CHAPTER 1

INTRODUCTION

1.1 Background

The campaign for the need for clean energy has recently been intensively carried out in line with the issue of climate change due to global warming and air pollution. Clean energy sources are expected to fulfill the electricity needs of the world's population, which has increased every year in line with the development of electronic technology products. Photovoltaics is one of the solutions for providing energy needs that are low in exhaust emissions when compared to fossil power plants. Photovoltaic energy generates electrical energy by converting solar radiation and temperature on the cell surface, so it is very suitable to be applied to areas that get solar radiation throughout the year.

The photovoltaic system's dependence on insolation and temperature causes the electricity generated to vary. Increasing the performance of this energy conversion system with an efficient maximum power point tracking system (Maximum Power Point Tracker). The MPPT algorithm has been developed and categorized based on input requirements, tracker accuracy and speed, effectiveness, and data processing techniques. The MPPT algorithm is categorized in terms of conventional methods such as peturb and observe (P&O), incremental conductance (INC), and hill fractional open or short circuit current, which calculates changes in power, current, or voltage manually with input information obtained [1]. In contrast to conventional methods, intelligent control methods and evolutionary algorithms such as fuzzy logic controllers (FLC) [2], artificial neural networks (ANN) [3], genetic algorithms (GA) [4], ant colony optimization (ACO) [5], and particle swarm optimization (PSO) [6] exist. The algorithm requires specific information about photovoltaics to track the maximum power point more accurately than conventional methods, but this method is more difficult to implement into the system and requires more time. Research on the performance comparison of several intelligent control methods with conventional methods was carried out to determine the advantages and disadvantages of each method in the same environment [7]. Many studies have been carried out by combining the two methods, either by combining conventional methods with intelligent control methods such as the FLC algorithm with P&O [8] or by combining intelligent control methods with one another such as the combined PSO-ANN algorithm [9] and GA-ACO [10].

Reinforcement learning (RL) is a machine learning method widely applied to control applications, one of which is the MPPT algorithm. This method has the advantage of tracking without specific system information. One of the reinforcement learning methods that has been widely used for photovoltaic power control applications is the Q-Learning (QL) algorithm. Control is carried out without clear model information (model-free) and based on value. QL application research on MPPT shows results that are more efficient than P&O in tracking the maximum power point, with a lower oscillation rate and faster tracking both in constant conditions and quickly changing conditions that are partially shaded [11], [12], [13]. Apart from photovoltaics, the QL algorithm has also been tested in microbial fuel cell technology by comparing each policy when selecting actions [14].

Bao Chou Phan et al., in 2019, combined the P&O algorithm with QL. The type of combination of the two methods calculates the difference between the duty cycle output value of the Q-Learning algorithm and the duty cycle value of the P&O algorithm [15]. The combination of the RL and P&O methods was also carried out by Christos Kalogerakis et al. in 2020. The combining the two methods is by running the QL algorithm to determine the duty cycle value, which will be used as a reference for the execution of the P&O algorithm [16], besides that the QL algorithm has also been combined with the FLC type II algorithm [17]. The benefit of a trim oscillation level may be achieved by combining algorithms from traditional and intelligent control techniques with the QL algorithm. However, doing so is challenging since state conditions must be discretized in the QL algorithm. With the same algorithm but with the addition of deep learning (DL), this algorithm is called deep reinforcement learning (DRL), where state conditions do not need to be discretized so the system can correctly identify that information about the state. In addition, the implementation of reinforcement learning in energy systems and modern power has been comprehensively discussed by Di Cao et al. [18].

The application of the Deep Q-learning Network (DQN) algorithm in MPPT shows results that are as good as QL, but the process of identifying models is better [19], [20]. In this research, the MPPT control method will be designed by combining conventional methods, namely the P&O algorithm, and the reinforcement learning method, namely the DQN algorithm. In the system's design, the P&O algorithm will be executed earlier to obtain the duty cycle value for tracking the optimal point of photovoltaic work with a fixed work step. The value obtained will be used as a reference duty cycle value in the DQN algorithm to be corrected with various work step values. In this thesis, system performance will be assessed based on tracking the maximum power point based on changes in radiation and temperature.

1.2 Problems Statement

According to the information, the problem of converting solar radiation and temperature by photovoltaic is ineffective, even when the P&O algorithm is used to calculate MPPT. Here are several issues with this thesis:

1. MPPT is one of the key factors in tracking the maximum power of a photovoltaic system.
2. How does the P&O algorithm perform under varying conditions?

3. How is the conventional hybrid method tested and reinforcement learning on MPPT on tracking the maximum power point of photovoltaics with changes in sunlight and temperature conditions?

4. How does the combination of P&O and DQN methods affect photovoltaic tracking and oscillation speed at the maximum power point?

1.3 Objectives

The aims of this thesis are as follows when articulated in terms of the problem that has been raised:

1. Combining the two algorithms seeks to optimize the power peak point on photovoltaics based on changing irradiance and temperature.

2. Understanding and evaluating the combined impact of the two techniques on photovoltaics under the changing irradiance and temperature conditions

3. The effectiveness of both traditional and hybrid approaches is examined in this thesis.

4. Choosing a good MPPT solution so that the maximum power point may be attained more quickly and with a more accurate value.

1.4 Hypotheses

The P&O algorithm is a simple algorithm for tracking maximum power points so that the tracking process does not require a long time and complicated computations. Since the step size value in the P&O algorithm tracking process is fixed at the beginning of the design, the maximum power value cannot be obtained when tracking because of an advanced step. Any backward that is done will remain so that oscillations occur at the maximum point—this tracking speed results in the P&O algorithm having drawbacks. In particular, tracking the maximum power point is not precise at the maximum value of photovoltaic power because the step size value in the P&O algorithm tracking process is fixed. Any backward that is done will remain so that oscillations occur at the maximum point.

In this study, the DQN algorithm, which can have varying step size values by previously carrying out the learning process, is expected to be a solution for reducing the level of oscillations that occur in P&O and tracking speed in rapidly changing environmental conditions.

1.5 Research Methodology

The research methodology steps as follows:

1. Literature study
   In the literature study, the latest research on developing the MPPT method, both conventional and artificially intelligent machine learning methods published in journals, papers, and proceedings, is collected to identify problems. The problem formulation and research objectives are set to confirm the hypothesis in the problem identification process.

2. System design
   The system will be modeled on Matlab or Simulink software at this stage. The system to be designed in the Matlab software includes a photovoltaic system; the MPPT algorithm consists of &O and DQN algorithms, while Simulink includes a buck-boost converter and the whole system that is connected to Matlab.

3. Simulation
   In the simulation phase, the previously designed system will be tested first to test the model's suitability with the actual system characteristics. After the relevant results are found, the simulation of the photovoltaic system without MPPT will be compared with the photovoltaic system that has been connected to the MPPT P&O algorithm and the P&O-DQN hybrid algorithm.

4. Analysis and discussion
   After the simulation is carried out in the software, the simulation results that have been obtained will be analyzed. The analysis will be carried out by looking at the comparison graph of the maximum power point achieved by the photovoltaic system without MPPT and with MPPT. The results of the photovoltaic system with MPPT using the P&O and hybrid P&O-DQN algorithms will be observed at the power point reached under changing light and temperature conditions, the time used, and the power stability at the point reached.

5. Conclusion
   At this stage, the results of the analysis and discussion based on the simulation can be concluded, and suggestions for improvement can be given to improve further research.

1.6 Problem Limitation

The limitations of this research are as follows:

1. The simulation is run on MATLAB/SIMULINK R2021a software with the design of the DQN algorithm based on the reinforcement learning toolbox.
2. The MPPT algorithm used is the P&O algorithm with the DQN algorithm, which is part of the reinforcement learning algorithm.
3. Photovoltaic modeling on Simulink is assumed to be in a fixed condition.
4. In optimizing the duty cycle with the DQN algorithm, selecting the best step size will be done using the epsilon- greedy method to make a trade- off between exploration and exploitation.