm.....	22
3.2.5. Q-Learning and Deep Q-Learning.....	24
3.2.5.1. Q-Values.....	24
3.2.5.2. Q-Learning	24
3.2.5.3. Deep Q-Learning algorithm	25
3.2.5.4. Double DQN.....	27
3.2.5.5. Prioritized Experience Replay.....	27

3.3. Reliability theory	28
3.3.1. Hazard rate.....	30
3.3.2. Exponential distribution	31
3.3.3. Series system	31
3.3.4. Parallel system.....	32
3.4. Discrete-time Markov chains.....	32
3.4.1. Geometric distribution.....	33
3.4.2. Steady-state probabilities.....	34
3.5. Heat pipe evacuated tube solar collectors.....	37
3.6. Heat pumps and refrigeration systems.....	38
3.7. TRNSYS.....	40
Chapter 4: Development of the training platform	42
4.1. System under study.....	42
4.2. Actions.....	44
4.3. Rewards	46
4.4. Environment state	48
4.5. TRNSYS-Python connection.....	49
4.6. Introducing stochastic failures.....	53
4.6.1. Failure rates of individual devices.....	54
4.6.2. Construction of the Markov chains	56
4.7. Pseudo-code versions of the Python Scripts.....	60
4.7.1. Initializer.....	60
4.7.2. Code to train the network	61
4.7.2.1. Main code	61
4.7.2.2. Interaction at 8.00 AM.....	62
4.7.2.3. Interaction from 10.00 AM to 8.00 PM.....	62
4.7.2.4. Interaction at 10.00 PM	63
Chapter 5: Methodology.....	64
5.1. Stages of the study.....	64
5.2. Result Analysis	64
Chapter 6: Results and Discussion	68
6.1. Comparison of DRL algorithms	68
6.2. Comparison to a non-smart-controlled baseline.....	74
6.2.1. Testing method	75

6.2.2. Results	76
6.3. Comparison of different network architectures and training hyperparameters	77
6.3.1. Comparing Different Architectures	79
6.3.2. Comparing Different Discount Factors	81
6.3.3. Comparing traditional DQN to Double DQN.....	84
6.3.4. Effect of momentum.....	85
6.4. Behavior comparison under different reward parameters	86
6.4.1. Changing the value of α_1	87
6.4.2. Changing the value of α_2	94
6.4.3. Changing the value of α_3	97
6.4.4. Effect of the α_4 parameter.....	98
6.5. System subject to failures	99
6.5.1. Training is carried out with the Markov chains of the real system	101
6.5.2. Training is carried out with planned failure cycles	108
6.5.3. Alternative Markov chains	114
6.5.4. Effect of momentum for failure-subject agents.....	117
6.5.5. Agent selection and final testing	119
Chapter 7: Conclusions.....	126
7.1. Accomplishment of objectives	126
7.2. Future work	127
8. Glossary	129
9. Bibliography	130
Annexes	134
Annexed A. Further details about the water heating system simulation	134
Annexed A.1. Detailed flow diagrams	134
Annexed A.2. Parameters of the elements in the system simulation (Types)	135
Annexed A.3. Elements (Types) with external files.....	138
Annexed A.4. Imposed Temperatures	142
Annexed B. All results of Section 6.5.	143