

Conclusions

In the following paragraphs, the main aspects of the present thesis contribution are considered.

The state of the art in the area of FD, one of the most important aspects of process engineering, has been summarised. Methods of FD have been classified in three groups: historical based, knowledge based and combinations of both. Advantages and disadvantages of each method have been highlighted, arriving to the conclusion that the use of a wise combination where methods are adapted to each other in order to enhance the strengths and to reduce the drawbacks is the best solution. This right choice also seems to be better than a hybrid framework, where methods are integrated to perform collective problem solving, because of the difficulties involved in the implementation of the individual methodologies. A detailed survey of FD methods for batch chemical plants have been carried out. They are quite few being the main problem the complex strategy of implementation required that delays their application in real industrial plants. The information provided by the FDS in a batch plant environment should contemplate its use at different levels in the decision-making hierarchy structure, including the advanced control system and the scheduling system.

A main contribution of this thesis deals with the development of a FDS consisting in a combination of a pattern recognition approach based on an ANN and an inference system based on fuzzy logic. Therefore, the background on those important techniques (ANNs and FLSs) has been reviewed. The basic concepts about HAZOP analysis and signal pre-processing using wavelets has been also summarised. Such techniques have been used in the design and implementation of the proposed FDS.

After presenting the structure of the proposed FDS, the steps for its successful development and on-line implementation have been described. The information needed to develop the FDS includes historical data, a HAZOP analysis and a plant model. With historical data of past faults the pattern recognition approach (based on an ANN) can be developed. From HAZOP analysis, part of the set of if-then rules of the FLS are defined. This set is then complemented with those coming from the experience with the use of the ANN. The plant model is useful to generate patterns of faults that have never occurred in the past, to acquire experience with the use of the ANN and to test the FDS. An important aspect for the successful implementation of the FDS is the feature extraction for the generation of the patterns used in the ANN training.

In order to optimise the parameters of the components of the FDS, a performance index has been proposed. It has an analogous form for batch and continuous processes. This performance index takes into account the time required for correct diagnosis in relation to the time needed to arrive to new steady state conditions in a continuous plant or to the following stage in a batch process. The index also allows to compare the results obtained with different FD methods.

The selection of the type of ANN is not a critical aspect for the success of the proposed FDS. However, along the applications some special types have been preferred. A PNN has been used to classify fault patterns given by features. A RBFN has been preferred for the classification of fault patterns given by the profiles of the variables. However, when the amount of the data training is very large, a RBFN is difficult to train and a BPN has been preferred. The special case of fault in sensors is solved with the use of AANN and a proposed algorithm has been added to improve its performance when diagnosing large bias errors in sensors.

The proposed FDS is the fruit of successive improvements by working with different kinds of case studies: academic scenarios, pilot plant and industrial cases. Academic scenarios correspond to test-bed problems published in the literature and include a continuous case and a batch process. Pilot plant scenarios consist of chemical plants located at UPC. The first one corresponds to a fluidised bed coal gasifier that has been operating for several years and historical data are available. The second one is a fed-batch reactor and a validated model is available. The third pilot plant scenario has been a multipurpose batch chemical plant by means of a simulation model. Finally, the industrial scenarios correspond to two sugar cane plants and a petrochemical plant. The variety of case studies allowed to generalise the implementation of the proposed FDS. Different aspects of the methodology presented have been illustrated by the

described case studies. In each scenario, a special aspect of the methodology has been highlighted and shown in detail.

The use of a wise combination of an ANN and a FLS has shown to be advantageous with respect to a ANN or an inference system working alone. The advantages correspond to the speed of fault diagnosis, the non existence of false diagnosis and correct multiple fault diagnosis. The complex cases considered, a continuous plant with recycle and a batch process, allow to demonstrate the powerful capabilities of the proposed FDS. The use of the ANN either by signal pre-processing or by using the variables profiles directly have been shown. The selection and optimisation of the ANN and FLS have been also illustrated. The proposed FDS has been also compared against a currently accepted statistical technique for batch process monitoring (on line MPCA). A higher performance with the proposed FDS has been observed because it is superior in relationship with its capability for isolating faults.

The implementation of the FDS in pilot plant scenarios has allowed to verify the good results of the proposed FDS. Real data, in the case of the fluidised bed coal gasifier, characterised by noise, have allowed to show that the proposed FDS has the advantages of faster fault detection and better fault isolation capability over statistical techniques. On the other hand, the use of batch plant scenarios at pilot plant scale permits to illustrate the implementation of the FDS in such complex operation mode. The FDS signals can be used by the scheduling system to update the schedule in the most effective way, by the control system in order to take automated control actions and by the operators, as a support for decision-making. The basis of the "translation" of the FDS's outputs has been defined. The implementation strategy, based on the HAZOP analysis, has been successfully illustrated in the multipurpose batch plant case study.

The implementation of the proposed FDS has been shown in three industrial cases. Each case differs in the availability of the sources of information. The flexibility of the proposed FDS has allowed to obtain successful results in all the cases. Having or not historical data or a plant model, having or not on-line measurements, the FDS can be adapted or implemented partially. A checklist for the operators has also been proposed in order to improve system performance by successive updating. Furthermore, the proposed FDS has shown to be flexible enough to handle the lack of information, an usual limitation in real industrial plants.

It has also been emphasised that the developed technology can take advantage of existing software packages that are familiar to plant engineers. These promising results gives to the presented technology a perspective of growth.

Perspectives

In the present thesis, the development of a FDS implemented on the basis of information sources available in current chemical plants (historical data, HAZOP analysis and a plant model) has been introduced. Also, the basis for the utilisation of the information sent by the FDS to other levels of decision-making, as the scheduling and the control system, has been presented. Such integration to the abnormal situation management system implies the development of the alarm handling system.

The mentioned alarm handling system should be considered in more detail by different tests in different case studies. The same case studies presented in this thesis can be used. By this way, the alarm handling system should be generalised. The industrial cases are available (the petrochemical plant simulated with HYSYS.Plant, historical data and HAZOP analysis for the sugar cane refineries). The multipurpose batch chemical plant (called PROCEL at UPC) has been simulated also in HYSYS.Plant. On those case studies the alarm handling technology can be developed. Commercial platforms like G2 (Gensym) could be used in order to speed-up its implementation in real industrial plants.

The standardisation of the interfaces of the FDS for real time systems is not the objective of the current scope of work of Global Computer Aided Process Engineering European project. Nevertheless, it is a potential task to be performed in the near future. Description of the information flows has been already done.