Multilevel Optimal Control With Application To A Distillation Column

THESIS

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APPROVAL SHEET

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بسم الله الرحمن الرحيم

To

MY DEAR WIFE, SON AND PARENTS

A C K N O W L E D G E M E N T

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ABSTRACT OF THE THESIS

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TITLE : MULTILEVEL OPTIMAL CONTROL WITH APPLICATION TO A DISTILLATION COLUMN.

This Thesis is concerned with the multilevel computational techniques used for the solution of complex optimal control problems. Different hierarchical structures are investigated, using generalized gradient techniques, such as two-level costate coordination, three-level multiple costate coordination, and three-level non-feasible costate coordination. A numerical example is included to illustrate these methods.

A multilevel technique based on trajectory decomposition is used to solve singular optimal control problems, besides the known Epsilon technique. Also a numerical example is included to illustrate the two techniques.

Then the distillation column is considered as an example of complex processes. The control variables are the deviations in both the heating power and the reflux flow rate. The control objective is to maintain the composition of the overhead product constant, where the system is subjected to a disturbance in the feed flow rate.

The optimal control is based on a quadratic performance which is a function of the deviations of the column states and control functions.

The thesis contained also a detailed numerical study for the evaluation of the optimum multilevel control schemes for a distillation column supported by the simulation results obtained from the digital computer.

C O N T E N T S

Page

Chapter (1)

Introduction

1.1) General Aspects of Hierarchical Systems

In any organization, whether of economic, biological or managerial nature, one can identify the hierarchy of decision problems and goals which vary with complexity. For example, problems at the base of the structure are fairly simple though numerous. Each of these problems can be solved subject to some decision rules which have been taken by other higher problems [1]-[5]. This model of parametrized subproblems repeats itself over many levels within the organization. A group of decision problems that perform similar kinds of activities is said to constitute a level in the structure. At the top of the whole structure there is one decision problem upon which the overall objective of the system depends. In this sense, a multilevel system is a hierachy of goal - seeking subsystems or decision problems.

The basic features of multilevel systems may be divided into three major groups :

i) information is only permitted to flow vertically between any two adjacent levels through the hierarchical structure of subsystems.

ii) various subsystems are interacting through their models, objectives and constraints.

iii) the overall objectives of a multilevel system, have to be satisfied. This implies that the response of the infimals (Lower level subsystems) to the interaction parameters is evaluated by the supremal units (higher level subsystems) against the prescribed objectives. Based on the resulting inbalance, the supremal units supply the local units with alternative forms of the interventions, and the process is repeated until the desired objectives are satisfied [1]-[8].

1.2) Decomposition and Coordination

The successful operation of multilevel system is best described via two basic processes, decomposition or infimals generation and coordination or overall objective synthesis. [1], [2].

1.2.1) Decomposition

In decomposition, the integrated control problem should be converted into a family of control subproblems. In this respect, one can classify three distinct ways of the decomposition procedure.

1) Decomposition based on the system structure: by partitioning the system into subsystems due to their physical behavior or operational phases. Control system problems are typical examples. [1]

2) Decomposition based on the amount of influence: This implies the arrangement of subsystems in several levels with upper levels holding higher priorities than lower levels. management systems and economic models could be treated this way. [2]

3) Decomposition based on the nature of control: This refers to the adoption of different methodologies to control the system under consideration. Interconnected power systems are perfect models for such a decomposition. [1]

1.2.2) Coordination

As a result of the decomposition process, whether natural or conceptual, a family of uncoupled subsystems is generated along with their coupling relations. Obviously the independent subsolutions would not result in the overall solution due to the interaction between subsystems. In this respect, one can define coordination as the task of the supremal control system in which it attempts to cause harmonious functioning of the infimal control systems. The success of the supremal in its task of coordination is judged relative to a given overall goal. Since the infimal contorl systems operate so as to achieve their own individual goals, a conflict generaly develops among them and results in a prescribed overall goal most likely not being achieved. The task of coordination is precisely aimed to reduce this conflict, if not to eliminate it all together. The intervention parameters through which the supremal influences the local units are termed coordination parameters. Figure (1-1) is a schematic diagram of the decomposition and coordination in multilevel systems.

1.3) Thesis Objectives

The objectives of this thesis is to study different types of hierarchical structures and its associated multilevel optimization techniques, in order to investigate the merits of these techniques. Two new three level techniques are introduced and an example is solved to show the differences.

The distillation column is considered as an example of industrial unit whereby the three level technique is employed to determine the control variables.

1.4) Outline of the thesis

The thesis is divided into five chapters. Chapter 1 serves as an introduction of the hierarchical systems.

In chapter 2, multilevel optimization techniques are presented. Two level and three level techniques are investigated. A numerical example is included for illustration.

Chapter 3, deals with the trajectory decomposition approach. A multilevel algorithm is developed to solve singular optimal control problems. An Epsilon technique using Riccati equation is also presented. A comparison between these two algorithms is made using a numerical example.

In chapter 4, the distillation column is considered as an example of industrial process. Three level technique is then employed to determine the control strategy of the column.

Finally, chapter 5 serves as a concluding part