CHAPTER 2

BACKGROUND CONCEPTS

2.1 INTRODUCTION

This chapter provides a background of the various methodologies and tools that are used in this research work. An overview of the aspects and salient features of symbolic computation, the features of the existing control structure of the superheated heated steam temperature control process of Mettur Thermal Power Station, Mettur (MTPS) is given.

2.2 SYMBOLIC COMPUTATION

Recently, symbolic computation has generated considerable interest in the area of advanced control and engineering applications. The driving force for this interest is the potential for solving complex problems that were hitherto impossible or difficult to undertake. The analysis and design of control systems for multivariable process described by polynomial arrays were practically nonexistent before the advent of symbolic computation. Manipulation of polynomial arrays by hand calculations is very complex and not amenable to computer implementation. The numerical methods developed to perform the necessary manipulations are computationally intensive and often suffer from numerical instability and imprecision. Plotting response graphs of the systems as functions of plant parameters to examine their mutual dependence requires multiple graphs and their interpretation. The assessment of the sensitivity of such relationships is hidden by numerical values.
Another major problem arising in many scientific and engineering studies is the problem of accuracy in computation. While most natural subroutine libraries on linear algebra produce results with no large errors, there are numerous occasions where large errors or failures can occur due to the numerical sensitivity of the data concerned.

Symbolic algebra languages handle functional numerical forms with infinite precision. Working with symbols and rational numbers can produce cancellation and simplification of sub-expressions more readily, giving enhanced accuracy, performance and code simplification.

2.2.1 Symbolic packages

The increasing popularity of symbolic computation has led to the development of new user friendly application software packages containing a number of built in functions and routines for symbolic manipulation of polynomials and matrices. A brief account of some of the packages that have been extensively used is presented in this section.

2.2.1.1 MACSYMA

MACSYMA is a powerful tool for performing symbolic computations. It is a large LISP program that can manipulate algebraic expressions involving constants, variables and functions. Functions are available for differentiation, integration, solving simultaneous equations, polynomial factorization and expansion of functions in power or Poisson series, curve plotting and for performing various mathematical operations. It operates both in an interactive mode and as a programming language. Application of symbolic packages to manipulate and simplify polynomials and rational matrices can be easily done using MACSYMA. CONDENS
package of MACSYMA is designed for the analysis and synthesis of nonlinear control systems.

### 2.2.1.2 MATHEMATICA

The Mathematica control engineering toolbox was closely modeled on the equivalent MATLAB toolbox. At the time of development, Mathematica offered better facilities than MATLAB but in more recent versions the balance has been restored. Mathematica has many useful plotting capabilities that include Polar plots, Nyquist diagrams, Bode Plots and Nichols Charts. It has an impressive hypertext interface, which allows mixing of text and graphics, for input and output. The packages of the toolbox are stored as notebooks. These incorporate standard examples for the user to execute, together with preprocessed graphical results. Design packages written using Mathematica can be used to provide common control system analysis effectively.

### 2.2.1.3 MAPLE-V

Maple-V is a computer algebra system developed for the manipulation and of complex mathematical expressions. It provides a well-developed linear algebra package containing the basic tools for performing symbolic and numeric computation, mathematical programming and visualization. T Tedious, repetitive and complex calculations that are quite common in process control application have been done much more easily using Maple-V.
2.2.1.4 Matlab symbolic math toolbox

The Matlab symbolic math toolbox incorporates symbolic computation in Matlab’s numeric environment. The extended Math Toolbox augments this functionality to include access to all non-graphics Maple packages, Maple programming features and user defined procedures. The symbolic math toolbox overloads many of Matlab numeric functions by providing symbolic-specific implementations of the functions, using the same function name. It defines a new Matlab data type called a symbolic object or ‘Sym’. Internally a symbolic object is a data structure that stores a data string representation of the symbol. This toolbox uses symbolic objects to represent symbolic variables, expressions and matrices. It supplements Matlab’s numeric and graphical facilities with several other types of mathematical computation like calculus, linear algebra, simplification, solution of equations, variable precision arithmetic, transforms and special mathematical functions.

The symbolic computations, utilized in the various schemes reported in this thesis, were carried out in Matlab’s symbolic environment.

2.3 SUPER HEATED STEAM TEMPERATURE CONTROL PROCESS

A brief account of the existing structure of the superheated steam temperature control process of Mettur Thermal Power Plant, Mettur, India, that has been taken up as case study in this thesis is presented in this section. The steam cycle in a thermal power plant commences from the boiler drum, where saturated steam is generated. The steam from the boiler drum passes through a number of stages of super heater where it acquires the desired degree of superheat. The superheated steam flows through right and left tubes
of the boiler and enters the high-pressure casing of the turbine where it expands giving a part of energy as mechanical energy.

The parameter to be controlled in the steam cycle is the steam temperature at the outlet of the final stage of the super heater. It has to be maintained within the permissible limits. A low temperature at the super heater outlet will cause the formation of water drops within the turbine causing erosion of the turbine blades. A higher temperature will drastically reduce the life of boiler tubes. Hence it is essential to closely monitor and control the superheated steam temperature and maintain it within narrow limits of the set point value of 540\(^\circ\)C.

Spraying water into the steam at a controlled rate controls the superheated steam temperature. The latent heat absorbed by injected water, while evaporating to steam, effectively controls the steam temperature. The spray water is injected to the steam line ahead of the final stage in the super heater. This has been done to ensure complete vaporization of the spray water before reaching the turbine.

Another factor, which affects the heat input to the final super heater, is the angle of tilt of the burner block. This determines the elevation of the fireball in the boiler and hence the distribution of heat absorption by various heat exchangers. The elevation of the fireball position angle in the boiler is varied from +30\(^\circ\) (100\%) to -30\(^\circ\) (0\%). The angle of +30\(^\circ\) corresponds to maximum radiation and an angle of -30\(^\circ\) to minimum radiation.

The control scheme for superheated steam temperature control process is shown in Figure 2.1. Two temperature sensors measure steam temperature on left side of the final super heater outlet. The discrepancy
monitoring circuit and facility for selecting healthy sensor is also included in the system. Measured temperature signal is compared with the set point temperature of 540°C. The controller output is summed up with the feed forward steam flow and burner tilt signal to obtain the desired value of the de-super heater outlet temperature.

![Figure 2.1 Control scheme for superheated steam temperature control process](image)

The significant time delay and changing process dynamics as a function of turbine load adds to the enormous difficulty in the above control process.

Measurements were made on the process variables and the data set obtained has been utilized for the schemes reported in this thesis.
2.4 SUMMARY

In this chapter an overview of symbolic computation along with the commonly available packages and the existing structure of the steam temperature control process of MTPS, is presented.