AN OPTIMAL CONSTRAINT MANAGEMENT PROGRAM FOR NEW ELECTRICITY TRADING ARRANGEMENTS IN THE UK

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Abstract: The New Electricity Trading Arrangements (NETA) implemented in England and Wales brought new challenges for National Grid as the system operator to operate and manage the transmission system. Under NETA, there is little lead-time from the final physical notification of generation/ demand to the real time operation. Yet the dynamic characteristics of 'Balancing Mechanism Units' (BMU) have become more variable. This paper presents a computer program specially developed for on-line optimal system constraint management under NETA. The development is focused on the tighter time scales and increasing uncertainty. Together with other post-fault actions, the BMU generation re-dispatch forms the basis for the constraint management.

Keywords*:* Power system operation: real time optimisation, economic dispatch, security assessment

1. INTRODUCTION

The New Electricity Trading Arrangements (NETA) have been implemented in England and Wales since March 2001. The aim of the change is to further enhance the economic mechanism under a truly open market environment. It is also hoped that the new trading arrangements could overcome some shortcomings in the old 'Pool' based model. For example, it will increase transparency of the market; encourage demand-side participation, and lower prices for customers.

The essential change under NETA is that a 'self-dispatch' mechanism has replaced the 'merit-order' central dispatch process. Under this arrangement, bilateral contracts are formed in Forwards Markets between generation and demand, and there is a 24-hour Power Exchange stage before the operation real time. A 'Balancing Market' starts from 3½ hour ahead of real time, when all 'physical notifications' have to be finalised (which is known as the 'gate-closure'). At this stage, the System Operator, i.e. National Grid Operations and Trading, is responsible for balancing energy mismatch left over from the contracted 'self-dispatch' positions, and for managing the system constraints during the transmission operation process.

Since the implementation of NETA, prices of the system marginal generation units have risen sharply. The 'capacity payment' under the Pool is now abolished and stations that used to be in this position have increased their prices. The generators capable of providing fast response in the past were often positioned just within merit. Under NETA these generators arrange their bilateral contracts separately from their Balancing Mechanism (BM) submission and are self-dispatched. This again implies the increased likelihood that higher BM costs will occur when there is an energy short fall (which may be due to some system constraints). These Balancing Mechanism Units (BMUs) have been playing important roles in energy balancing/ constraint management. National Grid has responsibility for energy balancing and has incentives to manage the BMU costs.

The assessment by control engineers of generator movements to solve system constraints is a more challenging task under NETA, because the 3½ hour lead time from the gate closure to the real time does not leave enough time to undertake full off-line analysis of all possible plant combination scenarios. Generator prices for the balancing mechanism may vary substantially in different half-hours, and may comprise up to five bids and offers from a generator (as well as a demand-side BMU), which is harder for control engineers to manage, particularly during unplanned operation conditions.

COmbined Dispatch Advisor (CODA) is a suite of computer programs developed for on-line constraint management. It provides security assessment for an appropriate forecast horizon, (e.g. up to 3½ hour-ahead), based on the on-line state estimation and the predicted system and commercial background. It then automatically calculates the best combination of the BMUs to advice control engineers for generator re-dispatch to resolve system constraints. Alternatively, it could also be configured to feed the on-line and forecast constraint information directly to the Dispatch program, fully automating economic and security-constrained dispatch (for both generation and demand under NETA). CODA therefore is an on-line tool for system operations to improve system security and to effectively reduce the balancing / transmission constraint costs under NETA.

The aim of this paper is to introduce CODA as an on-line tool specially developed for constraint management under NETA. The paper is organised as follows. The technical need for CODA is identified in the second section, based on examinations of the power system analysis tools currently used in the National Grid operations. In sections 3 and 4, the approach of CODA is justified by the consideration of several development options and operational requirements. Sections 5, 6 and 7 report the development of the thermal constraint management module of CODA, which has now been used as a working prototype in the operation.

2. INITIATIVE FOR CODA

National Grid has developed a suite of computer programs for both system planning and operational analysis. Optimal Power Flow (OPF) programs have been developed for some comprehensive off-line steady state analysis. They are widely used for system reinforcement planning within National Grid. In real time scales, the Dispatch program and EMS are also used for the dispatch and on-line security assessment.

In a classical formulation of an economic dispatch problem, the total operational cost is minimised, subject to: (a) energy balance in the system, (b) physical limits on the generators and (c) some system constraints. The system constraints are represented by the area or zonal constraints, reflecting the effectiveness of generators in the region to influencing certain critical boundary circuit flows. There is no system network model in the formulation. The advantages for this formulation

	Online security assessment	Off-line security assessment	3.5-hour ahead study mode	Generator post-fault re-dispatch	Power flow optimisation
Dispatch	no	no	-	post-fault secured via pre-fault dispatch	Potentially, via CODA
EMS	yes	-	no	No	no
Planning tool suite	-	yes	peak study only	no	no
OPF	no	yes	no	no	yes
CODA	yes	-	yes	yes	yes

Table 1 A summary of functions of various National Grid programs

are typically computation speed for on-line implementation, and flexibility for incorporation of various types and large numbers of system constraints for the security constrained pre-fault dispatch. However, it has limitations. The deficiencies of this model have been discussed in an earlier paper of CODA [1]. As a direct consequence, it is not possible to accommodate the requirement of managing overloads on a per circuit/ per contingency basis via re-dispatch. CODA therefore intends to overcome this problem by providing the economic dispatch program with generator sensitivities relating to the particular constraints under consideration, e.g. an overloaded circuit, or the voltage depression in an area, or a stability problem caused by some heavy flows over certain boundaries.

The EMS system provides control engineers with on-line security assessments, and supports system management functions (e.g. substation and circuit re-switching etc). It uses the metered data for the re-construction of system states based on the current system configuration. The current EMS is a separate system from the Dispatch program and the commercial system. It does not have direct access to NETA BMU commercial data. It would be nontrivial to further extend the current EMS system to accommodate an economic dispatch program due to the lack of these functions.

In an optimal load flow formulation, a system model can be incorporated with the economic dispatch objectives, covering both thermal and voltage aspects. However, with typically 800 credible thermal contingencies, using a fully coupled AC OPF program for the fast on-line thermal security assessment is both unrealistic and unnecessary. This will be discussed further in the next section.

CODA intends to bridge the gaps in between the current EMS, Dispatch and other OPF programs as discussed previously. CODA is designed to

- resolve the system constraints via optimal generation re-dispatch and other means of post-fault actions economically, flexibly and efficiently;
- carry out predictive security assessments on-line based on the most updated EMS information, on a continuously rolling basis.

Ultimately, CODA will cover all thermal, voltage and stability aspects.

The thermal module of CODA, which is referred to below as DC CODA, has been extended into an on-line advisory tool. It assesses post-fault overloads on the per-circuit / per contingency basis and provides the on-line advice on optimal post-fault actions. This implementation meets the requirements from control engineers for managing thermal constraints under the NETA operation. Table 1 summarises the discussion of this section.

3. MODULAR APPROACH

CODA is developed in modules, i.e. it has separate procedures for thermal, voltage and stability analysis functions. In the initial design, these modules will be integrated with the economic dispatch program module. This approach maximises the flexibility of the program, and at the same time, shortens the development cycle. Because of the separation of these modules, the best algorithms can be employed focused on each individual problem. For example, separation of thermal and voltage procedures allows the fast screening of all possible system thermal faults (around 800 cases), mean while the voltage related faults (which is far fewer than thermal cases) can be studied via a different algorithm module to achieve better accuracy and efficiency.

Clearly, the different requirements on algorithm and modelling aspects between these modules (in particular between the steady state power flow and the dynamic / transient stability programs) can be better accommodated in a modularised approach. The sensitivity between a generator output to the line flow (known as effectiveness or partial attachments, and they will be used interchangeably here in the paper) is fairly linear, whilst the partial attachments relating generation to voltage and stability are less simple. This effectiveness information is fed from CODA to the dispatch program for representation of the network model. Separation of these modules and extracting the effectiveness from each program independently increases robustness and avoids unnecessary modelling dependence and complexity. For example, there is little point when extracting MW information all voltage compensation devices are modelled in great detail.

The DC CODA module has been completed for NETA and it is under tests in the control room for real-time operation. Some sample results are presented at the end of this paper.

4. CODA - DISPATCH INTERACTION

Initially, CODA is designed to improve the accuracy of the dispatch program by providing the dispatch linear programme with the generator effectiveness. However, there are some practical concerns if it is fully automated to interact with the Dispatch program to form a closed loop operation.

Primarily, if the CODA-Dispatch loop is closed, there will be very little chance for system operators to intervene when they wish to do so. The accuracy of CODA is largely dependent on sufficiency of models in the program. For example, if some special actions were not modelled in CODA, it would tend to constrain more (and potentially extremely excessive amount of) generation pre-fault to secure the potential fault. Had this happened, system operators should be able to override and correct the CODA-instructed dispatch. This is the major concern when the program is used on-line in real time.

Secondly, when the Dispatch program optimises the generation based on the constraint information provided by CODA, the implication is that generation will be constrained pre-fault for all the *potential* thermal contingencies. Indiscriminately applying these constraints can lead to infeasibility to the dispatch program. This is because some of the contingencies in practice are not secured by pre-fault constraints, but are secured by proper post-fault actions, e.g. post-fault generation drops and operational tripping schemes. This is the choice between 'preventive' and 'corrective' approaches. In practice, they are not used in isolation but used in combination. The closed-loop CODA-Dispatch operation is essentially a preventive strategy, with the allowance of available post-fault actions. Pre-fault over-constraining means inaccurate interpretation of security standards, and could be costly. To represent the security standards accurately with minimum over-constraining in the preventive strategy will require careful selection of contingency cases and accurate information on some system parameters, such as short-term thermal ratings of circuits. Currently there are difficulties to maintain or obtain the information to the accuracy as required.

Thirdly, in the dispatch and re-dispatch problems, there is only one global objective, which is the economics. When post-fault actions are considered, the thermal constraints that CODA provides to Dispatch for replacing thermal group constraints need to be modified. If this modification is done in CODA (which is outside Dispatch), it is necessary to introduce a heuristic process to estimate the effects and costs of the generation re-dispatch on the thermal overloads. Since there is no cost information in CODA, it is not at all clear in what sense so determined post-fault actions are optimal. Any local objectives in CODA would make the program unnecessarily complicated and may be in conflict with the global economic dispatch objective.

To overcome the problems considered above, an interim open-loop approach is adopted. This change in configuration has essentially shifted CODA from the preventive approach to the combined preventive-corrective approach.

In this approach, the effectiveness information is not used directly to replace the thermal group constraints in the Dispatch program, but instead, is used to construct an on-line advisory display for system operators. All thermal constraints can now be covered, without risk of over-constraining. Any inadequacy in modelling of post-fault actions can now be judged by control engineers individually. The post-fault situation is analysed on an individual overload/ contingency basis, and security standards are met precisely as required. In addition, an optimisation process can be built in the CODA on-line advisory display for the post-fault re-dispatch process. This post-fault generation re-dispatch advisor complements the on-line (pre-fault) Dispatch program with the advice for all post-fault scenarios without affecting the real dispatch process.

Although not discussed further here, the closed-loop dispatch-CODA configuration has been considered for future development under the National Grid NETA projects.

5. OPTIMISATION FORMULATION

The algorithm in CODA is based on post-fault re-dispatch, formulated with NETA implementations.

5.1 Effectiveness

A DC load flow problem can be expressed as

$$P = H\theta$$

where P is the nodal power injection vector, θ is the phase angle vector, and H is the nodal susceptance matrix

$$H = \begin{bmatrix} \frac{\partial P_1}{\partial \theta_1} & \cdots & \frac{\partial P_1}{\partial \theta_{n-1}} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_{n-1}}{\partial \theta_1} & \cdots & \frac{\partial P_{n-1}}{\partial \theta_{n-1}} \end{bmatrix}$$

Solving θ from the load flow equation by inverting the susceptance matrix, one obtains $\theta = H^{-1}P$. It is noticed that phase angles θ are linear combinations of the nodal injections P.

$$\theta_k = \left[H^{-1}\right]_{k-th\ row} P = \sum_i h_{ki} P_i$$

power flow on a line can now be obtained from phase angle differences, as:

$$P_{flow k1,k2} = b_{k1,k2}(\theta_{k1} - \theta_{k2}) = b_{k1,k2} \sum_i (h_{k1,i} - h_{k2,i}) P_i = \sum_i a_i P_i \quad (1)$$

Therefore the effectiveness of a given generator on the flow, or a 'partial attachment', can be obtained from this alternative form of the DC loadflow equation. In this expression, '*i*' runs through all nodes, including both generation nodes and demand nodes.

This formulation is the basis for DC CODA formulation. It is the system information independent of commercial arrangements.

5.2 NETA Prices

A BMU submits its 'final Physical Notification' (FPN) 3½ hours before the real time operation. The FPN is simply a notification of a Market Participant's energy profile throughout a Settlement Period. Together with an FPN it also submits a set of Bid-Offer Pairs that enable National Grid to alter the output from the BMU. A Bid is either a reduction in generation or an increase in demand. An Offer is an increase in generation or a reduction in demand. A Bid - Offer pair in the case of a generator gives the Offer Price to increase the output of the BMU and the corresponding Bid price that is the 'cancellation' price for reducing the output of the BMU. The corresponding Bid price does not literally cancel the original Offer as both the Bid and the Offer still remain for the purposes of Settlement. It is the action of raising the output of the BMU that is caused by accepting the Offer that is cancelled by accepting the corresponding Bid. Up to ten of

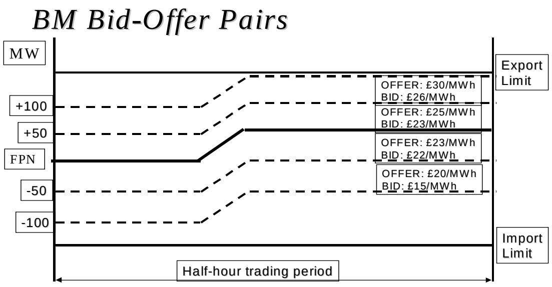

Figure 1 Bid and Offer pairs

these Bid/ Offer pairs can be submitted for a BMU, with a maximum of five of them on either side of the FPN. Successive Bid / Offers must be monotonically decreasing / increasing in price. Each price segment has an integer value assigned to it with positive numbers representing Offer / Bid above the FPN and negative numbers below the FPN.

In addition to these fairly static submissions, there are also some 'dynamic' parameters that BMUs can re-declare from time to time. Typical parameters are Maximum Export/ Import Limit (MEL/MIL), Stable Export Limit (SEL), ramp rates, min On/Off times, etc.. MEL/MIL changes allow bid/offer withdraw.

5.3 Resolving Overloads Using Optimal Re-dispatch

Partial attachments capture the network information, and they relate powerflow and system states to the loading and generation background. The costs and dynamic potentials of BMUs are additional information of the commercial trading arrangements. The basis for thermal constraint management is generation re-dispatch, where system and commercial considerations are combined.

The problem can be formulated such that the total cost of the re-dispatch required for thermal security is minimised, subject to the removal of overloads and energy balance. In addition, it is also subject to some BMU dynamic characteristics, such as Stable/ Maximum Export Limits (SEL and MEL, respectively), and ramp rates (reflecting the post-fault requirements).

The mathematical formulation of this problem is as follows:

$$\left.\begin{array}{l}
\min \quad \sum_{i=1}^{m+n} c_i x_i V_i \\
\text{subject to} \\
-\sum_{i=1}^{m+n} \alpha_i x_i V_i \ge P_{overloads} \quad \text{(removal of overloads)} \\
\sum_{i=1}^{m+n} x_i V_i = 0 \quad \text{(energy balance)} \\
MEL_L - (P_{L0} + \sum_{i \in L} x_i V_i) \ge 0 \quad \text{(MEL for the L–th BMU)} \\
(P_{L0} + \sum_{i \in L} x_i V_i) - SEL_L \ge 0 \quad \text{(SEL for the L–th BMU)} \\
\sum_{i \in L} x_i V_i - r_L \Delta t \le 0 \quad \text{(ramp rate for the L–th BMU)} \\
\text{and} \\
0 \le x_i \le 1
\end{array}\right\} \qquad (2)$$

where the sign of the BMU volume, V, is as defined for the Bid /Offer pairs in the previous section; and the symbols in the above expression are defined blow:

n, m - numbers of offer and bid segments
i – index of the BMU price segment
x_i - % of the volume from a BMU w.r.t its FPN
c - BMU segmental price
α- effectiveness or partial attachment
V - BMU volume w.r.t the FPN
Δt - user specified post-fault action time
r – ramp rates
(The ramp-rates here is an indicative expression only.)

$$P_{overloads} = P_{flow} - Rating = \sum_{i \in Generator} \alpha_i P_i + \sum_{i \in Demand} \alpha_i P_i - Rating$$

The objective function here is formulated based on individual BMU price segments, where the constraints for SEL, MEL

$$0 \ge P_{NewOverloads} = \sum_{i \in Generator} \alpha_i (P_i + \Delta_i) + \sum_{i \in Demand} \alpha_i P_i - Rating$$
$$= \sum_{i \in Generator} \alpha_i \Delta_i + P_{Old\,Overloads}$$

and ramp rates pertain to the BMU in question.

Under NETA, a BMU is not necessarily a physical generating unit, but rather a commercial trading unit, which may be consisted of a group of generating units. This is particularly the case for the units in Scotland and for embedded generations in the low–voltage network. In these cases the effectiveness is taken as the average. This representation is sufficient for the security assessment here since the approximation only arises outside the National Grid system.
The constraint for the removal of the overload can be derived as follows. From equation (1) the overloads can be expressed in terms of partial attachments (separated into generator nodes and demand nodes) as
Suppose the overload can be removed solely by generation re-dispatch, with demand kept unchanged. Then the overload after the re-dispatch should be less than or equal to zero:
which leads to the overload constraint in equation (2) (here Δ=xV).

Operational tripping is another important class of post-fault actions, in addition to the generation drops used in the constraint management. Automatic calculation of intertrip requirement is currently under development in the DC CODA.

Clearly, the network model can be represented in the dispatch by the partial attachments as shown in the overload constraint in equation (2), whilst CODA is separated from dispatch process and solely functioned as a security assessor.

Another interesting observation is from the formulation of the dual problem of this linear programme. The dual formulation reveals among many other variables the system constraint price (the variable associated with the overload constraint) and the equivalent system marginal price (the variable associated with the energy balance condition).

6. IMPLEMENTATION

6.1. An Overview

The implementation is shown schematically as in Figure 2 below.

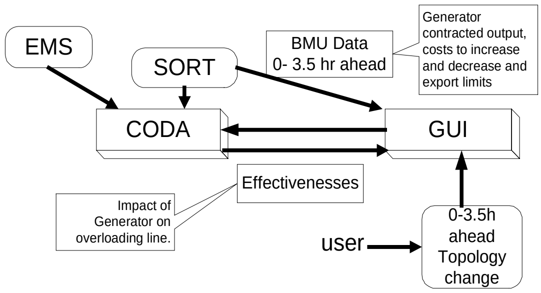

Figure 2 CODA flow chart

In the diagram, 'EMS' represents the on-line security assessment data. The EMS AC state-estimation is updated every 15 minutes. 'SORT' is the 'System Operation Real Time' database, where the live BMU commercial information is stored. The CODA module calculates the partial attachment and the DC security status, using equation (1). 'GUI' is a Graphical User Interface module, which supports a graphical display and the user network re-configuration facility. The 'GUI' also has a processor, where BMUs are optimised and re-dispatched for relieving thermal overloads.

6.2 The 3 ½ Hour-Ahead Study Mode

Studies covering up to 3½ hour-ahead period require the modelling of demand, generation and network switching for outages etc. These issues are discussed below.

Demand prediction and nodal allocation

There are two issues here:

(1) National Grid system covers England and Wales, and it is interconnected with the Scottish system. However, National Grid does not produce a Scottish demand forecast, but this information is required for the 3½ hour-ahead security assessment.
(2) National demand forecast needs to be allocated to nodal demand. Incorrect allocation could lead to inaccuracy in flows, and hence errors in overload estimation.

The former problem is resolved by scaling the current Scottish demand. This scaling factor is found as the demand ratio between the 'time-now' and the forecasted National Grid system demands.

The second problem is overcome by using the national demand forecast, and then allocating demands based on the 'time-now' EMS demand pattern to the Grid Supply Points.

Generation and commercial information

The information on generator parameters and their contracted positions is obtained from the BMU submissions, which are stored in the SORT database. The generation requirements are obtained from the Dispatch program by BMU, and they are allocated to physical generating units (as in EMS) according to a mapping process. Embedded generations are considered in this process as well.

The commercial information is also extracted in this process and passed on to the GUI optimisation module for the later re-dispatch calculation.

Network changes

Within the 3½ hour-ahead period, the system configuration may change due to both planned and unplanned outages.

Network re-switching is a comprehensive subject, which involves combination of fault level control, as well as thermal and voltage security considerations. Often iterations are required between these different studies to achieve a final switching strategy. Also with the same outage /system fault situation, substation running-arrangements may vary significantly, since generation levels are different.

Fault level analysis and voltage aspects are beyond the scope of DC CODA. Although plans of maintenance outages are available, the actual switching could be completed well before the scheduled start of the outage, e.g. during night. For these reasons, it was decided to implement a manual control rather than an automatic algorithm for the re-configuration.

The requirement for the network re-configuration therefore is clarified and a user interface is required, which should support all re-switching operations. In fact, when combined with the predictive mode, this program has essentially formed a flexible study facility for the user-defined cases. Also with minor development, it will be able to support the user-selected substation re-switching as a post-fault action. This study mode is a significant development in DC CODA.

When there is no requirement for a study of any network changes, DC CODA will run on-line automatically updating the demand and generation background within the 15-minute EMS AC security assessment cycle.

6.3 Computing Considerations.

CODA module is implemented on a mainframe processor for the communication with other commercial systems on the same platform and for fast on-line analysis of all credible DC contingencies of National Grid transmission system.

The GUI is implemented in VBA. This gives advantages of:

- easy data handling;
- analysis power with MS EXCEL add-ins;
- minimum user training requirement;
- reliable off-shelf product, fast development cycle and low costs

The communication is via wide/ local area networks, and the program is now accessible by all operation and planning staff from their desktop PCs. A working prototype of DC CODA has now been placed in the National Control Centre.

7. SAMPLE RESULTS

A sample of the DC CODA graphical display is shown in Figures 3-5. This example is obtained from the real system, but data with commercial sensitivity are removed.

The DC CODA display consists of three levels. The front page is a summary of contingency screening of thermal overloads. The detailed information of each overload is linked to this page. (Figure 3).

The second level of the display shows the detailed information for an overloaded circuit (Figure 4). This includes a list of BMUs that could be used for relieving this overload. It can also show the potential BMUs that could be used for energy re-balance. These BMUs can be heuristically ordered by their effectiveness and cost benefit with respect to the overload under consideration. A linear programme solution for this re-dispatch problem can be obtained by pressing the 'optimise' button, which brings the user to the next level of the display.

Figure 5 shows the solution to this re-dispatch problem, which removes the overload of 45 MW on the circuit BXXX and at the same time minimises the cost of moving these BMUs. The total cost for securing this fault is £914, which requires 4 Bids and Offers (in this case it involves only 3 BMUs). A closer examination reveals detail of the process. First, 40MW of the overload is removed by the 2 most effective BMUs, which offered 'Bids' to the system operator for decrements. The 'best' BMU, which offered to pay the system operator £10/MWh for a decrement, is selected first, and 100% of its volume (-237MW) is taken. The second BMU, which is more effective but less beneficial in price, is dispatched to 20% of its offered -245 MW decrement volume. 'Offers' are taken to make up the decreased generation, where the system operator pays BMUs for their increased MW output. Two such BMUs (Offers) are selected. Their effectiveness towards the overload in this case are negative, which means the increase MW from these generators helps to relieve overloads. 'INCBMU2' is dispatched to 60% since the price is slightly higher than that of 'INCBMU1' (this is not shown due to rounding-up in the display). It is clear from this example that the re-dispatch module, although containing no network model, manages thermal overloads accurately and efficiently as if there were one.

Finally, a brief comment on the overall system security. The thermal constrained re-dispatch is done on a per circuit basis here. In theory, the solution to a particular overload might violate the limit on another circuit. This situation has not proved to be a problem in practice, since the dispatch program should secure the overall pre-fault generation pattern with a pre-fault loading margin, and the security standard assumes no multiple faults (in particular, no second fault which is near the increased generation). Nevertheless, this problem will be fully addressed when the closed-loop CODA is in place.

8. CONCLUSIONS

This paper presented the development of an optimal system constraint management program, which addresses the issues on optimising the 'Balancing Mechanism Units' to resolve the system constraints under NETA.

The needs for the program are justified and options for resolving the constraint management problem are examined. Based on this analysis, concept of CODA is formed for optimal management of system constraints. The post-fault generation re-dispatch forms the basis of this concept, where other type of post-fault actions could also be incorporated into this formulation.

DC CODA has been developed into a working prototype program for providing on-line advice on thermal constraint management. The development meets the requirements arose from operations under NETA, which has been demonstrated through a real-event example.

The feasibility has been established that CODA concept can be implemented in modules. Voltage and stability modules and closed-loop automatic dispatch have been planned for further NETA development.

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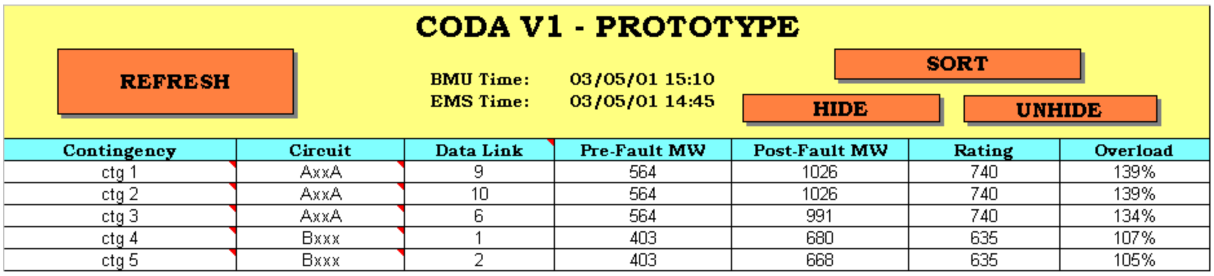


CODA V1 - PROTOTYPE

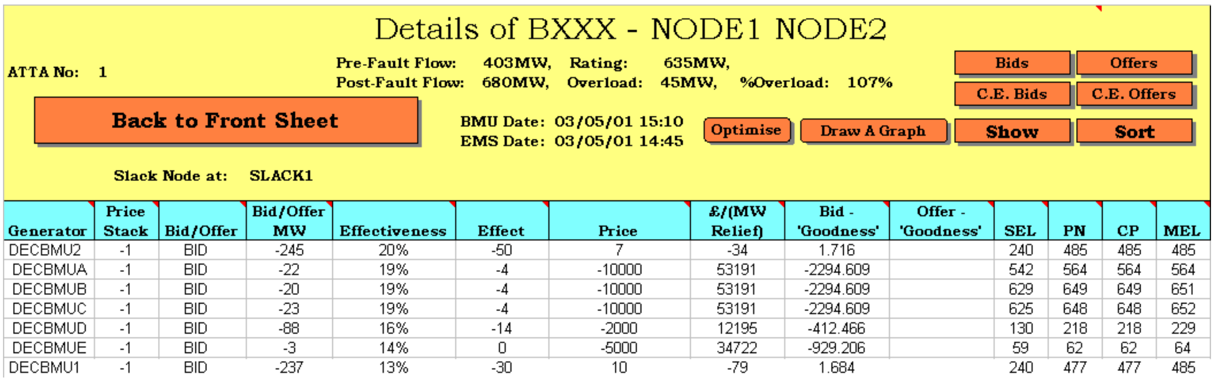
REFRESH

BMU Time: 03/05/01 15:10
EMS Time: 03/05/01 14:45

SORT HIDE UNHIDE

Contingency	Circuit	Data Link	Pre-Fault MW	Post-Fault MW	Rating	Overload
ctg 1	AxxA	9	564	1026	740	139%
ctg 2	AxxA	10	564	1026	740	139%
ctg 3	AxxA	6	564	991	740	134%
ctg 4	Bxxx	1	403	680	635	107%
ctg 5	Bxxx	2	403	668	635	105%

Figure 3 The front page of CODA: security assessment



Details of BXXX - NODE1 NODE2

ATTA No: 1

Pre-Fault Flow: 403MW, Rating: 635MW,
Post-Fault Flow: 680MW, Overload: 45MW, %Overload: 107%

Bids Offers C.E. Bids C.E. Offers

Back to Front Sheet

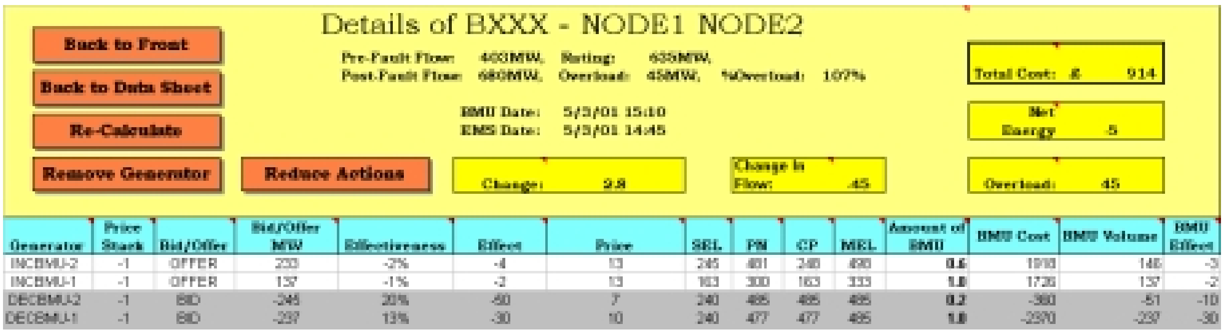
BMU Date: 03/05/01 15:10
EMS Date: 03/05/01 14:45

Optimise Draw A Graph Show Sort

Slack Node at: SLACK1

Generator	Price Stack	Bid/Offer	Bid/Offer MW	Effectiveness	Effect	Price	£/(MW Relief)	Bid - 'Goodness'	Offer - 'Goodness'	SEL	PN	CP	MEL
DECBMU2	-1	BID	-245	20%	-50	7	-34	1.716		240	485	485	485
DECBMUA	-1	BID	-22	19%	-4	-10000	53191	-2294.609		542	564	564	564
DECBMUB	-1	BID	-20	19%	-4	-10000	53191	-2294.609		629	649	649	651
DECBMUC	-1	BID	-23	19%	-4	-10000	53191	-2294.609		625	648	648	652
DECBMUD	-1	BID	-88	16%	-14	-2000	12195	-412.466		130	218	218	229
DECBMUE	-1	BID	-3	14%	0	-5000	34722	-929.206		59	62	62	64
DECBMU1	-1	BID	-237	13%	-30	10	-79	1.684		240	477	477	485

Figure 4 The data page of CODA: BMU data and ranking



Details of BXXX - NODE1 NODE2

Back to Front
Back to Data Sheet
Re-Calculate
Remove Generator
Reduce Actions

Pre-Fault Flow: 403MW, Rating: 635MW,
Post-Fault Flow: 680MW, Overload: 45MW, %Overload: 107%

BMU Date: 5/3/01 15:10
EMS Date: 5/3/01 14:45

Total Cost: £ 914
Net Energy -5
Change: 2.8
Change in Flow: -45
Overload: 45

Generator	Price Stack	Bid/Offer	Bid/Offer MW	Effectiveness	Effect	Price	SEL	PN	CP	MEL	Amount of BMU	BMU Cost	BMU Volume	BMU Effect
INCBMU-2	-1	OFFER	233	-2%	-4	13	245	481	248	490	0.6	1918	148	-3
INCBMU-1	-1	OFFER	137	-1%	-2	13	163	300	163	333	1.0	1726	137	-2
DECBMU-2	-1	BID	-245	20%	-50	7	240	485	485	485	0.2	-380	-51	-10
DECBMU-1	-1	BID	-237	13%	-30	10	240	477	477	485	1.0	-2370	-237	-30

Figure 5 The optimisation page: BMU re-dispatch