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CHARACTERISTICS OF OPERATOR, AUTOMATIC EQUIPMENT AND DESIGNER IN PLANT AUTOMATION

A LECTURE

by

JENS RASMUSSEN

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Abstract

Methods for evaluation of the influence of technical failures in plant and instrumentation on operational economy have now reached a stage where it seems appropriate to discuss whether the methods for evaluating the designer and operator are considered at the same level.

The technical reliability of a system is assessed from an evaluation of the functioning of the system under normal and abnormal conditions and a breakdown to elementary functions the reliability of which can be estimated from failure records for components and system parts obtained during operation in a great variety of applications.

To get reliable material for the evaluation of the human role in the reliability of power plants it is important to formulate the functions of the designer and operators in such a way that they too can be broken down into elementary operations which may be evaluated on the basis of operating records from very different sources (industrial plants, traffic accidents, psychological experiments).

The paper is an attempt to formulate a simple functional model of the control system comprising instrumentation and operators. The model is used to discuss the allocation of tasks to operator, instrumentation and designer.

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Characteristics of Operator, Automatic Equipment and Designer in Plant Automation

A Lecture

By Jens Rasmussen

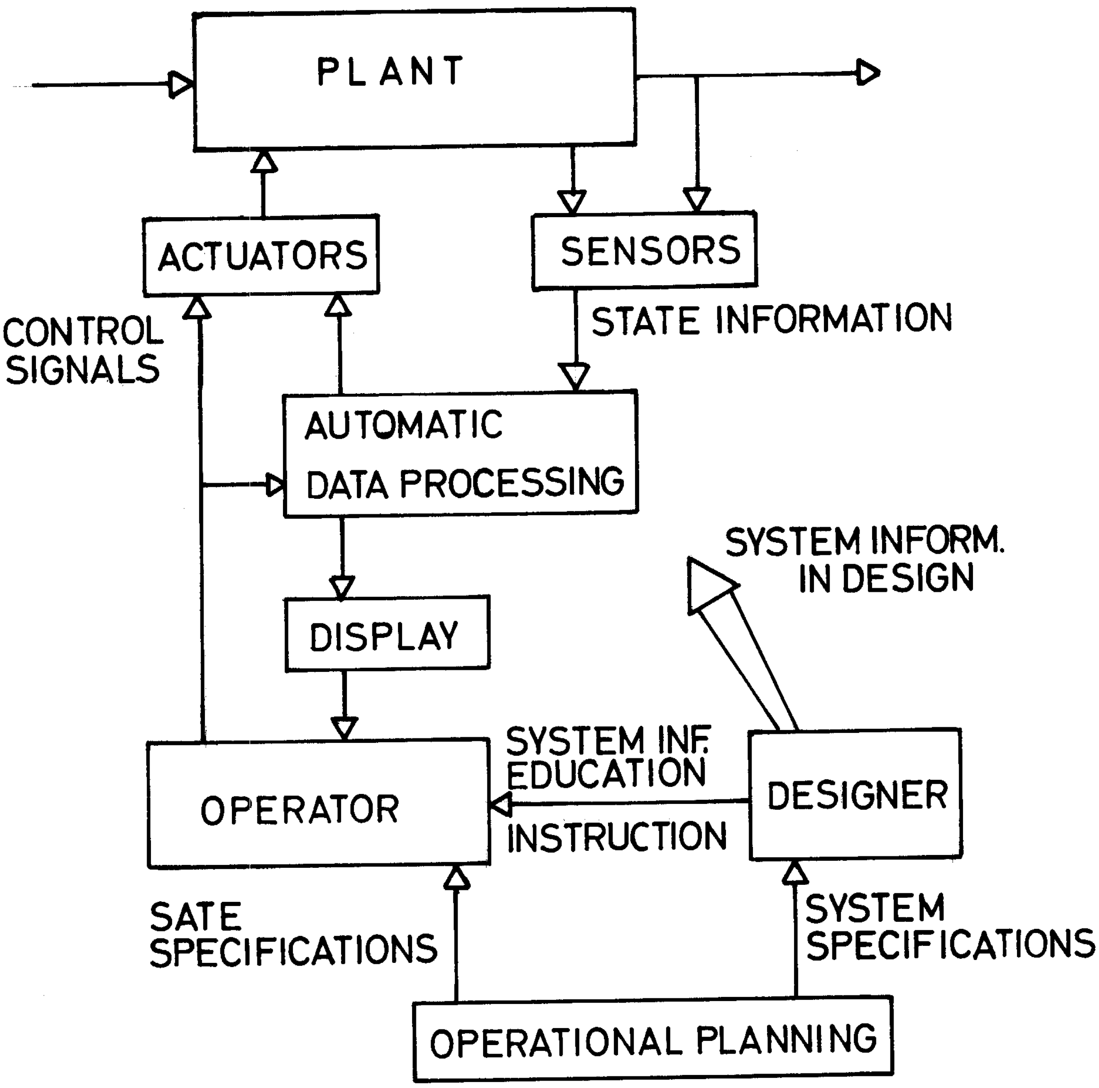
Introduction

The introduction of the digital computer to the field of process control gives rise to a rapid change of the technology used in the realization of automatic control systems. As is always the case in periods with fast technological progress, this means that the reliability of advanced systems cannot be demonstrated by experience from systems already operating, but has to be evaluated in the design phase by systematic methods of analysis.

The flexibility and capacity of the process computer, which is a mass-produced and thus a cheap and reliable piece of equipment, open very promising possibilities to the control engineer of automating very complicated functions closely related to the conditions in individual plants.

In this development the designer has to compare the reliability obtained with automatic equipment with that obtainable with human operators; here he must consider not only the abilities of the operator as known from conventional systems, but also the abilities he will have when he is supported in his task by a process computer with its capacity for providing efficient man - machine communication. Furthermore the designer has to face the fact that automation merely transfers the human task from supervision and control of the plant to supervision and testing of the automatic control system.

To find the optimal level of automation the designer therefore has to evaluate the two alternatives for the different control tasks, a human operator effectively supported by the instrumentation, and automatic equipment supervised and tested by a human operator. In both cases the human element - operator or designer - may be a major source of failure, and regardless of the level of automation the functioning of the entire system must be broken down to elementary tasks which can be related to the characteristics of automatic equipment, operator and designer., and for these tasks quantitative reliability data have to be found.



Model of control system.

The Control System

The control system of a process plant is a system in which automatic equipment and a human operator co-operate. Normally the operator is not just one,, but several persons, whose intercommunication is not considered in the present discussion, but is dealt with elsewhere.[1]

The input information to.the control system may be split into two categories: the specifications. defining the desired mode of operation, and the state .information, describing the actual conditions in the plant. From this information the control system generates the signals needed to control the plant during normal operation and in abnormal situations. This implies that the control system must be capable of a variety of transformations between input information and control signals corresponding to different operational modes. These transformations necessitate the presence in the control system of various transformation models based upon,a great amount of system information, i.e. detailed knowledge about physical, technical and economic aspects of the plant and the different possible modes of operation under normal and failure conditions.

The specifications originate from sources outside the control system. They may be general in nature, giving e.g. economic optimizing criteria, or they may be rather detailed, specifying e.g. the operational state; this will depend upon the extent to which the technical and economic planning functions are included in the model of the control system, Inadequate communication of specifications, especially of system specifications from user to designer, may be a major source of reliability problems, especially in highly automated plants, where economic consideration of abnormal operation is an important design task.

The state information is supplied to the control system by the measuring channels, and the amount of state information necessary depends largely upon the complexity of the transformation models in the control system. A large amount of redundancy in the state information during normal operation is necessary for the detection and identification of abnormal operation, and an optimal choice by the designer of state information and transformation procedures must be based upon analysis, including reliability considerations.

The system information needed for the transformations can be made available to the control system by the designer in different ways, depending upon the object of the transformation in question.

The designer may provide the control system with means of extracting and storing system information from the state information during operation by utilizing optimizing or learning procedures in operator or instrumentation. In this case the transformation model is a purely abstract or formal model, describing the relation between control signals and their response in state variables with no information of the physical properties of the plant. This mode of transformation is able to maintain or even refine the quality of transformations during operation.

Another possibility for the designer is to condense the system information into fixed sets of transformations linking patterns of state variables to the appropriate control signals.

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This transformation model will also be purely formal, but the stored system information will not be automatically maintained during operation. If the transformation model is engaged in a reversible, feedback function, the degradation of the stored system information can be detected during normal operation; if the model has a discrete, irreversible function, special testing procedures are necessary to detect degradation of equipment or operator performance.

The designer may realize a transformation model of this nature by selecting the structure and parameters of automatic equipment, e.g. conventional feedback controllers, fixed sequence control and simple automatic protection circuits, or he may train an operator to follow instructions in fixed, automatic stimulus-response reactions.

If the control system has to cope with operational conditions which the designer is unable to analyse in the design phase, and which do not leave sufficient time for the system to evaluate a proper control action, in an experimental adaptive mode,,, the control action must be based upon a large amount of detailed system information describing physical and technical Properties of the plant and control system, and upon a general method of generating in the actual case a suitable transformation model from this system information. This mode of operation today characterizes the intelligent human operator who has a fundamental understanding and knowledge of the nature and functioning of the plant.

Tasks of the Control System in different Modes of Plant Operation

The designer's choice of a method **of** storing system information in the control syster-n depends very much upon the operational tasks in question.

Normal Operation

During normal operation the control system has to generate control signals that provide for production within the limits specified for the system.

The physical nature of the plant normally calls for a control system of a multilevel structure. The lower levels are characterized by a great number of simple functions corresponding to the different subsystems of the plant,, but with a very heavy input - output data traffic in contrast to the complicated transforms with little traffic in the higher coordinating levels of the system.

The normal operation is generally accessible to analysis by the designer, who may therefore condense the system information into fixed, purely formal transformations. As the tasks during normal operation are of the nature of a reversible, feedback mode of function with ample time for experimentation, the designer may also utilize adaptive or learning features in the control system.

Abnormal conditions due to Failures

Abnormal conditions here means operating conditions that are not properly counteracted by the formal transformation model normally operating in the control system. In the advent of such situations the tasks of the control system are changed rather radically. Although the ultimate purpose is still to control the plant in an economically optimal way, the control system now has to take into account the risk of losses from damage to the plant. The immediate goal of the control system as well as its mode of operation is changed as the plant may show fast response to failures that leaves no time for closed-loop cut and try operation, and as absent or incorrect control action may have serious consequences.

The task of the control system in case of failures may be divided into separate steps. First the control system has to <u>detect the departure from normal operation.</u>, that is to uncover failures in the plant as well as in the control system itself. This may consist in the detection of abnormal state variables or of changes in system properties through abnormal plant response. The detection initiates an <u>identification</u>, not necessarily of the faulty component, but of the properties of the failing system. On the basis of the identification, the consequences of different possible counter-measures upon the plant and its operation have to be predicted and a <u>decision</u> about the optimal action must be made.

This sequence of tasks has to be simulated in detail by the designer, and the results must be stored as complicated transformation models in the control system; or he must enable the control to make the evaluations on the basis of stored basic system information.

The detection of departure from normal operation thus switches the control system from a mode of operation based upon a purely formal transformation model,, considering only average cost**,** to a mode that needs a transformation model corresponding closely to detailed physical and technological properties of the plant, considering mainly the immediate risk.

Changes of operational Conditions. Sequence Control

Changes in operational conditions may be initiated and the operation specified by sources outside the control system*.,* e.g. start - stop procedures, or by the control system, e.g. protecting actions. The control system has to generate a sequence of control signals that lead the different subsystems of the plant to other states of operation in a coordinated way. Again the control system acts as a hierarchy, the lower levels of which take care of the corresponding subsystems,, with higher coordinating levels.

Planned Abnormal Operation

Apart from periods with failures in the plant or control system, there will always be periods with operating conditions departing from those during normal production., such as initial plant operation, testing after major repairs or replacement of equipment, and testing of protective control equipment. During such periods the system operating, may not be described by the system information normally available to the control system, and during the planning of these periods special measures must be taken to remedy this by means of special equipment, procedures or education.

Allocation of Control Tasks to Operator, Instrunentation and Designer

The control system is formed by the co-operation of an instrumentation system and the hu-nan operator. Both are able to work in three different modes as discussed above: a purely formal transformation mode, adapted to past experience, a fixed formal mode based on ordered recalling of stored procedures, and a mode with transformations especially adapted to the actual operating conditions., based upon a detai.led transformation model related to the physical properties of the plant., The mode of operation to be chosen depends upon the operational conditions and the ability of the designer to analyse them in advance. To make complete automation possible, this analysis should cover not only the primary specifications, (technical as well as economic), and physical functioning, (anatomy and dynamic properties), but also possible and allowed operational modes, frequency and operational consequences of failures in plant and control system, the related patterns of state variables and counter-rqeasures, and finally the "improbable", but risky combinations of failures.

Normal_Operation

The purely formal transformations relating the control signals to patterns of state variables during normal operation may be analysed by the designer in advance, analytically or by simulation studies, and stored in the instrumentation by the choice of structure and parameters, and because of the large number of data involved and the boring nature of the task, the low levels of the control system are always automated. On account of the reversible, feedback nature of the task., the operator can perform reliably in the higher, coordinating levels of the hierarchy., and the highest level, the control of the primary specifications for the production, will always be left to the human operator. The amount of information to be presented to him by the display equipment will be Very limited. He has a need for the Presentation of accurate information to be compared with the primary specifications, preferably in digital form with engineering units, and of supplementary information indicating the response of the plant to his adjustments. This information need not be very accurate, and coding in symbolic form, e.g. computer-controlled graphic display corresponding to his formal transformation model, may be advantageous.

Abnormal Conditions during Failures

Under abnormal conditions a complicated co-operation exists between operator and instrumentation.

The detection of departure from normal operation in plant or control system implies a high degree of alertness and monitoring of a large amount of state information. The limits of normal operation can be defined by the designer in his analysis or during initial plant operation., and therefore detection will normally be fully automated. Especially the great data-handling capacity of the process computer opens the way to effective monitoring of system properties, e.g. by supervision of dynamic properties or energy and mass balances.

The identification of failing system and the decision about proper counter-measures call for a detailed evaluation of system information on plant anatomy, dynamic properties, economic consequences of possible failures, and relevant counter-measures; the evaluation should take into account failures not only in the plant, but also in the control system. To protect both plant and continuity of operation, the control system must be able to relate the corrective action to the actual conditions in an optimal way, i.e. not to make the corrections more drastic than necessary. This implies very complicated transformations, and the control system will have to include very general abilities, as represented e.g. by an operator or a digital computer., which brings with it a great variety of failure modes in the control system,, the consequences of which cannot be fully uncovered by analysis in advance. For this reason and. because of the need for fast response, protection of the plant against r.najor breakdowns has to be automated. This must be done by a safety system the reliability of which can be proved by analysis. Therefore the designer must base it upon simple classifications of the possible failures in the plant characterized by only a few state variables and upon simple and drastic actions, and he has to realize the system by technical means, with only very limited operational possibilities (failure modes).

To ensure a, high degree of operational continuity, minor failures have to be counteracted before they develop to a degree that initiates drastic actions from this safety system. This means that the control system should be able to apply countermeasures adapted to a great variety of failure modes in an optimal way, and this task may be wholly or partly automated or left to the operator.

If a failure can. be counteracted by a feedback control action that maintains operation under reasonable conditions (e. g. set-back of power) until fault finding and repair can take place,, this may be done by a control system by purely formal transformations without detailed identification of failure conditions. Such action may be effected if abnormal state variables initiate a shift in feedback loop references or acts as a constraint on optimizing or learning control systems. This mode of correction does not imply system information in the control system that cannot be extracted from the system in an experimental mode; therefore the actions need not be analysed in detail by the designer.

It is different in cases of failure that call for irreversible., open-loop correction. Here the control system has to go through the stens of identification., evaluation and decision, and thus needs very detailed system information, which is not maintained during normal operation and is therefore apt to degenerate. The ability of the process computer to store large amounts of data and complicated procedures invites automation of the task although it leaves the designer with the need for very complicated analyses.

The identification of failure modes resulting from the designer's analysis could then be stored in a pattern recognition procedure working on large number of state variables and resulting in the initiation of a correcting sequence according to the designer's evaluation and decision.

The designer may choose to base the protection of plant operation on human operators for two reasons. He may not be able to analyse the failure modes of the entire system to a degree that permits economically optimal protection; in this case he wants the assistance of an operator,, who stores the necessary system information as a physical understanding of plant and instrumentation properties. Or he may find it advantageous to utilize motor-skills in the operator; in this case he may store in the operator the requisite system information in condensed form as instructions controlling automatic stimulus-response action.

Quite often situations occur in which, formally, the operator is supposed to act automatically in the stimulus-response mode in accordance with instructions., but where the real function will be intelligent evaluation, and instructions therefore only act as task specifications. This mixture is highly unreliable because of the different kinds of system information needed in the two modes, and if intelligent operation is expected, this has to be formally accepted and the system designed accordingly to support the operator.

If Protection of continuity of operation is based upon intelligent actions by the operator, the designer must face the fact that detailed system information imparted to the operator during education is likely to degenerate, and that he will have a pronounced tendency to adapt himself to automatic stimulus-response actions in failure situations he has experienced a number of times (e. g. instrument failure). This will influence his response when the pattern related to frequent events is part of a more complicated and risky situation. The problem of the designer is to support the operator in a way that facilitates the shift needed in his transformation mode upon the detection of abnormal conditions.

This support may be given by an effective coding of the state information presented to the operator or by storing system information resulting from the designer's analysis in the instrumentation in a way that makes it accessible in the actual situation.

The identification and evaluation calls for a great amount of detailed state information, and the problem is to present this in such a way as to limit the number of data presented to the relevant information, but also to present it in such a way as to force the operator to consider all relevant data.

In conventional instrumentation., where state information is displayed by a continous presentation of all measured data on individual meters,, the operator himself selects data and chooses certain patterns corresponding to different subsystems or situations, and the designer can in a simple way assist in this adaptation by the grouping of meters.

In a more advanced system, e. g. a computer-controlled display, the designer can in advance define sets of state information related to characteristic subsystems, operational conditions and control tasks. The presentation of the relevant set in the situation concerned may be initiated by a rather coarse identification, carried out by the operator or automatically by the failure detecting routine (alarm analysis).

Only in the few cases where the operator has to compare state information with mentally stored. specifications (e. g. radiation levels) does he need accurate data, which may appropriately be presented as digital data. By far the most important part of the identification and evaluation will be intercomparison of data to evaluate their relations, for which analogue presentation in some form of graphs or figures is most effective. Equipment suited to this has been developed to a large extent for computer-aided design. This kind of data presentation corresponds to the use by the operator of conventional displays, where he percieves the meter indications as patterns and only decodes by reading when he needs accurate data. The widely used line printers and. typewriters in today's computer installations may be seen as a relict from the administrative use of computers.

Computer-controlled graphic displays allow the coding of a large amount of state information in a way that matches the mental transformation model of the operator and makes possible an effective utilization **of** the operator's input capacity and a minimization of time and effort needed for decoding. In the identification and. evaluation, the operator's transformations should be based upon a physical model to which the graphic displays must be related(schematic diagrams from manuals?) whereas the graphic displays during normal operation may reflect his stimulus-response mode of operation and thus be purely symbolic. A change of graphic display mode on the detection of failures may support the necessary change in the goal and mode of the operation.

When the operator has formed a hypothesis of the identity of the faulty system he may need. supplementary information to test it, that is accessible detailed state information in the form of accurate data or trends. This may be effected, e. g. with a light pen working on the graphic displays.

Efficient coding of state information in proper sets corresponding to different subsystems, operational conditions and control tasks should increase the probability of the operator using a great amount of relevant information as the basis of his first hypothesis. This will counteract his tendency to be stressed if he has to change his hypothesis several times, and his tendency to limit his attention to only a few parameters in stressed situations.

Apart from effective coding of state information., the storage capacity of the digital computer gives the designer the possibility of storing system information and supplying it to the operator when needed. If evaluations by the operator are wanted because of a limited ability of the designer to give a reliable analysis covering all abnormal conditions, the designer should not store system information resulting from his simplified analysis as procedures and data ending up with a suggestion to the operator of possible causes of failures; this would enhance the tendency of the operator to choose the probable and familiar explanations more readily than those related to risky conditions. In a well-designed plant risky failures are improbable and therefore not likely to be included in the designer's suggestions. As the operator's treatment of the state information presented will be highly influenced by his expectations, he should not be placed in a situation where he has to test a proposed but probably wrong hypothesis, but rather in an open situation where he is supported by the designer by the presentation of system information that limits his field of attention in a reliable way. This may be done by automatic procedures investigating only the most probable and trivial failures, which may be treated reliably in analysis. In case of more complicated failures the instrumentation would then be able to exclude as sources the most common failures which will first come to the operators mind, and by indication of this enable the operator to devote time and effort to more realistic and important hypothesis.

The designer may want the assistance of the operator even in failure situations he is able to analyses because he can effectively use the great variety of motor skills present in the operator to carry out the correcting actions. This is the case when automatic equipment and the related testing and maintenance are inferior to human operation with respect to cost and reliability. Where that is so, he may support the operator by storing the instructions in the computer, and initiating the presentation of these instructions to the operator by an automatic identification procedure, or he may support the operator by automatic interlock procedures.

To gain reliable operator function it is necessary clearly to define in which tasks the automatic stimulus response to instructions is expected, and in which the operator is supposed to make intelligent evaluations. The system information stored and the coding of the presented information used should be carefully planned accordingly.

This is not always the case in conventional systems where warning or alarm signals to the operator calling for minor routine control actions are mingled with signals that may indicate the advent of serious trouble.

Changes in Operational Conditions. Sequence Control

A complicated sequence of control actions will be necessary in routine operations, e. g. start-up, and in abnormal situations caused by failures. As is the case during normal operation, the control task will be a hierarchical one the lowest level of which may be grouped in fairly separate tasks related to the different subsystems **of** the **plant,** and which implies a lively data traffic and is therefore normally automated. The higher, coordinating levels may be automated or left to the operator.

Routine sequences, such as start-up, may be analysed by the designer and stored in the instrumentation. Frequent start-stop operations may be automated to provide a tightly controlled function leading to better economy and less wear than manual operation. In a plant exposed to infrequent start sequences, automation may be advantageous as the operator may not maintain proper training. However, plants with infrequent starts may not have "routine start" operations as the only shut-downs may be those due to maintenance and repairs; in such plants restart asks for special planning and procedures.

The plant subject to abnormal start operations or correcting sequences after failure detection may not be easily defined in the design phase, and optimal automation may thus not be realized. The operator may therefore be left with a sequence task the individual steps of which may be routine operations based upon formal transformations, or operations that implies careful evaluation depending upon the actual conditions of the system. This switching to a special mode of operation in single steps of a sequence the rest of which is routine may be endangered by the tendency of the operator to lean on his past experience., and should be supported by a suitable way of presenting information to the operator.

<u>Abnormal, but Planned Operation</u>

Analysis may show that normal operation and sequence control as well as high-level safety actions and lower level protection of operation can be automated to advantage, but even so human operator problems remain.

All plants will be exposed to periods with operational conditions not considered by the designer and under which the control and safety systems may therefore not be operating reliably.

Such periods may occur during initial plant operation, start-up and operation following upon major repairs., modifications of equipment, and. changes in operational policy. This makes it necessary that the designer clearly defines the operation conditions covered by the automatic system. Even automatic plants must therefore incorporate effective means of communication between plant and operator and of manual intervention so that the task of the operator during such periods may be safely planned and conducted. This is the more important as the different tasks may only be required infrequently.

Furthermore all automatic functions of a discrete and irreversible nature which do not take place and are thus not tested in routine operation must be subjected to special test procedures at regular intervals if they are not to degenerate. Automation therefore only transfers the human task from control and supervision of the plant continuously during operation to testing and maintenance of the functioning of the automatic equipment. The benefit of this will be that the human operator is moved from a task in which he may be caught unawares by a badly defined situation in stressed circumstances to a task that is concentrated in time and can be clearly defined and planned. Furthermore the operator will have ample time to look up system information in drawings and manuals.

In planned abnormal periods the operator stil-.L has both clearly defined tasks that should be carried out in a prescribed way (testing), as well as open tasks needing intelligent evaluation (protection, fault finding).

In his evaluation connected with fault location his procedure will not be bound by serious considerations of risk if the plant is automatically protected, but only the probability of his hypothesis has to be considered; this gives the designer increased possibility of supporting him by appropriate displays of state and system information; even computer augmented problem solving procedures may be considered.

Reliability Data Sources

For a quantitative reliability prediction to be possible., the plant and control system and its operation have to be broken down to elementary components and tasks so generally used that reliable statistical material on failure mechanisms can be found from a variety of applications. What is needed is statistical material on elementary component faults and on minor incidents and mistakes., not on major accidents, which normally show only a low probability coincidence of elementary faults.

Stores of failure data on plant and instrumentation components are forthcoming and collection may be organized as all failing equipment will normally be repaired by a special maintenance group.

Reports on minor or elementary human failures that do not lead to incidents or accidents are not easily collected, and therefore valuable material may be obtained if recording of operator manipulations is included in systems with advanced data logging equipment.

Some quantitative information may be obtained from experiments in psychological laboratories, but this information seems mostly to be relevant for human stimulus-response tasks, whereas the tasks involving intelligent evaluation seem to be so complicated and closely related to the actual situation that results from laboratory experiments are extremely difficult to relate quantitatively to operator behaviour in a plant environment.

Thus there seems to be a need for carefully planned and conducted experiments with operators functioning tinder plant conditions or in simulated plant situations.

Other sources may be found if it is possible to break down the functioning of the operator to subtasks which are important for his r-,ode of operation in other technical installations from which statistical Yriaterial is available, such as traffic systems or experimental nuclear installations where collection of failure reports is carefully organized.

Incidents and accidents reported within the nuclear field from research reactors, hotcells and chemical plants seem to give information of human behaviour in planned experiments! periods related to periods of initial operation and modifications in industrial plants. Reports on aviation incidents and accidents may give information of the human onerator in abnormal situations where he is responsible for both detedtion, identification and decision. Finally reports on railway traffic may bring light to operators in instructed sequence tasks.

Conclusion

The control system of a power plant is characterized by two modes of operation. One is the reversible closed-loop operation, which is governed by system information in the form of a formal response model. This model may be realized by the designer by lay-out of structure and choice of parameters in automatic equipment as a result of detailed analysis or by detailed instruction of a human operator. This system can cope with operational conditions analysed by the designer. lie may also realize the response model by defining a goal for a control system, automatic (Dr human, with experimenting and learning abilities, in which case the system can also handle conditions not foreseen and analysed by the designer. In this mode the control system may effectively protect continuity of operation in cases of failure that leave time for and physical possibilities of adaptation in the system. Advanced learning or even selforganizing systems seem to open a way to the designer for automation of protection without the unrealistic task of covering failure analysis.

Another mode of operation is irreversible, open-loop control, which in all cases has to be based on detailed physical analysis of the plant. Again the designer may carry out the analysis and condense the system information into formal response models present in the control system as a structure of automatic equipment or an instructed human operator. In both cases he is left with the problem of testing the performance to avoid degeneration. In open-loop control requirements that he has not been able to analyse he has no choice; he must rely on the intelligent analysis by a human operator, who then has to work according to a detailed physical model imparted to him by general education. In all analysis - including that of the operator - of open-loop control an important thing is that the choice of action should not be based. solely upon a consideration of probability of success, but to a high degree upon evaluation of risk.

In present-day power plants as well as future highly automated systems the human operators will have these modes of operation mixed together, and to support the reliability of his operation the designer has to relate the display of state and system information very carefully to the mode of operation. Especially the shift from routine, formal model considering average cost to a detailed physical model considering immediate risk in unexpected situations should be supported.

A fair choice between automatic and manual control in failure situations requires a reliability assessment of automatic equipment, an intelligent operator and the designer's analysis.

To this end vie feel a need for theoretical and experimental studies on the operator under power plant conditions as intelligent supervisor, tester and repairman, which may enable us to break down his mode of operation to elementary operations that can be related to the way of resenting information to him in education and display, and for which reliability figures can be obtained by experiments, preferably in plant environment.

REFERENCES

1)P. Timmermanns Instruction Systems and Administrative Procedures for Nuclear Reactors. Risø-M-809, 1968

2) D. Russel Davis, Human Errors and Transport Accidents. Ergonomics, 2, 1958.

3)Jens Rasmussen., On the Communication between Operators and Instrumentation in Automatic Process Plants. Risø-M-686 (1968)