論文の内容の要旨

論文題目　Optimization of Electric Vehicle Operation and Infrastructure of Wireless Power Transfer System
（電気自動車の運転とワイヤレス給電地上設備の最適化）

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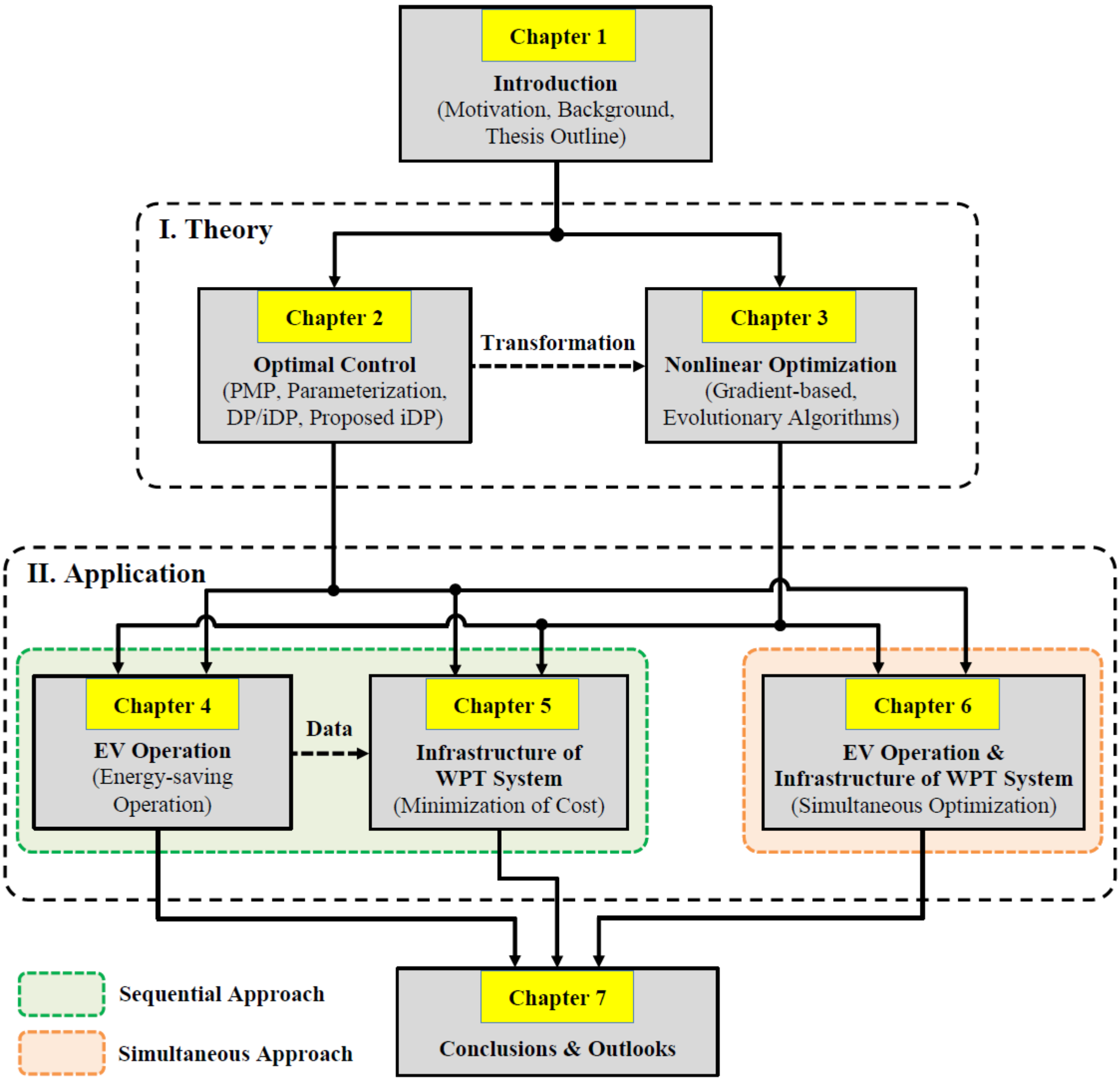

The purposes of thesis are to optimize the operation of electric vehicle (EV) and infrastrucutre design of wireless power transfer system (WPT), so that the eco-driving (energy-saving) operation of EV can be achieved, and the investment cost of WPT system is minimized. These are stated in **Chapter 1**. For those purposes, the disseratation is organized into two main parts: **Theory** and **Application** as below:

<I> In theory part, optimal control theory and nonlinear optimization theory are reviewed, then current problems of the conventional approaches are investigated. In order to resolve those problems. The following five methods are proposed:

(1) Parameterization method (**Chapter 2 + Chapter 3**). The features of the method are 1) unlike analytical methods e.g., Pontryagin's maximum principle (PMP), it avoids analitically mathematical derivations; therefore, it can handle complicated models of optimal control problem (OCP), (2) instead of finding a functional, i.e, the control signal, like analytical methods, it solves an nonlinear optimization problem to obtain unknown parameters of the control signal; thus, the control signal is determined, (3) if the initial condition is appropriately chosen, solution of the optimimization problem is easily obtained; therefore, it is faster than conventional dynamic programming (DP). However, drawback of the parameterization method is when the model of OCP is strongly nonlinear with strict constraints involved, it is not easy to choose an appropriate initial condition for a correct solution.

(2) Iterative dynamic programming with proposals of approximate generation of forward-reachable state space and grid resolution adaptation (AHiDP) (**Chapter 2**). It is well known that DP always guarantees the global optimality of solution, but its computational time is large. In order to overcome this drawback, iterative dynamic programming (iDP) was proposed. However, the global optimality of its solution is not completely guaranteed, and its computational time is still large. Therefore, in order to reduce the computational effort and enhance the accuracy of solution, approximation of forward-reachable state space and grid resolution adaptation are proposed.

(3) Iterative dynamic programming for optimal control problem with isoperimetric constraint (**Chapter 2**). In general, optimal control problem (OCP) with isoperimetric constraint is a difficult problem since the constraint of integral type is included. One only finds a solution in analytical form for simple problems, e.g., Dido's problem, by using Euler-Lagrange equations. For complicated problems, new states are defined to handle the isoperimetric constraint, resulting in increase of the OCP's size. The author proposes the combination of AHiDP with adaptive objective function to consider this isoperimetric constraint. Therefore, the computational time is kept as same as that of the orignial OCP (without isoperimetric constraint).

(4) Dynamic programming with variable time step (**Chapter 2**). It is known that the control signal of the OCP obtained by conventional DP is in the switching form, where this control signal is continously changed. This is an undesired phenomenon in some particular cases. By augmenting the time step in a vector of control signals and the instantaneous time in a vector of states, the time step can be flexiblely adjusted in a wide range, which allows the number of time steps to be small. Therefore, the switching phenomenon is removed while a high accuracy of solution is guaranteed.

(5) Modified epsilon-constrained method (MeCM) (**Chapter 3**). This method is proposed to handle with severe equality and inequality constraints of a nonlinear optimization problem. Besides being used in DE, MeCM also can be applied in other evolutionary algorithms (e.g., PSO and GA).

<II> In application part, mathematical models of EV operation and allocation of WPT system are constructed. Then, the following five models are proposed such as:

(1) Optimal eco-driving control problem of EV operation with isoperimetric constraint (**Chaper 4**). By transforming the conventional optimal eco-driving control problem of EV operation to the one with isoperimetric constraint, the proposal in **Chapter 2** can be applied. Therefore, the computaional effort of using AHiDP is reduced, and the solution accuracy is improved. In addition, it can handle optimal eco-driving control of EV with very long operational range (e.g., more than 100 [km]).

(2) Optimal control problem for allocation of WPT system (**Chapter 5**). With conventional approaches, allocation of WPT system is a static nonlinear optimization problem for minimizing the total length of WPT sections, leading to minimizing the investment cost. It is well known that the solution obtained by solving a nonconvex nonlinear optimization problem can not guarantee the global optimality. However, it is possible to obtain the global solution of an optimal control problem (OCP) by using dynamic programming (DP) or Pontryagin's maximum principle (PMP). Therefore, a new approach of transforming the allocation problem of WPT system to an OCP is proposed. Thus, the proposals in **Chapter 2** can be applied to find the global solution.

(3) Simultaneous optimization problem of EV operation and allocation of WPT system (**Chapter 6**). For conventional approaches, EV operation and allocation of WPT system are separately designed. However, since allocation of WPT system depends on EV operation, there exists an optimal EV operation so that the optimal allocation of WPT system is achieved, where the investment cost of WPT system is minimal. By applying the parameterization method in **Chapter 2 + Chapter 3**, simultaneous optimization of EV operation and allocation of WPT system is considered, which allows us to design a WPT system with the lowest investment cost.

Besides, the other applications of the proposals in theory part are considered such as:

(4) Parameterization of control signal of EV for optimal eco-driving control of EV (**Chapter 4**). It is a simple and intuitive method proposed in **Chapter 2 + Chapter 3**. For a simple road profile and sectional speed constraint, the solution is obtained with much less computational time than that of DP.

(5) Parameterization of control signal of WPT power in optimal control problem for allocation of WPT system (**Chapter 5**). With the initial condition of control signal of WPT power obtained by Pontryagin's maximum principle (PMP) at the first step, it is easy to obtain an improved solution at the second step by using parameterization method proposed in **Chapter 2 + Chapter 3**. Calculation results show that Pontryagin's principle + parameterization method achieve a high accuracy solution, compared to DP.

In **Chapter 7**, technical contributions are stated, where the advantages and disadvantages of the proposed methods for problems of EV operation or allocation of WPT system are compared. Academic contributions are presented also. Finally, outlooks of this dissertation are discussed.