OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

RESTRICTED

16421

DP/ID/SER.A/862
3 July 1987
English

MICROPROCESSOR APPLICATION ENGINEERING PROGRAMME

DP/IND/84/030

INDIA

Technical report: Automation in chemical industries*

Prepared for the Government of India
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of D. Popovic, expert in automation and control

Backstopping officer: V. Smirnov, Engineering Industries Branch

United Nations Industrial Development Organization
Vienna

* This document has been prepared without formal editing.

V.87 87191

Table of Contents

1. Summary

As per Job Description, formulated in 2. here, the Expert has

- visited the Thal Unit of Rashtriya Chemicals and Fertilizers Ltd., Bombay;
- informed himself about the running Project activities in the area of microcomputer application to industrial process control;
- discussed the problems to be solved within the ammonia production plant of Rashtriya at Thal, Bombay;
- delivered a compact course in modern methods of model building, system identification, parameter estimation and optimal process control as needed for the company staff (s. Appendix A. here).
- discussed the process control strategy to be used for amonia plant automation as well as the steps to be undertaken for the practic l realization of such a strategy;
- planned the next activities in the areas mentioned above.

2. Objectives of the Mission

The following items are subject of the Job Description DP/IND/84/030/11-03 of the Expert:

- advising the use of modern automation and control methods in industrial control;
- review of progress in design and development of process control computer application and suggestion of means for its improvements;
- suggestion of appropriate approaches for practical implementation of running promotional activities;
- lecturing in modern methods of microprocessor-based process control related to the specific industrial branches.

3. Activities of the Expert During his Mission

The main activities of the Expert can be summarized as follows:

- visiting the ammonia production plant of Rashtriya at thal and review of conventional and the modern, computer-based plant instrumentation;
- discussions with the plant engineers about the future intentions of the company in the direction of optimal plant control;
- review of the state-of-the art in the area of special hardware and software for optimal plant control;
- review of past theoretical work of control engineers and the computer specialists in the area of model building of plant as well as in the area of partial plart simulation;
- lecturing for the company staff and the Project Centre Staff from New Delhi (approximately 35 participants) in the areas needed for further automation work within the company;
- final discussions with the Project Staff about the further actions to be taken within the Project in order to enhance the microcomputer application for process control;
- planning of possible future courses, training of Project Staff abroad, visits of the Expert, information exchange modes, etc.
- discussions concerning the urgent necessity to prolongue the duration time and to increase the UNIDO input to the Appropriate Auromation Promotion Programme.

4. Findings of the Expert

The ammonia production plant at Thal, Bombay is a two streams production unit which rated capacity is 1350 tpd of ammonia and 1700 tpd of CO_2.The plant was designed and delivered by M/S Haldor Topsoe A/S, Denmark, and has the typical reaction stages which mathematical models are interesting and technically promissing for computer-based optimal process control:

- feed gas disulphurication and reforming
- CO conversion with CO_2 removal
- synthesis gas compression
- ammonia synthesis.

Near the ammonia plant just described, there are also three streams of urea plant, each stream having the rated capacity of 1500 tpd.The two production plants are coupled to each other via the CO_2 stream comming from the ammonia plant and fed into the urea plant.

The plants are equiped modern Digital Control Systems for process monitoring, data logging, graphics generation, process parameter calculation and display, as well as for historic data storage and partially for Direct Digital Control.

Rashtriya Chemicals and Fertilizers Limited has in the mean time a skilfull team of young plant and control engineers and of computer specialists.Within the company, thus, a solid background knowledge and a many years know-how is available in chemical, control and the computer engineering.This has proven during the lecturing to be very useful for an expedient further education in modern areas of control and systems engineering.For instance, inspite of a rathes speedy lecturing in parameter estimation methods, there have been no problems concerning the theoretical pre-requisites of the participants.Also the optimal process control algorithms to be programmed have been understood within a relatively short time.

Especially useful seems to be the know-how available in the area of chemical and physical plant description.Here, the interrelations between the individual process variables seems to be relatively clear, so that the writing of material and energy balances is also not difficult.This is, however, the most important part of work in deriving the mathematical model of the plant.

In a series of round-table discussions and in the direct talks with the company staff the readiness of the young people was identified to seriously work on system engineering problems which should bring the benefit to the company through a better plant control.

Beside this facts, the Digital Control Systems already installed in the plant can directly be utilized for plant data collection and for plant parameter estimation, for process simulation etc. This is essential during the derivation and the validation of mathematical model of the plant.

The necessary steps to be undertaken in the near future would thus be to build a work-team of the specialists, both of company and the Project staff which will work, step by step, on mathematical description of the plant starting with the output production stage(synthesis).Here, the expert can provide the team with the necessary literature on model building of individual parts of the ammonia production plant and consult them when necessary.

It is, finally the impression of the Expert, that also the management of the plant as well as the responsible persons of Rashtriya itself are ready to support the actions undertaken by the Project Staff in New Delhi, so that in the oppinion of the Expert also UNIDO should in the future support these actions.

5. Summary of Findings

Ammonia production plant of RCFL at Thal is a well-selected object for microcomputer application in model building and optimal process control, this at least from the following reasons:

- mathematical model building of ammonia plants, e.g. the derivation of static and kinetic model of gas reformer, CO shift unit, compressor stage and the synthesis part of reactor is a relatively well-solved problem in systems engineering;
- the problem of optimal control, e.g. the choise of relevant optimality criteria for the process at each of its stages is also very well defined in the engineering;
- there is a sound knowledge available with the company concerning the mathematical plant description;
- the plant itself is a very well equiped one as regard the conventional as well as the modern, computer-based control instrumentation;
- there is the readiness of the company staff and the company management to further work in the direction of the mathematical model building of the plant and the optimal plant control;
- there is also an outstanding interest of Project Centre in New Delhi to support and to finally carry out the activities that will contribute to the application of a modell-based computer system for optimal control of ammonia plant at Thal;
- the results, achieved during the automation of the ammonia plant can easily be transferred to other indian production plants in the basic industry;
- it is also to be expected, that the experience and the technical know-how gained during the project work is in an adequate way transferrable to similar automation problems within the both Projects (AAPP and MAEP)
- from these reasons the Expert recommends the following.

6. Summary of Recommendations

6.1 The activities in model building, parameter estimation, system simulation and optimal control of the ammonia plant in Thal, Bombay, should be promoted through the UNIDO Projects.This promotion has already been recommended by the Expert in his Technical Reports 1986(DP/IND/82/034) and 1987(DP/IND/84/030 and DP/IND/82/034).

6.2 The attempt should be made to generalize the results of the project work in Thal and apply them for the solution of similar problems in the petrochemical, cement, pulp and paper as well as in some other industries.

6.3 National Project Co-ordinator should try to install a large-scale Project for optimal process control in the chemical industry, similar to INCOS-Project.

6.4 Also in other Project Centres intensive, compact courses should be organized in modern methods of control and systems theory for engineers with a solid backgroun knowledge like the engineers in New Delhi(from the iron and steel industry) and thal have been.

6.5 The Project Centre in Delhi should intensify the efforts in collecting and completing the publications in the area of methods for model building and optimal process control.

6.6 At least 2 engineers from Rashtriya and 2 from Project Centre in Delhi should be sent for training abroad.The training should include the work on mathematical modelling and should last longer than 3 months.

6.7 Program packages for system simulation, parameter estimation and optimal process control should be purchasses and used during the Project work in Thal.

6.8 UNIDO should speed up the decision process concerning the further inputs to Appropriate Automation Promotion Programme as applied for by the National Project Co-ordinator.

APPENDIX A:

Modelbuilding of Industrial Processes

1. Introduction: Motivation and Basic Terms

- What is the mathematical model of a plant
- Why do we need model building
- How the plant model is integrated into the modern computer-based plant control system
- What are the prerequisite for a successfull model building
  - engineering knowledge
  - plant instrumentation
  - measurement data
  - systems identification and parameter estimation methods

2. Classification of Systems, Models and Methods

- systems classification: linear, nonlinear, lumped and distributed parameters, continuous, sampled, deterministic, stochastic.
- model classification: physical, mathematical, static, dynamic, linearized, adaptive, reference, predictive
- classification of parameter estimation methods

3. Model Building Procedures

- Theoretical analysis of the system: balance-equations for flow, energy; transport equations for mass and heat transfer; heat exchanging processes (conduction and radiation); reaction dynamics (endotherm and exotherm).
- chemical reactor: geometry (tubular, stirred-tank and mixing reactor), boundary conditions, initial values, input,output, internal and control variables, parameters.

4. Systems Identification Procedures

- Design of identification experiment (building of (input, output or generalized) error equation, choise of test signal, sampling rate, total sampling time, performance index, noise-suppression and parameter estimation method)
- Model verification, validitation and improvement.

5. Parameter Estimation Methods

Least-squares Methods (problem formulation, derivation of sampled parametric model, error equation, penalty function, minimization method, best estimate-recursive-version, weighted version, software implementation aspects: initialization, convergence, etc.).

6. Model-Based Process Control

Advanced Process Control Techniques (static and dynamic optimal control (set- point control), direct digital and self-tuning control, adaptive control, state-feedback and feed-forward control, multilevel control), some examples: optimal winding of strip, optimal reheating of slabs, etc. .

7. Case Study 1 : Chemical Industry

Model-Based Control of a Batch Polymerization Reactor (building of dynamic process model, initial, end and boundary conditions, model simplification, optimal conditions, stability problems, selft-tuning and adaptive control).

8. Case Study 2: Fertilizer Industry

Computer-Oriented Control of an Ammonium Synthesis Plant (plant description, mass balance of primary and secondary reformer, CO-converter, purificator, multistage compressor and synthesis reactors, formulation of objectives, derivation of control equations, evaluation of results).