DATA PROCESSORS FOR POWER SYSTEM CONTROL

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فى مراكز التحكم الحديثة يوجد معالج البيانات لمعالجة البيانات الغير دقيقة أو الخاطئة المرسلة إلى مركز التحكم حيث يظهر بعد المعالجة بيانات دقيقة تمثل الوضع الفعلى للنظام . ولهذا أصبح معالج البيانات جزءاً مكملا وحيوياً فى برامج التحكم الآلى لصنع قرارات فعاله ذات درجه ثقه مقبوله وفى السنوات الأخيرة إقترحت عدة مداخل لتصميم معالجات البيانات للتطبيق فى مجال التحكم فى منظومات القوى الكهربية وفى الأبحاث الأخيرة تم تعديل المعالجات الخطية لتجميع البيانات بحيث يؤدى هذا العمل لتقليل المتطلبات الحسابية ، ومع ذلك تبين الخبرة أن التطبيق المباشر لهذه المعالجات الخطية يتطلب حسابات كثيرة وما زالت المشكلات الملحة للتطبيق مثل تحديد درجة الثقة والسرعة والتخزين والتكلفة لم تحل بعد ، ولذلك فإن حل هذه المشكلات تتطلب مزيداً من البحث . والمحتوى الرئيس للبحث الحالى يختص بإيجاد طريقة أكثر فعالية عند تصميم هذه المعالجات والحصول على نتائج مقبولة مع الأخذ فى الإعتبار تقليل كمية الحسابات وتكلفة التشغيل . وتبدو فعالية الطريقة وذلك عند تطبيقها على مجموعة من نماذج منظومات القوى تحت ظروف تشغيل غير عادى . ويحتوى البحث على النتائج الحسابية والمقارنة بين الطريقة المقترحة والطرق الأخرى تبين أن الطريقة المقترحة تقلل من كمية الحسابات المطلوبة والنتائج التى تم الحصول عليها تتميز بدرجة ثقة عالية .

ABSTRACT

In modern control centers, Data Processor (DP) has been installed to process the unreliable and erroneous telemetered data. The main focus of the present paper is concerned with developing more efficient algorithm of Parallel Data Processing (PDP), to generate satisfactory results with minimum amount of computation expense and implementation costs. Both algorithms of the conventional Central Data Processor (CDP) and the proposed PDP are programed. The effectiveness of PDP is verified by number of tests on different models of power systems under extreme conditions. A set of results for PDP and for CDP are obtained. The results show that more reduction in processing requirements and high reliability is gained using PDP.

INTRODUCTION

Within a power system, large number of transducers are available at various locations in the network to measure states of the system. The measurements are telemetered to a computer control center. In general, telemetered measurements are subject to random noise and also to errors due to equipments malfunction. However, computer-aided control of power systems requires reliable data about the present system operating conditions. Therefore, a Data Processor (DP), using digital computers is required. The raw measurements and switching status information, together with a mathematical model of the network, are used to produce more accurate values and provide the quantities which are not physically measured. Hence, DP becomes a vital and integral software part of modern automatic control centers, for building up a reliable data to make active decisions for on-line security and control [1,3,4].

A large amount of research has been undertaken on conventional Central Data Processor (CDP) techniques, based on linear programming approach [5-8]. It requires all measured data to be communicated to a central computer and processed at a central level. One of the know difficulties of CDP is due to the fact that the system may not be expanded beyond a certain limit without violating system reliability and economy. Another disadvantage of the CDP is the difficulty of developing efficient monitoring and control software to provide the required computational parameters (such as time, storage, accuracy, and data transmission) needed for high performance on-line control.

Consequently, In the present work a new algorithm is proposed for Parallel Data processing (PDP) which has a number of adavantages over CDP and can provide the following properties:

- It uses more than one DP, one at the secondary level and the others at the primary level.
- The major part of the processing work is performed simultaneously via local computers at the primary level which process local telemtered data. These are responsible for local control functions.
- The local computers are coupled and coordinated via the central computer at the secondary level, resulting in saving of central processor execution time.
- Data to be transmitted among computers is designed to be small, it allows cost reduction.
- It allows greater freedom in software design and hence improved system flexibility.
- If the central computer fails, all the central fuctions are transfered to a local computer which becomes the new central, i.e. improved effectiveness and ease of maintenance.

CENTRAL DATA PROCESSOR (CDP)

In electric power systems data processing problem concerns with determining system's state variables [X], i.e. N complex voltages, from M of raw measurements [Z] in the presence of errors [e]. The mathematical model describing the functional relations between [Z], [X] and [e] can be formulated in the following set of nonlinear equations of the network:

$$[Z] = [h(X)] + [e] \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

Applying the linearisation technique to the above problem, the relation between the changes in the measurements [ΔZ] and the changes in the variables [ΔX] is given by:

$$[\Delta Z] = [H] [\Delta X] \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (2)$$

Where [H] is the m.n Jacobian matrix, and its elements are the partial derviatives of the measurement equations [h(x)] with respect to the components of [X]. The solution of eq. (2) is obtained iteratively. Every iteration requires a considerable amount of computation requirements. To overcome this difficulty the decoupling technique is applied. Two subproblems, namely P- Θ and Q-V, those resulted from the application of the decoupling technique to the problem of (2) may be written as

$$[\Delta Z_a] = [H_a] [\Delta \Theta] \quad \ldots\ldots \quad (3) \qquad \text{and} \qquad [\Delta Z_r] = [H_r] [\Delta V] \quad \ldots\ldots\ldots\ldots \quad (4)$$

Where a and r refer to active and reactive components respectively. There are two approaches to tackle the CDP problem. The first is based on equality constraints and the second is based on inequality constraints. They will be called through this work CDP1 and CDP2, respectively. The mathematical formulations of CDP1 and CDP2 are outlined below.

CDP1

The vectors $[\Delta Z_a]$ and $[\Delta Z_r]$ deviate from the ideal mismatches of the true values of the measurement vectors, due to the noise and the meter errors. This deviation could be positive or negative and thus the general linearised form of the power mismatches (3) and (4) become, inconsistent. To remove this inconsistency and cater this change, active positive slack variables A_{a-i} and D_{a-i}, respectively representing the postive and the negative deviation associated with the ith active measurement, are added . The active residual can be expressed as the difference between $[A_a]$ and $[D_a]$:

$$[A_a] - [D_a] = [\Delta Z_a] - [H_a][\Delta \Theta] \quad \text{..........................} \quad (5)$$

Then the processing subproblem P-θ can now be formulated as a linear programming problem in matrix form as

$$[\Delta Z_a] = [H_a][\Delta \Theta] + [A_a] - [D_a] \quad \text{..........................} \quad (6)$$

To satisfy the requirements of the linear programming approach, it is necessary that all the changes in $[\Delta\Theta]$ should be positive. But in the power systems, the change in $[\Delta\Theta]$ is not always positive as well. To ensure that the change in $[\Delta\Theta]$ is always positive, a sufficiently large constant d_{a-j} is added to each $\Delta\Theta_j$. This changes the structural variables from $[\Delta\Theta]$ to $[\Delta\tilde{\Theta}]$, and the power mismatches from $[\Delta Z]$ to $[\Delta\tilde{Z}]$. Equation (6) is then modified to become

$$[\Delta \tilde{Z}_a] = [H_a][\Delta\tilde{\Theta}] + [A_a] - [D_a] \quad \text{..........................} \quad (7)$$

where

$$[\Delta\tilde{\Theta}] = [\Delta\Theta] + [d_a] \quad \text{..........................} \quad (8)$$

$$[\Delta \tilde{Z}_a] = [\Delta Z_a] + [K_a] \quad \text{..........................} \quad (9)$$

$$[K_a] = [H_a][d_a] \quad \text{..........................} \quad (10)$$

Similarly, the reactive subproblem (4), P-Q, can be modified to become

$$[\Delta \tilde{Z}_r] = [H_r][\Delta\tilde{V}] + [A_r] - [D_r] \quad \text{..........................} \quad (11)$$

where

$$[\Delta\tilde{V}] = [\Delta V] + [d_r] \quad \text{..........................} \quad (12)$$

$$[\Delta \tilde{Z}_r] = [\Delta Z_r] + [K_r] \quad \text{..........................} \quad (13)$$

$$[K_r] = [H_r][d_r] \quad \text{..........................} \quad (14)$$

To arrive the best processing of the state variables, the sum of the active slack variables $[A_a]+[D_a]$ and the sum of the reactive slack variables $[A_r]+[D_r]$ must be minimised. Let $[W]$ is a row matrix, $[1xM]$, where, the ith element W_i is a weighting factoor assigned to the ith measurement. Also let the active and reactive cost functions C_a and C_r are the sum of the errors, i.e.

$$C_a = [W_a]([A_a] + [D_a]) \text{ ....} \quad (15). \qquad C_r = [W_r]([A_r] + [D_r]) \text{ ....} \quad (16)$$

The algorithm of CDP1 can now be summarised by the following steps:

(1) Minimise C_a (eq.15) to satisfy the following constraints:

$$[H_a][\Delta\hat{\Theta}] + [A_a] - [D_a] = [\Delta\hat{Z}_a], \quad [\Delta\hat{\Theta}] \ge 0, \quad [A_a] \ge 0, \quad \text{and } [D_a] \ge 0 \quad \text{.........} \quad (17)$$

(2) Minimise C_r (eq.16) to satisfy the following constraints:

$$[H_r]\ [\Delta\hat{V}] + [A_r] - [D_r] = [\Delta\hat{Z}_r], \quad [\Delta\hat{V}] \ge 0, \quad [A_r] \ge 0, \quad \text{and } [D_r] \ge 0 \quad \text{.......} \quad (18)$$

This process is repeated iteratively until the change in the state variables between two successive iterations is less than or equal to a prefixed tolerance. Thus CDP1 is a linear programming algorithm of (M) equality constraints and (N+2M) variables.

CDP2

If (M) slack variables can be handled implicitly by the linear progrmming algorithm without requiring computer storage, then the size of the subproblems of CDP1 can be reduced as a way of reducing computer memory and improving speed. It is possible by reformulating the equality constraints as inequality constraints. Since A_{a-i} is by definition either positive or zero where it is desired to minimse $A_{a-i} + D_{a-i}$, thus the equality constraints of eq. (17) can be rewritten as equalities as:

$$[H_a][\Delta\hat{\Theta}] - [D_a] \le [\Delta\hat{Z}_a] \quad \text{..........................} \quad (19)$$

Furthermore, the sum of the slack variables $[A_a] + [D_a]$ can now be defined from eq. (17) as

$$[A_a] + [D_a] = 2[D_a] + [\Delta\hat{Z}_a] - [H_a][\Delta\hat{\Theta}] \quad \text{....................} \quad (20)$$

But $[\Delta\hat{Z}_a]$ is a constant, and may be omitted, giving

$$[A_a] + [D_a] = 2[D_a] - [H_a][\Delta\hat{\Theta}] \quad \text{......................} \quad (21)$$

Similarly;

$$[A_r] + [D_r] = 2[D_r] - [H_r][\Delta\hat{V}] \quad \text{....................} \quad (22)$$

Therefore, the active and reactive cost functions, C_a and C_r, can be modified using equations (15), (16), (21) and (22) to become $\hat{C}_a$ and $\hat{C}_r$

where
$$\hat{C}_a = [W_a]\ \{2[D_a] - [H_a][\Delta\hat{\Theta}]\} \quad \text{........................} \quad (23)$$
$$\hat{C}_r = [W_r]\ \{2[D_r] - [H_r][\Delta\hat{V}]\} \quad \text{........................} \quad (24)$$

Then, the CDP2 can be summarised, as linear programming algorithm of (M) inequality constraints and (N+M) variables, in the following steps:

(1) Minimise $\hat{C}_a$ (eq. 23) subject to

$$[H_a][\Delta\hat{\Theta}] - [D_a] \le [\Delta\hat{Z}_a], \quad [\Delta\hat{\Theta}] \ge 0 \quad \text{and } [D_a] \ge 0 \quad \text{.................} \quad (25)$$

(2) Minimise $\hat{C}_r$ (eq. 24) subject to

$$[H_r][\Delta\hat{V}] - [D_r] \le [\Delta\hat{Z}_r], \quad [\Delta\hat{V}] \ge 0 \quad \text{and } [D_r] \ge 0 \quad \text{.................} \quad (26)$$

The above two subproblems of steps 1 and 2 are iterated in sequential manner until convergence stopping criterion is obtained.

COMPUTATIONAL EXPERIMENTS

Because of the assumptions involved in calculating the elements of the $[H_a]$ and $[H_r]$, the sum of any row is zero. Consequently, if the $[D_a]$ constants, or $[D_r]$ constants added to the structural variables are the same, then from eq. (10) and (14) the value of K_{a-i} (or K_{r-i}) will be equal to zero. If the $[D_a]$ constants, or $[D_r]$ constants, are different, K_{a-i} (or K_{r-i}) would be representative of only the differences among them and not their true. But the true values of $[D_a]$ and $[D_r]$ constants are essential because at the end of the processing they are subtracted from $[\Delta\Theta]$ and $[\Delta V]$ to give the change $[\Delta\Theta]$ and $[\Delta V]$. An effective and simple way to go around this problem is to create an offset or bias the row just big enough to make the value of k_{a-i} and K_{a-r} felt on R.H.S. Which is not too big to affect the accuracy of the solution. Therefore, the diagonal elements of $[H_a]$ and $[H_r]$ are increased by a small fixed scaler quantity $\propto$. Thus the performance of CDP1 or CDP2 depends heavly of the value of these additional constants $[D_a]$, $[D_r]$ and $\propto$ However, the optimum values of these constants are difficult to calculate, but they can be determined empirically.

In an attempt to achieve fast and reliable convergence, it is necessary to establish ranges for these constants. So, series of tests with various values of these constants were performed by CDP1 on different systems with various redundancy ratios (M/N). The results are obtained using VAX Computer. Only the results of the 14-Bus system with redundancy ratio of 1.8 are reported here. These results are summarised in figure (1) which indicates the effects of $[D]$ and $\propto$, where $[D] = [D_a] = [D_r]$, on the processing time and the performance indicators SD1 and SD2. Where SD1 and SD2 are the standard divation of the errors in the voltage magnitudes and in the phase angles, respectively. The results shown that the addition of a small value of $\propto$ makes the difference between convergence and an unbounded or an infeasible solution. This resulted in the following ranges of 0.25: 0.75 for $[D]$ and 0.25 : 1.25 for $\propto$. The one chosen was a good compromise between computing time and accuracy ; i.e. when $\propto = 0.5$ and $D_j = 1.0$, (j=1,2, ..., N)

The effeciency of CDP1 and CDP2 is verified by two set of tests on the 14 bus system under redundancy ratios ranged from 1.8 to 2.9. The first set is carried out in the absence of bad data. While the second set of tests is carried out in the presence of three bad measurements which are immersed in the system. These bad data are the negative values of their actual values which are all active power line flows, and two of them are directly affecting the same node (interacting bad data). The results obtained from these set of tests are given in figure (2) . Which indicate storage requirements, processing time and errors. The results showed that:

(a) Both CDP1 and CDP2 were able to reject all these bad data points, which were indicated in the program by their associated slack variables.
(b) CDP1 requires additional computer memory over that required for CDP2.
(c) In all cases, CDP2 was much faster than CDP1.
(d) Approximately, both processors gave the same accuracy.

In general, the convergence characteristics of CDP2 were found to be very good and far superior than CDP1.

However, CDP2 ignores the natural decomposition of the large system into subsystems and has been applied to process the whole system's data at one central level. It requires all measured data to be communicated to a central computer leading to heavy information transmission from many sites on the system to the control center. Also, the results showed that the direct result of the increase in the system's size is the increase in the processing requirements and errors. So, the results would be useless by the time they are made available at the control center, where we hope to achive reliable decisions as fast as possible for real-time control. Therefore, the Paralcet Data Processor (PDP) is proposed in the present work and explained in the next pages.

PARALLEL DATA PROCESSOR (PDP)

The overall power system consisting of (N) nodes and (L) lines can be decomposed into A subsystems, consisting of N_i nodes and L_i lines, where i=1,2, ..., A. These subsystems are interconnected by L_t of tie-lines, which terminate at N_b boundary nodes, this area is known as the interconnection area. This decompostion scheme can be summarised as follows:

$$N = \sum_{i=1}^{A} N_i \qquad \text{and} \qquad L = = L_t + \sum_{i=1}^{A} L_i$$

The measurement and state variables are then decomposed into subvectors, according to their association with the subsystems, as follows:

$$[Z] = \{[Z]^t_1 , \ldots\ldots\ldots\ldots , [Z]^t_i , \ldots\ldots\ldots\ldots , [Z]^t_A , [Z]^t_t\}^t$$

where $[Z]_i$ is the measurement vector of the ith susbsystem, and $[Z]_t$ is the measurement vector of the tie-lines interconnection area. The local measurement vactor $[Z]_i$ can be expressed as a function of the local states vector $[X]_i$ as;

$$[Z]_i = \{h([X]_i)\} + [e]_i \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (27)$$

where $[X]_i$ is the local state vector of the ith subsystem which has its own slack node, i.e. one component of $[X]_i$ is set to zero. Thus in the complete system, there A slack nodes. In the final processing $[X]_i$ is referred to a global reference. This in turn demands the introduction of (A-1) - dimensional coordination phase angle vector [U] where

$$[U] = \{U_1, \ldots\ldots\ldots , U_i, \ldots\ldots\ldots U_{A-1}\}^t \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (28)$$

where the slack node in the Ath subsystem is chosen as the global reference, i.e. $U_A=0$, and the variable U_i is the phase angle of the slack node in ith subsystem with respect to that of the global reference. Then the measurement vector $[Z]_t$ of the tie-lines can be related to the vector [U] by:

$$[Z]_t = \{h([U])\} + [e]_t \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (29)$$

Therefore, the CDP Problem is now decomposed into A+1 subproblems, A for A sushsystems plus one for the coordination. The overall processing can then be carried out by using PDP at two levels (primary and secondary). The primary level involves A local computers, each in charge of one subsystem. The interaction caused by individual operation of local computers is coordinated by central computer at the secondery level.

PRIMARY LEVEL

At this level, equations (27) are processed simultaneously in parallel and independently for all A subsystems by A local computers, which the boundary condition is represented by the equivalent nodal injections. The local measurements $[Z]_i$ are processed and the local vectors $[X]_i$ are obtained using an iterative procedure similar to that of CDP2 (equations 23-26). To differentiate between local processing and global processing, the vector $[\Delta \Theta]_i$ is used instead of $[\Delta\Theta]$ in equations (23) - (26). Where $[\emptyset]_i$ comprise of the local phase angles at all nodes within subsystem i with respect to its own local slack node. This leading to a local iterative procedure for subsystem i, which consists of the following steps:

(1) Minimise $\grave{C}_{a-i} = [W_a]_i\ (2[D_a]_i - [H_a]_i\ [\Delta\grave{\emptyset}]_i)$ .... (30)

subject to

$$[H_a]_i\ [\Delta\grave{\emptyset}]_i - [D_a]_i \leq [\Delta\grave{Z}_a]_i\ , \quad [\Delta\grave{\emptyset}]_i \geq 0 \quad \text{and } [D_a]_i \geq 0$$

(2) Minimise $\grave{C}_{r-i} = [W_r]_i\ (2[D_r]_i - [H_r]_i\ [\Delta\grave{V}]_i)$ .... (31)

subject to

$$[H_r]_i\ [\Delta\grave{V}]_i - [D_r]_i \leq [\Delta\grave{Z}_r]_i\ , \quad [\Delta\grave{V}]_i \geq 0 \quad \text{and } [D_r]_i \geq 0$$

Upon completion of the local processing, the local vectors $[X]_i$ is obtained where $[X]_i = [V,\emptyset]_i$. However, coordination between subsystems is not yet possible because the vector [U] is still unknown. Therefore, the complex voltages at all boundary nodes, $[X_b]$, as a part of the local vectors $[X]_i$, will be sent to the secondary level.

SECONDARY LEVEL

The function of the central computer at the secondary level is confined to obtain the coordination vector from the active power flow measurement vector $[Z_a]_i$ of the tie-lines of the interconnection area, i.e. incorporating the effects of the following equation

$$[Z_a]_t = [h([U])] + [e]_t$$

Applying the inequality constraints approach of linear are decoupled techniques to the above equation, yields the following model of the iterative procedure at the secondary level:

Minimise $\grave{C}_{a-t} = [W_a]_t\ (2[D_a]_t - [H_a]_t\ [\Delta\grave{U}])$ .... (32)

subject to

$$[H_a]_t\ [\Delta\grave{U}] - [D_a]_t \leq [\Delta\grave{Z}_a]_t\ , \quad [\Delta\grave{U}] \geq 0 \quad \text{and } [D_a]_t \geq 0$$

The above iterative procedure is started from $[U^0] = 0$, and the vector $[X_b]$ is used as contant information about the boundary conditions. At the end, the processed vector [U] is obtained and the components U_i are transmitted back to the corresponding subsystems.

All the local phase angles $[\emptyset]_i$ can now be reported to the global reference by adding to each of them the corresponding component U_i, i.e.

$[\Theta]_i = [\emptyset]_i + U_i[E]$ where [E] is a unit vector. The final form of the vectors $[X]_i$ is presented by $[X]_i = [V,\Theta]_i$

TEST RESULTS

A good data processor depends on :

- the speed and the reliability of convergence,
- the accuracy of the final solution,
- the ability to minimise or eliminate the effects of bad data,
- storage requirements, and
- the amount of information transfer.

Therefore, the present step of the investigation is to determine which algorithm satisfies all the essential qualities. This section has been focused on the efficiency and implementation of CDP2 and PDP. Its aim is to determine the merits and demerits of each algorithm under different conditions.

Both algorithms CDP2 and PDP are tested on 23-bus system which derived from reference [8] . This system is the 275 KV network of the North of Scotland Hydro Electric Board (NSHEB) system. It comprises of 23 nodes and 26 lines. The natural decomposition of this system consisting of two subsystems (A=2). The first subsystem consists of 11 nodes and 10 lines, while the second subsystem comprises of 12 nodes and 14 lines and the overall reference bus. These subsystems are connected by an interconnection area with 2 tie-lines and 3 boundary nodes. Two sets of tests are carried out on this system and these are explained as follows.

++ Both sets of tests are performed under four different configurations of measurements and redundancy ratios (which were 1.5, 2.1, 2.3 and 2.5).
++ In the first set; both algorithms CDP2 and PDP are tested in the absence of bad data.
++ In the second set; tests on CDP2 and PDP carrried out in the presence of five bad measurements which are immersed in each measurement configuration; and are numberd from A to E.

The bad measurements A to E are on mixture of active and reactive power of both line flows and nodal injections, and are injected into the system according to the following :

- reading A is increased by 30 MW,
- readings B and E are decreased by 50%,
- reading C is the negative value of its actual value, and
- reading D is reduced to zero.

The first four bad points (A to D) are immersed in subsystem (1), and three of them (A to C) are directly affecting the same node (interacting), and the fifth bad point E, is confined to the interconnection tie-line area.

The local processing were carried out in parallel (simultaneously) for the two subsystems but indepently for each other. It was found that the voltage magnitudes of both subsystem (1) and subsystem (2), even at the boundary nodes, are closely approximated to their true values. Also, the phase angles of subsystem (2) are equal to their true valus which has the global refernce, while that of subsystem (1) needs the coordination phase angle. This means that the local obtained values may be considered as true valus and only the coordination angle needs to be evaluated by the central computer at the secondary level.

The convergence properties and the performances of the CDP2 and the proposed PDP under different conditions of redundancy retios and bad measurements are summarized in figure (3), which gives the storage requirements the total processing time and errors. It was found that all the five bad measurements were rejected using either the CDP2 or the PDP (which were indicated in the solution by their associated slack variables). The additional time required to reject the bad data was not significant. However, from figure (3), it can be seen that the proposed PDP algorithm performs well and more effective with different redundancy ratios and bad measurements, and offers significant advantages over the CDP2.

The PDP offers a big reduction in storage requirements, and was faster which converged in about 10% of the processing time required for the CDP2. The results proved that the PDP and the CDP2 can all be assumed to converge to the same final value because the differences between the processing errors are not significant which were about $2X10^{-5}$ p.u. and 10^{-4} degree. On the other hand, in the case of centralized CDP2, the measurements are transmitted from various points throughout the system to the processor. It necessitates communications between all these data points with the central computer. While in the case of the decentralized PDP, the local computer uses its local measurements, and the central computer receives and transmits certain measurements to the local computer. It means that data communication requirements are lower in the PDP than for the CDP2.

CONCLUSION

Two central data processors (CDP1,2) for power system control are formulated. The first is based on the equality constraints and the second on the inequality constraints. Tests were performed to establish ranges for the related constants. The performances of both algorithms are tested in the absence and in the presence of bad data, and under different redundancy ratios on 14-Bus system., using VAX computer. The results showed that the second algorithm looked the most attractive.

However this approach ignores the natural decomposition of the system and involves computations in a centralized nature with measurements made at various points throughout the system, and are processed at the same single level. Experience showed that the CDP for a large power system is a paramount task. Therefore, in this paper, parallel data processor (PDP), incorporating a two-level technique and based on inequality constraints is proposed, simulated on a computer, and compared with the CDP algorithm. Both the CDP and PDP are programmed and tested against the redundancy ratios and bad data. The results confirmed the advantages of the proposed PDP algorithm.

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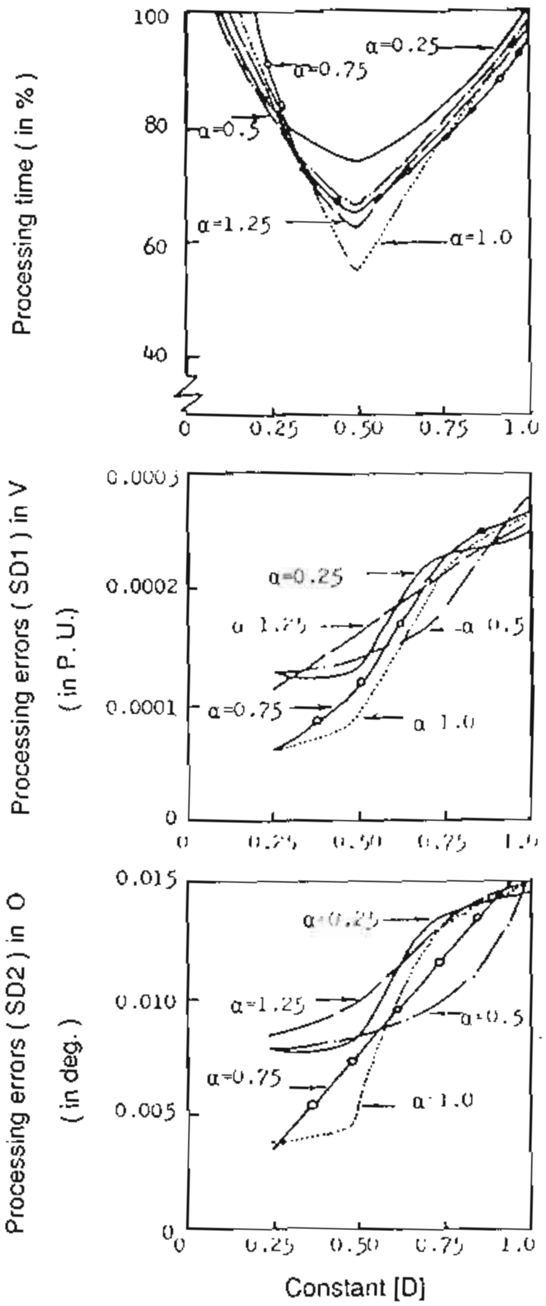

Fig (1) : The effect of the constants [D] and ∝ on the performance of CDP1.

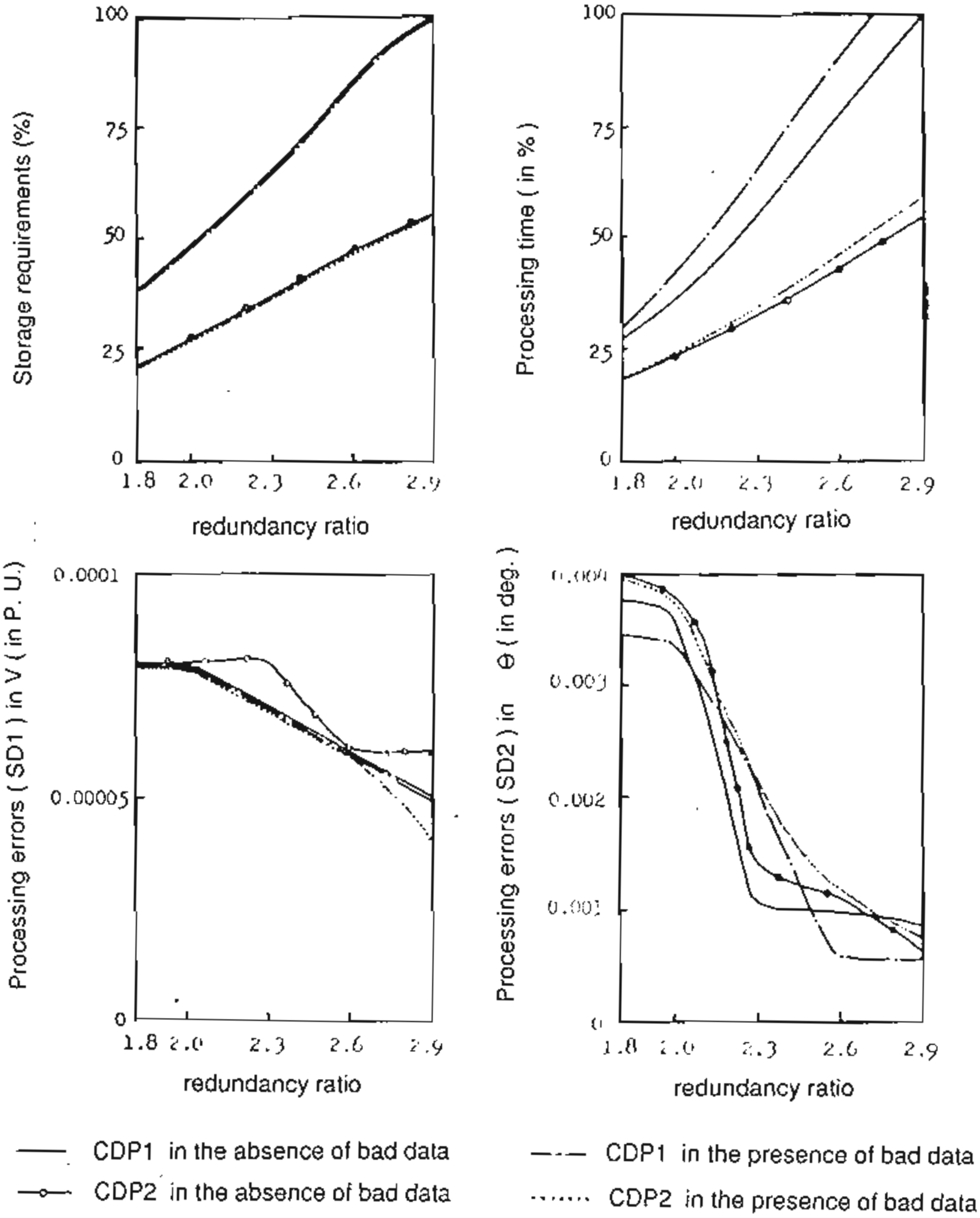

Fig. (2): Performance of CDP1 and CDP2 for the 14 - bus system.

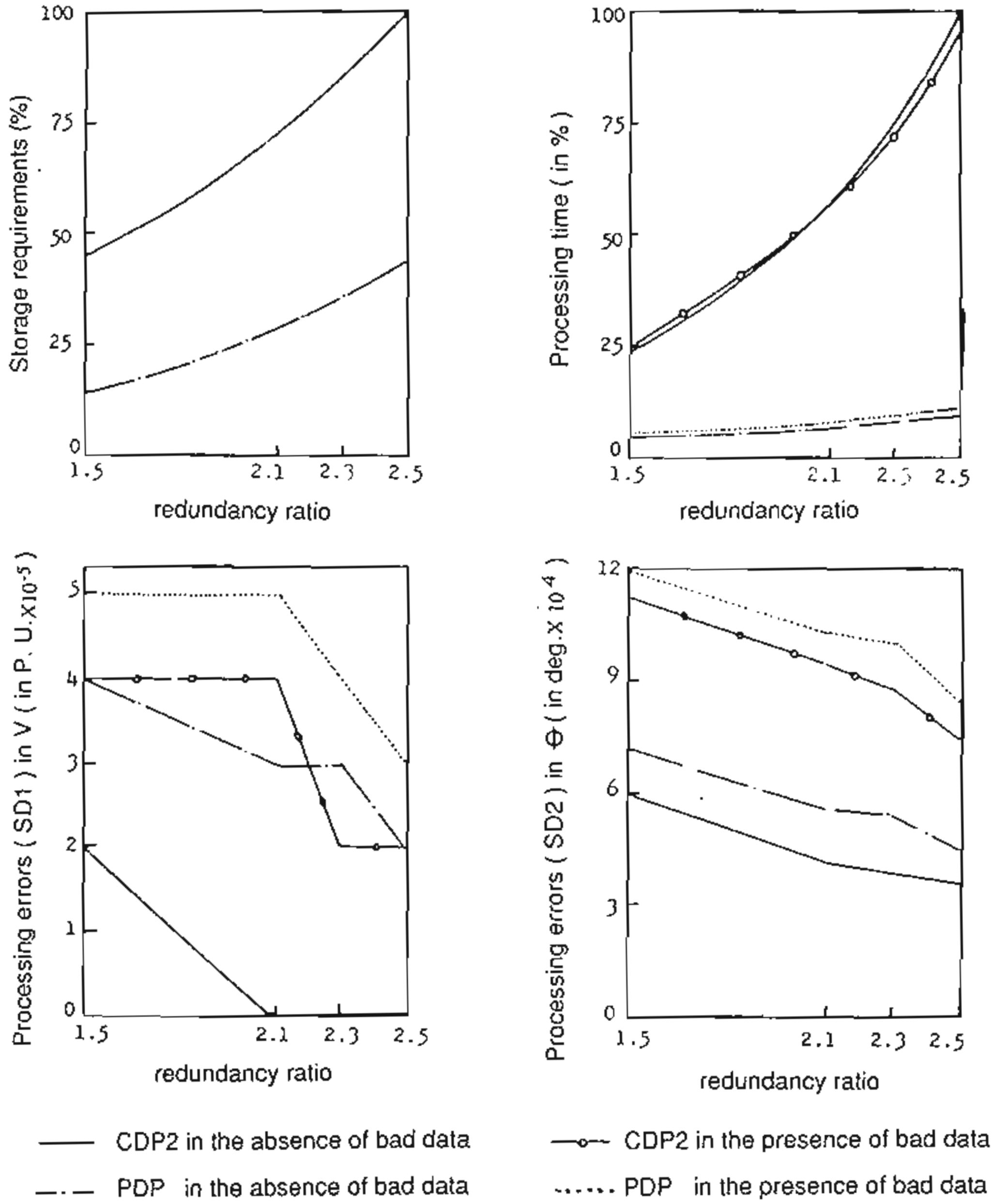

Fig. (3): Performance of CDP2 and PDP on the 23 - bus system.