SIMULATION OF THE OPERATION OF THE COAL SUPPLY SYSTEM AT A 2000 MW GENERATING STATION

R. D. Walkley and N. D. Hutson
Central Electricity Generating Board
Operational Research
Laud House
20 Newgate Street
LONDON E. C. 1.

Abstract

The paper describes the G. P. S. S. simulation of a complex coal conveying system. This is represented by a functional flow model incorporating the design capabilities of the proposed real plant.

The flows between the several inputs and outputs are controlled by a separate process control which simulates the monitoring and decision making functions of the operators. This takes into account the present state of the system (coal supply/demand, plant breakdowns, weather conditions, etc.) plant operating policies and incorporates some measure of anticipation (coal arrivals and shortages).

The objectives of the study are to compare the effects of various coal supply patterns and plant operating policies.

1. INTRODUCTION TO THE PROBLEM

The size and complexity of the coal conveying systems at the 2000 MW generating stations at present being built and commissioned by the C. E. G. B. create new operational problems on both a local and a national scale.

A modern station of this capacity, operating at an annual load factor of about 75%, will burn well over 5 million tons of coal a year. Moreover it must be available to generate for more than 90% of the time and must hold stock to be able to generate for at least six weeks in the event of delivery failures. New forms of coal delivery, discharge and handling have had to be devised, the established methods of tippling coal from flat wagons being inadequate. The satisfactory operation of the plant at such high throughput depends on the integration of the station coal requirements, coal arrival patterns, and operating, stocking and staffing policies. New operational policies are needed to cope with the complexity of the new plant.

Some factors, such as coal availability and coal transport, are beyond the control of the local plant managers but their effect on the operation of these large stations must be determined to guide national policy. The C. E. G. B. generation and distribution system operates on a nationally integrated basis to meet at minimum cost the total demand placed on it. On a national scale it is economically important that the large modern stations have the highest possible availability. The pressure on local management is to operate as efficiently as possible to maintain the generation 'merit rating' of their particular station on the basis of "to him that hath shall be given but to him that hath not shall be taken away even that he hath".

2. THE CASE FOR SIMULATION

The complexity of the plant configuration and the number of factors that had to be taken into account in determining the system flows defeated the original attempts to solve the problems analytically.

The case for using simulation was further strengthened by the lack of knowledge about the methods of operating the new plant and thus the need to investigate several different alternative policies. Also local managers would probably find it easier to recognise a simulation model as a true model of this plant system and thus more likely to accept the results of the studies.

The choice of the simulation language was limited to digital systems that were compatible with the Board's computers. The IBM General Purpose System Simulator language was selected because its construction enabled the system to be represented in a functional form that could easily be understood by the site engineers being consulted. G.P.S.S. III was used because an IBM 7094 was readily available but the model was written with a view to later conversion to G.P.S.S. 360.

A very simple analytical model was written to compare with a simulation run in which no disturbances were introduced and all coal supplies arrived on schedule.

3. SIMULATION STUDY

The primary purpose of the simulation is to predict the performance of the overall coal plant system and the response to major breakdowns and different methods of operation. It was used to test the effect, on the short term response of the system, of disturbances and changes in methods of operation when operating under specified input/output conditions. It was not used to predict system states at specific times since it was recognised that the future state of the system was highly dependent on unpredictable variations in input and output data.

It was necessary for reasons of size to limit the boundaries of the study to the station site. External factors influencing coal supply and rail transport (weather, strikes, etc.) could not be taken into account.

However, coal supply arrivals may be varied by influences arising from within the plant system and care was taken to ensure that the relationship between these inputs was compatible with the known laws of the external system.

3.1 SYSTEM DESCRIPTION

At this stage it would probably be helpful to give a simple description of the coal plant system. This is accompanied by a schematic diagram, Figure 1.

The track layout for the permanently coupled rapid discharge trains forms a loop which splits into a twin track section for some distance either side of the discharge hopper. Off this are additional rail sidings for the standing, shunting, tippler discharge and exchange of flat wagons.

There is one discharge hopper (capacity 1,300 tons) for the rapid discharge trains, serving both

SCHEMATIC DIAGRAM COAL PLANT

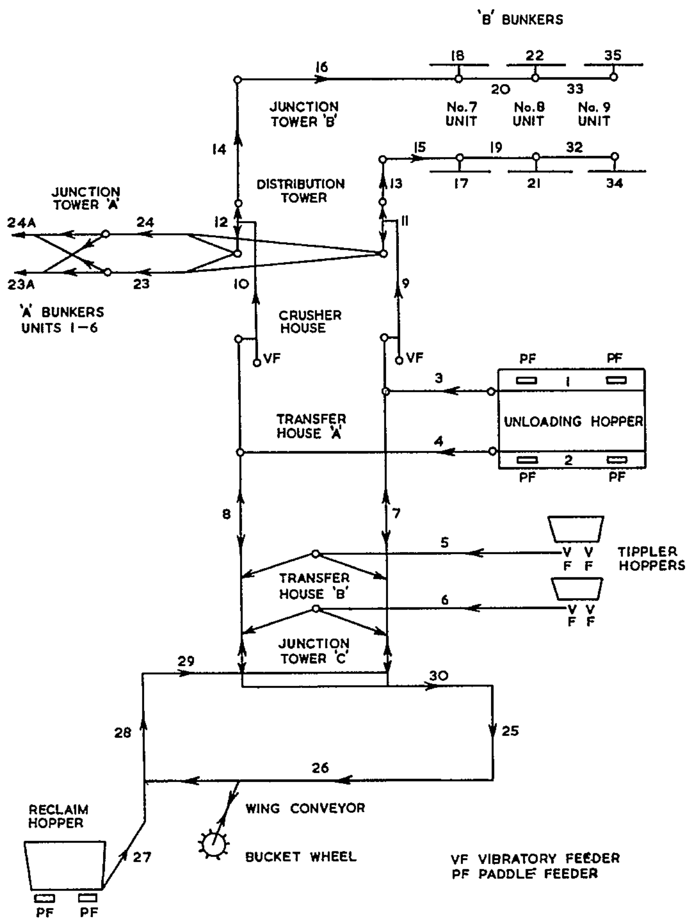

Figure 1

tracks of the loop system. This is emptied by four paddle feeders onto a pair of 1,000 T.P.H. (tons per hour) conveyor belts, one of which feeds No. 7 reversible conveyor and the other No. 8 reversible conveyor. There are two tippler hoppers each discharging via twin vibratory feeders onto 250 T.P.H. conveyors. Both these conveyors can feed either No. 7 or No. 8 conveyor. The 1,250 T.P.H. Nos. 7 and 8 conveyors can feed to the station bunkers via the screen/crusher house or to stock via a system of unduplicated 2,500 T.P.H. conveyors and the bucket wheel wing conveyor. Further spreading of the stock coal is carried out by mobile plant.

Coal is reclaimed from stock using the bucket wheel or by mobile plant into a reclaim hopper and thence by the 2,500 T.P.H. conveyor system onto conveyor No. 7 or No. 8. Coal to or from stock on the Nos. 7 or 8 conveyors passes over continuous automatic weighers.

Coal to the station bunkers passes, via vibratory feeders, on twin 1,250 T.P.H. conveyors to the distribution tower. There, reversible conveyors and chutes enable it to be fed to either A or B stations (via either or both conveyors in the case of the A station). Coal on the 500 T.P.H. A station conveyors passes over continuous weighers to a cross over/sampling facility and thence via a further pair of 500 T.P.H. conveyors to the six bunkers. Each of the pair of conveyors feeding the B station (again passing over continuous weighers) can supply any of the three unit bunkers via a system of 1,250 T.P.H. conveyors and shuttle conveyors.

3.2 SIMULATION MODEL

It was expected at the outset that most of the complexity of the plant would have to be incorporated into the model. The schematic diagram of the plant (shown in Figure 1) gives some indication of this complexity. Certain simplifications were acceptable, e.g. the outputs (station coal bunkers) were assumed to consist of two groups rather than a number of separate units. Greater simplification of the functional system was only possible at the expense of loss of confidence in the model by the local site management.

On the operational side the engineers work in a great amount of detail in controlling the plant. The complex factors influencing these decisions had to be incorporated in the decision rules of the model. It was evident that the model would be too large if it were to be constructed in the generally accepted form with the functional and operational systems integrated. The solution lay in departing from the established technique and splitting the model into two distinct sections.

(1) Functional Section - representing the physical paths along which coal and trains can move.

(2) Process Control Section - simulating the control and decision making of the plant operators.

The functional section worked as a continuous model of the real system (in so far as the digitalization of the coal flow process allowed). The process control section was only scanned once every 18 minutes (real time) and, according to the state of the functional system and the external variables (weather, etc.), set up the functional system until the next scan.

This had several advantages:-

(1) The site engineers were able to see the functional section as a direct model of the real system.

(2) The process control could be seen as the total control of the whole plant. The logic inherent in decision rules could thus be easily checked.

(3) The model size and study run time were drastically reduced since the pieces of coal encountered a preswitched system. Previously at each decision point each piece of coal had to take into account all the relevant factors influencing the next move.

(4) Extra realism was introduced. There was now a chance of some delay occurring between an event (e.g. a breakdown) and the next process control scan reswitching the system to take account of the event. There is a similar effect in the real system due to operator action delay.

3.3 CONSTRUCTION OF MODEL

3.3.1 Functional Representation

A digital model differs from an analogue model in that any flow process must be broken up into "bits". Similarly, time must also be divided into discrete intervals or clock units. Flow rate is then governed by the number of clock units a bit takes to traverse a plant transfer facility.

In these circumstances a compromise between computing time and accuracy of flow control is necessary when choosing the size of clock units and bits. In this model coal was divided into 50 ton bits and a clock unit of 6 minutes was adopted.

The functional section of the model can be split into a section representing the main conveying plant (shown in Fig. 1) and sections which represent the inputs and outputs of coal to this system.

<u>Main conveying plant.</u> This is represented on a functional basis rather than as an exact replica incorporating every plant item. Thus where there are duplicated paths and crossover or decision points these are represented. However series of plant items between these decision points are regarded as a single transfer facility. A breakdown on any of the component parts of such a transfer facility stops the flow on the whole facility (as in the real plant). The flow on previous transfer facilities will be jammed up and the flow on subsequent facilities dry up until the next process control scan reswitches the system, where possible, to bypass such a breakdown. Bunkers and hoppers are represented as storages capable of containing a certain number of "bits" of coal. In all cases functional relationships between items of plant are

observed, i.e. coal cannot leave the line hopper via the A side transfer facility (Nos. 1 & 3 conveyors and paddle feeders) unless:

(1) There is room on the transfer facility,

(2) All plant incorporated in the transfer facility is working.

The decision points incorporated in the functional section stop, permit or direct the flow of coal bits as decided by the previous process control. Thus in the example above the previous process control must have decided that coal is required to be discharged from the line hopper onto the A side transfer facility for this flow to be possible.

Primary input. This is coal on to the conveying system via the unloading hopper. In this input section the transactions are generated as trains arriving according to a predetermined timetable modified by earliness/lateness functions. Various logical operations are performed on these trains, e.g. having arrived they queue, where necessary, in order of scheduled arrival time rather than actual arrival time. Thereafter this section forms a functional replica of the track layout around the unloading hopper - various sections of these lines are represented as items of plant which the train transactions seize while passing over or waiting on the appropriate track section. Functional restrictions such as time intervals between successive trains on the same track are built in.

Train approach to the discharge hopper is supervised by the process control which reviews such variables as coal requirements at particular points of the system, types of coal in the trains and availability of plant. At discharge a number of transactions, representing the train's load, are split off the train transaction and enter the unloading hopper in the main conveying plant section at a rate controlled by such factors as type of coal, weather, etc.

Once fully discharged, trains leave the model, plant conditions permitting. However in the real system lateness incurred by a locomotive on one trip affects its ability to arrive on time on subsequent trips that day. Further, trips which would arrive so late that they would jeopardise the next day's timekeeping are abandoned. This feedback between arrivals and departures is incorporated in the model by noting departure lateness and adding a corresponding amount to the next arrival of the same locomotive. This ensures a compatible relationship between arrivals and departures. Satisfactory sorting of the trains into the system is achieved by a refined use of the G.P.S.S. link block, which also resulted in considerable saving in computing time.

Secondary input. This is coal via the tippler hoppers. Coal 'bits' are always available in these hoppers whenever the process control determines that the system needs and can handle coal from this source. (This is realistic since the available supply is greater than the station requirement. Moreover the hopper discharge conveyors limit the flow from tippler hoppers to below the capability of the tippler wagon handling and discharge facilities. Thus the handling of these wagons could conveniently be omitted from the simulation). In later studies this supply was limited in accordance with economic and contractual considerations.

Coal stocks. These are within the boundaries of the site system. However it would be expensive in computer store to represent these by actual, though idle, transactions. Instead coal from/to stock is treated as input/output to the conveying system via the bucket wheel and reclaim hopper. Such transfers are counted to keep a record of coal on stock. Logic associated with subsidiary counts ensures that certain types of coal are reclaimed first. Coal is available at the bucket wheel or in the reclaim hopper whenever required. This is justified in view of the short term nature of the studies since the reclaim rate from the short term stock can easily match the handling rate of the stock conveyors. Breakdowns of the reclaiming plant on the stock are simulated by loss of the appropriate input. Flows to and from stock are governed by the process control.

Note: Since it is expensive to have coal transactions waiting in the system, tippler and stock supplies are created by the process control only when necessary. The process control transaction is transferred to the functional system with appropriate changes in information content and priority.

3.3.2 Process Control

The process control models the functions of the coal handling engineer, his staff, and the boiler operators in ensuring that:

(1) Trains are unloaded,

(2) Adequate bunker levels are maintained,

(3) Stocking out and reclaiming from stock is carried out as required,

(4) Appropriate switching action is taken to minimise the effect of any breakdowns on the coal plant.

It is made up of series of logic sets each performing a particular function. These can be split into three categories:

(1) Those that obtain information about the state of the system and impart information to the control transaction to be referenced or used to modify the path of this transaction later in the control process:

(2) Those that assess such information to determine necessary action.

(3) Those that switch the main coal flow.

Factors taken into consideration are:

(1) Time of day and shift patterns,

(2) Weather,

(3) Data on trains on site or due to arrive shortly - type of coal, scheduled departure, etc.,

(4) Data on discharge hopper - contents, type of coal, discharge rate capability etc.,

(5) Coal availability from tippler wagons and stock,

(6) State of coal stocks,

(7) State of bunkers,

(8) Plant breakdowns,

(9) Present switching of plant.

The amount of data required to control the plant under all conceivable situations is enormous but the logic required to cope with every possible situation had to be included. In order to minimise this logic the assessment of plant state is carried out in stages. Each stage takes any switching action requiring no further assessment, and eliminates any redundant information, before selectively directing what further assessment is required.

In some stages only one factor is assessed, in others the assessment of two or three is performed. Numerical analysis was carried out to determine the order in which factors should be assessed, and which should be combined, in order to minimise the total logic.

In general, before a selective branch is taken, all data that may be required for assessment on more than one branch is imparted to the transaction to avoid duplication of data collection logic sets. Given this, data is collected as far down the process control logic as possible. Information is tagged to the transaction in numerical form in such a way that the numbers assigned during successive data collection fit together to enable some subsequent assessments to be carried out on a purely numerical basis. A simplified example could be the bunker levels:

A bunkers

'full' ≡ 0 'full' to 'low' ≡ 3 below 'low' ≡ 6

B bunkers

'full' ≡ 1 'full' to 'low' ≡ 2 below 'low' ≡ 3

giving the nine possible combinations as Nos. 1 - 9. By careful selection of numbers, plant situations which are different but require the same switching action can be arranged to possess the same number, thus eliminating redundancies. The efficiency of these methods can be seen in the fact that, if all the combinations of each factor (e.g. state of bunkers) are allowed to act on each other the total number of individual plant states is in excess of five million. By the above means the data collection, logic assessment and plant switching of the process control was accomplished using about 300 G.P.S.S. blocks.

3.3.3 Auxiliary Section

Apart from the two main sections of the model there are several supporting sections.

Shift pattern. This imposes upon the main flows the effects of the shift pattern being worked. It is thus possible to simulate a different shift working by changing this block diagram only. The initial studies examined a two shift operation of the coal plant. This section:

(1) Altered variables in the process control to ensure the bunkers were coaled up before the end of the second shift,

(2) Stopped and started plant during shift changes,

(3) Caused trains which arrived too late on the second shift to wait on site overnight,

(4) Removed the night burn from the bunkers.

It is thus possible to avoid simulating the night shift with consequent saving in computer time.

Breakdown flow. Transactions are generated into this flow at intervals randomly selected from histograms of breakdowns of particular plant types. These pass through blocks which allow them to pre-empt the appropriate plant item in the main model for a time randomly chosen from the relevant duration histogram. Certain logic is built into this flow to take account of consecutive breakdowns on the same type of plant and the effect of manpower and spares limitations on the duration of the outage.

Simultaneous decisions. In some parts of the functional section progression from one plant item to another is dependent on a number of conditions being satisfied simultaneously. Unlike G.P.S.S. 360 G.P.S.S. III does not contain the boolean variables which would solve this problem. Logic switches are inserted in the functional model at the relevant points and controlled by independent transactions which make a pass through an external loop whenever a condition changes.

Event generators. Certain events such as weekends or adverse weather are generated either regularly or randomly from histograms as appropriate, and persist for specified or randomly determined lengths of time.

Information retrieval. This sets up savevalue locations in the model to collect data on train arrivals, discharge times, coal flows, etc., at periodic intervals. These are printed out on a daily basis and the savevalue locations reset for the next days data. To minimise core usage several items of data are packed into each savevalue.

Note: A structure of priorities is established between the different sections of the model.

4. GENERAL INPUT INFORMATION

4.1 INFORMATION SOURCES

To simulate the operation of a coal plant system still under construction posed considerable information problems.

The functional layout of the system and the theoretical capacities of the individual plant items were available; not so the practical operating capabilities of the inter-related system. The likely behaviour of the plant was discussed at length with experienced engineers. Using their experience, gained on similar plant, a careful analysis was made of the interaction between the plant items of this particular system.

A picture of the way in which the system would most likely be operated and the factors which would influence operating decisions was obtained from discussion with the engineer in charge of the coal plant. Details of probable generation demand and coal supplies policies were obtained from discussions with the planning staff.

4.2 FRAMEWORK OF STUDY

The coal plant would first be under stress following the commissioning of the first 500 MW generating set. National plans predicted that the total station fuel requirements would then be between 50,000 - 60,000 tons per week.

Because the study did not actively include the operation of coal sources and rail links to the generating station, a hand simulation was used to determine a feasible train schedule which required the minimum number of locomotives and wagon sets. This schedule was used as the basic time-table for coal arrivals in the main simulation.

4.3 STATION THROUGHPUT OF COAL

The station coal supply is subject to fixed contracts and cannot be varied from day to day to suit the short-term demands on the station made by the national grid. As these short-term demands could not be predicted accurately it was decided to investigate initially the situation when the coal consumption was equal to the coal supply (representative of cold weather conditions) and then a situation when the consumption was considerably less than the supply.

The majority of railborne coal deliveries were to be in trains of the newly developed permanently-coupled rapid discharge type. However it was accepted that, due to the small size of some of the supplies, a proportion would have to be taken via the less efficient wagon tipping method. The plant engineers were unable to say when this would be taken during the week or in what quantities. The approach adopted was to permit the simulation to handle these supplies whenever it could do so without disruption to the main coal supplies. Having determined when and how much the system could handle, further discussions with the engineers enabled limits to be set so that the total amount taken was no greater than they were prepared to accept.

4.4 DECISION RULES

The decision rules governing the safe and efficient operation of the plant had to be specified in detail to enable the process control section of the model to be formulated. This paper described in detail under 'Construction of the model' the large number of possible switching and control possibilities that could arise. It was necessary to rationalize these sets of conditions and draw upon the experience of expert plant supervisors and operators to understand how they would react in particular circumstances. The validity of this approach is acceptable if one considers that the operators consulted will be those finally responsible for control of the plant and that their philosophy of operation is simply being anticipated!

4.5 TYPES OF COAL

A particular source provided high sulphur content coal that could not safely be put to stock for long periods due to fire risk. It was important that this weekly tonnage of 10,000 tons should be sent to bunkers as quickly as possible and special rules had to be incorporated in the model to achieve this.

It appeared that the position in the arrival schedule would significantly affect the size of this problem. It was decided to keep these rules fairly simple and determine whether more stringent rules were necessary by measuring the quantity of such coal sent to stock.

4.6 BREAKDOWNS

These could be split into two groups, each having a different effect on the system:-

(1) Frequent minor ones that slow down the operation of the system for periods not exceeding two hours.

(2) Infrequent major ones that cause disruption to the operation for up to several days.

A considerable amount of data on minor breakdowns was available from parts of the plant already in commission. The frequency and duration of such breakdowns were compiled into histograms from which the computer could sample at random for each plant type. No satisfactory data on major breakdowns was available and these were imposed on the system for a particular length of time so that the resulting disturbance could be measured.

4.7 TRAIN DATA

Statistics of train lateness and load size were collected from station records. These were analysed to eliminate variations due to factors that would not influence study conditions and to identify any bias associated with particular coal sources. On train lateness, an attempt was made to eliminate the variations due to on-site delays. These would be inherent in the simulation and thus should not be an input.

5. EXPERIMENTS WITH THE MODEL

5.1 USE OF MODEL

The model has been used in 3 modes.

(1) To predict overall system behaviour under normal conditions, i.e. using random sampling of data related to system variables.

(2) To test the effect of specified conditions imposed on the system when no historical data is available.

(3) To generate data for future model inputs, e.g. train arrivals and sources of coal, when current information about these inputs is unreliable.

The results from the experiments on the model were designed to show the dynamic behaviour of the plant system. Output data was requested to provide as much information as possible about actual train arrivals, coal bunker and discharge hopper levels, conveyor belt switching, etc. This data was collected on a time sampling basis to provide a picture of the system behaviour.

The intention at this stage was to study the response characteristics rather than tabulate statistical data on levels, etc.

5.2 STUDIES

Runs were carried out as follows:-

(1) At burn rates of 40,500 and 58,000 tons per week.

(2) With and without limits on tippler coal supplies.

(3) With and without major breakdowns.

Further one week studies were carried out at both the high and low coal burn rates as a control against which fluctuations shown in the other studies could be compared. These control runs did not include train lateness, train load variation or plant breakdowns.

5.3 SIMULATED RUNNING TIMES

The shake-down period from start (system empty) to steady state condition was expected to be less than a week. The coal supply pattern operates on a weekly cycle and it was decided that a nominal run-time of 4 weeks would be a reasonable compromise for the initial studies. This period would allow the system to stabilize before and after major breakdowns. Output data would also be of reasonable size to allow for convenient analysis.

6. ANALYSIS OF RESULTS AND CONCLUSIONS

6.1 ANALYSIS

The data on coal storage levels, coal flows, plant utilization, train journeys and breakdowns was plotted against a time scale for all of the studies.

The plots for the main studies listed in section 5.2 were compared with those of the appropriate control study. Deviations from the control response were analysed to determine the explanation (train lateness, coal type, etc.) of each.

These studies were intended as model proving runs and as a tentative exploration of further areas of study. Thus insufficient data was available for the frequency or the probability of any occurrences to be determined at this stage. However certain tendencies were clearly apparent and, in general, further analysis showed the causes of these to be a logical combination of known characteristics of the system. The value of the simulation at this stage lay in drawing attention to such problems.

6.2 FINDINGS

As a result of these initial studies the following points could be made.

In general the proposed train arrival timetable appeared compatible with the operational requirements of the coal plant. Delays to trains caused by waiting to discharge or by interference between trains on site were not significant. Some 'unstockable' coal was put to stock to avoid delaying trains but this was invariably reclaimed within a few days.

The accumulation of lateness by the locomotives on successive trips throughout the day frequently resulted in a train arriving too late on its last trip to be discharged that night. However the extra discharge the following morning did not seriously affect the time-keeping of that day's trains.

The station coaling requirement assumed could be met by two shift manning of the coal plant. It was not necessary at this stage to man it continuously. (The cost benefit accruing from this saving of a shift is of the order of £25,000 a year)

The lateness of trains, by spreading out the coal arrival, caused the plant to be used at a lower efficiency since the conveyors were frequently working at less than half their capacity. However it appeared feasible to coal the two stations using only half of the duplicated conveyor system with considerable gain in efficiency.

The use of only one track over the discharge hopper added significantly to the chance of a train being delayed on site overnight. Once this had occurred it was likely that two trains would be delayed the following night and there was little chance that such delays would be made up on subsequent days.

The variation in train loads, particularly the variation in total tonnage delivered each week, had a considerably greater effect on the timing and qualities of coal flows to and from stock than had been envisaged. (Recent discussions with coal suppliers indicate that such weekly variations may be unlikely and that, although the train load data was correct, some correspondence between successive loads from the same source will have to be written into the model).

Demand for tippler coal was almost entirely confined to the weekend and thus, if possible, deliveries should be scheduled for Friday and Saturday to reduce demurrage charges on wagons.

6.3 MODEL VALIDITY

The validity of a simulation model of this type must rest upon the accuracy with which the variables and decision rules of the real system have been modelled. A necessary but not sufficient test is that the model exhibits similar characteristics to those of the real system and that it reacts in the same way as the real system to imposed disturbances.

During the development many proving runs were carried out to test the response of this model to specified inputs, and the causes of implausible behaviour were sought out and rectified. The decision rules and behaviour built into the model were frequently checked against the experience of the plant engineers.

For the particular studies described in this paper the results of the two control studies were compared with the response of the analytical model to the same input. In all cases discrepancies were traced to the additional sophistication of the simulation model.

At the time of writing this paper the real system has not yet reached the level of input represented in these studies, but will shortly do so. It has been emphasised that the model cannot predict future plant states in view of the inherent unpredictability of the actual station inputs and disturbances. But the model characteristics will undoubtedly be closely compared with the real system characteristics. Apart from changes arising from discrepancies there will inevitably be changes caused by a revision of the plant engineers understanding of the system.

6.4 FURTHER STUDIES

As a result of these initial investigations further studies are proposed.

To establish at what coal supply level it becomes necessary to:

(1) Use both sides of the duplicated conveying plant

(2) Change to continuous manning of the coal plant

and to note the effect on this of various proposed coal arrival schedules.

To investigate the effect of different plant operating policies on the operation of the system with a view to reduction in manning.

To investigate possible changes in the coal arrival timetable to reduce the quantity of unstockable coal sent to stock and to determine procedures for handling this type of coal.

To determine on what occasions it is necessary to use both discharge lines to avoid serious delays to trains.

To examine the possible retention of trains on site overnight on Friday to discharge on Saturday and thus reduce quantity of coal double handled (sent to and from stock) each week. Also to determine when to discharge tippler coal over the weekend.

To examine the effects on the operation of the system of having to reclaim coal from longer term (and hence less accessible) stocks. (The extra functional and decision logic required for this study has already been formulated).

The model has been written to incorporate much of the detail of the real system. The sensitivity of the model to certain items of detail needs to be tested and the model simplified by the removal of non-significant detail.

7. PROJECT SUMMARY

7.1 MODEL DEVELOPMENT

We found that at least 6 man/months were necessary to achieve expertise in G.P.S.S. modelling. At first, using the technique 'according to the book' consumed too much computer time and short-cuts had to be learned. Emphasis was placed on this reduction process because long periods of operation would need to be simulated. Finally, the real time/simulation time ratio was 6720 : 1.

Practical studies were produced in a further 4 man/months during which time information from the user had to be checked and analysed. Analysis of results was found to occupy about one third of the time of the simulated operation although investigation of the first sets of results occupied much longer than this. The time taken to analyse the results from later studies should be further reduced when only selected output information is required. [It may be noted that the G.P.S.S. output, even using the 360 Output Editor, will not give the dynamic plots we require, as even the graph plotting facility is designed for statistical displays. For automatic plotting of longer detailed studies it will be necessary to write the G.P.S.S. results on tape and subsequently run this as input to a separate graph plotting program].

7.2 MODEL UTILITY

Models of this size and complexity (750 + blocks) need to be manipulated by one project team. They cannot be easily handed over for use by another analyst who is not completely familiar with the plant system and the modelling devices used to portray particular features. It is doubtful whether operational engineers employed on site systems would ever be in a position to find the time to manipulate G.P.S.S. models. If it were simply a question of adjusting the values of functions and/or variables in the model then the task of the uninitiated would be easier, but if the basic philosophy of operation alters by a simple decision rule this may require several man/days by a trained analyst to modify and check the decision matrix of the model.

The model construction should preferably be of modular form in easily identifiable parts. This simplifies the checking/testing procedure which can then be carried out in sections. Other advantages are that understanding of the model and additions and modifications to it are made easier.

As a point of interest, the model required 60 sq. ft. of wall-space so that the detailed G. P. S. S. flowcharts could be presented clearly. The limitations to the mobility of the detailed model are obvious!

7.3 COMMUNICATION WITH USER

The objectives - and limitations - of simulation studies were readily understood and accepted by management. The operating engineers showed an understandable reluctance to become involved with the computer applications. This was offset by the evident enthusiasm in wanting to discuss plant operating methods and in ensuring that their years of practical experience were faithfully introduced into the model.

At first it was difficult to obtain the necessary detail on practical operating decisions and plant capabilities. This was mainly due to the plant engineers' understandable reluctance to commit themselves and also to a lack of appreciation of the type of detail required. We found that a valuable technique was to see the plant, discuss its operation with the engineers, and then independently write initial assumptions of its capabilities and principles of operation. Talking these over with the engineers served as the necessary spur since correction of our errors involved supplying the information we wanted. However, sufficient information had first to be gleaned to make these initial assumptions appear reasonable (though wrong) to the plant engineers since we could not afford to lose their confidence at this stage.

Results from the studies were conveyed to management by the usual reporting methods. Care was necessary to provide adequate detail where operational matters were concerned and to qualify any conclusions and recommendations by reference to the assumptions made during model construction.

An important side-effect of the studies was the high-lighting of several points of interest that were only incidental to the simulation model. There included stock layout patterns, simultaneous discharge of trains and availability of mobile handling plant. Although not included in the modelling process, they became the subject of other studies or projects, the results of which were valuable to local management.

8. BIOGRAPHIES

ROGER WALKLEY was engaged on research and development in the aircraft and missile industries before joining C. E. G. B. Headquarters in 1962. Since then he has been concerned with the application of management services techniques to the solution of problems in the fields of power generation and distribution.

He has been involved with the simulation project that is the subject of this paper for about 18 months.

NEIL HUTSON has spent 4 years in the power industry. Since 1967 he has worked in Operational research at C. E. G. B. Headquarters and been involved in the application of management services techniques such as linear programming, information flow and simulation. In particular, he has gained considerable expertise in the dynamic modelling of complex systems.