Calculation the Critical Clearing Time CCT for Iraqi super grid in a fast manner of three - phase fault

حساب زمن الازالة الحرج CCT لمنظومة العراق الفائقة بطريقة سريعة لعطل ثلاثي الاطوار

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Abstract

This paper describes the use of direct method (Relative Unstable Equilibrium Point method (RUEP)) to evaluate the Critical Clearing Time (CCT) of power system subjected to large contingencies. The main aim is to reduce the execution time of the process of finding of the Critical Clearing Time for transient stability analysis, this method runs fast but with poor accuracy due to the over-simplification of component models; the time-domain simulation method is accurate but time- consuming. Results of the (RUEP) method applied on the simulation examples and actual system calculation are analyzed, and the range of error is discussed. Via complementarity of direct method and time-domain simulation method, a new crossbred method is proposed: in the calculation of the critical clearing time, the result of the direct method is used as the initial value and then the time-domain simulation method is employed for further search, which can meet the requirements of transient stability in terms of accuracy and speed. The results obtained by two methods show that the proposed method reduces the execution time of the Central Processing Unit about 8-10 times. In this paper the CCT was calculated for power system 400kvIraq Super Grid.

Keywords: Relative Unstable Equilibrium Point method, time-domain simulation, crossbred method, critical clearing time.

الملخص

يصف هذا البحث استخدام الطريقة المباشرة (طريقة نسبة عدم توازن نقطة عدم الاستقرارية (RUEP)) لتقدير زمن الازالة الحرج لمنظومة قدرة خاضعة لحالة عطل كبير. الهدف من ذلك تقليل الزمن المستغرق في عملية ايجاد زمن الازالة الحرج من اجل تحليل الاستقرارية العابرة ، تمتاز هذه الطريقة بكونها سريعة لكنها تفتقر الى الدقة المتناهية بسبب التبسيط لمكونات منظومة القدرة ، طريقة محاكاة المجال الزمني دقيقة ولكنها تستغرق وقتا طويلا.النتائج المطبقة من طريقة (RUEP) لامثلة من مظومة حقيقية تم احتسابها و تحليلها مناقشة نسبة الخطأ. عن طريق اقتراح طريقة جديدة لكلا من الطريقة المباشرة وطريقة المحاكاة المجال الزمني ،الطريقة الهجينة الجديدة: في حساب زمن الازالة الحرج ،النتائج المستخدمة من الطريقة المباشرة كقيم اولية و ثم يتم استخدام طريقة محاكاة المجال الزمني لمزيد من البحث ،والتي يمكن أن تلبي متطلبات الاستقرارية العابرة من حيث الدقة والسرعة. تظهر النتائج التي تم الحصول عليها بواسطة طريقتين أن الطريقة المقترحة تقلل من وقت تنفيذ وحدة المعالجة المركزية حوالي 8-10 مرات.في هذا البحث ال(CCT) المحسوب لمنظومة قدرة شبكة العراق االفائقة (400KV).

الكلمات الافتتاحية : طريقة نسبة عدم توازن نقطة عدم الاستقرارية محاكاة المجال – الزمني ،الطريقة الهجينة ،زمن الازالة الحرج .

1. Introduction

In recent years, research on the transient stability problem revolves around the identification of critical machine, critical clearing time and system transient stability modeling. However, solving nonlinear calculations on transient stability requires a long time, in contrast with the necessity to overcome the problem quickly and accurately [1].

An alternative approach, called transient energy function methods [2-3], assesses system stability based on the transient energy. Those methods provide fast stability assessment, while a common disadvantage is concerned with the accuracy of stability judgment. The limitation in accuracy comes from the fact that all those methods are inherently approximations.

The critical clearing time (CCT) of three-phase short circuit is an important parameter which shows the transient stability limit of power system. The research on CCT calculation by the direct method concentrates on improvement of the accuracy [4],[5]; the corresponding study on CCT solved by the time-domain simulation method focuses on enhancement of the speed [6]-[7]. The method proposed in[8] combines the advantages of the two methods, where the direct method is used for fault scanning and the time-domain simulation method is used for those serious faults. However, this method does not consider the possible omission of serious faults caused by the inaccuracy of the direct method and does not directly shorten the time for CCT calculation.

In this paper, the error range of the "RUEP (Relative Unstable Equilibrium Point method) is discussed, then the results of RUEP method are used to provide search ranges of further CCT calculation by the time-domain simulation method, and finally this new method is testified by the simulation on 400kvIraq Super Grid[9].

Several researchers studied the problem and put suggestions and trails to overcome Instabilities. Review of many previously published works is presented as follows:-

Lewis G. W 2015 [10]: This study shows that an analytical approximation of the selective clearing time (CCT) is derived from the direct methods of stability of the energy system. This formula is designed to incorporate as many possible characteristics of transient stability analysis as possible, such as different error locations and different network situations after the failure. The purpose of this measure is to analyze trends in stability (in terms of CCT) of energy systems under the system parameter change.

Shikha Sharma2018[11]: In this study, the researchers devised a new and accurate version of the first-time sensitivity of the system's time-frame for the system parameter. The equation is evaluated through integrative equations forward in a timely manner along the error path in the case of the rule and the integration of convergent differential equations back in time along the path after the error.

Kumkratug2012[12]: this paper investigate the critical clearing time of power system with synchronous machine. The mathematical model of non-salient pole and salient pole synchronous machine model in power system are symmetrically derived. The critical clearing time of both models are tested and compared on various cases. Results: The critical clearing time of the power system with synchronous including saliency is slightly higher that of non-saliency model.

3. Time-Domain Simulation Method[13]

In transient analysis, the models of generators, loads, controllers and other various Components of the power system are composed of differential equations that describe the dynamic characteristics of the components and linear algebraic equations that describe the network. The method that uses numerical integration in solving the system differential equations is called the time domain simulation method. Then the Differential-Algebraic Equation DAE is solved with a certain steady-stat**.**

$$\begin{cases} \dot{X} = F(X,Y) \\ Y = G(X,Y) \end{cases} \quad (1)$$

where $F=(f_1,f_2, \ldots,f_n)^T$, $G = (g_1, g_2,\ldots, g_n)^T$ $X = (x_1, x_2,\ldots,x_n)^T$ is the factors of differential conditions) Y = (y1, y2,… ..yn)T is the factors of logarithmic conditions.

In this paper, the trapezoidal verifiable reconciliation strategy is embraced in the iterative calculation of differential conditions; the direct triangular deterioration technique is joined with the iterative calculation to fathom the arithmetical conditions; the emphases of the differential conditions and the logarithmic conditions run then again until the point when they combine and this is the unraveling procedure of one time step. Under the state of deficiencies, the differential conditions are not consistent when the event and evacuate of the shortcomings prompt changes of the permission network. Right now, the DAE should be altered and settled independently in various time interims. At present, the time-area reproduction technique is extremely develop as far as mathematic display, estimation calculation and programming, and as an intense instrument for disconnected examination it has been comprehensively utilized in useful activities. The real points of interest of this technique include:

1) Precise models

2) Good numerical soundness

3) Ability to test the legitimacy of other systematic techniques for different physical issues and control methodologies.

With the amplification of the power framework, the prerequisite for constant examination is updated and in this manner the shortcomings of the time-area recreation technique are getting to be self-evident:

1) Huge outstanding task at hand and long work time for transient strength examination of substantial scale control framework;

2) Inability to give a quantitative dependability record.

3) Low use of the gigantic data accomplished in the recreation procedure.

The CCT figuring by time-area recreation ordinarily embraces the division strategy and considers.

the point at CCT as the Not-Return-Point (NRP). The definite procedure is as per the following: right off the bat, set the underlying clearing time, $t_0 = 0$ s, $t_e = 5$ s (The underlying inquiry run is set to be 0-5s for the reason that CCT bigger than 5 seconds won't impact the framework soundness because of the activity of transfer and control gadgets.); at that point decide the framework dependability at the center clearing time $tm = (t_0 + t_e)/2$. The transient security paradigm is the conventional rotor edge standard and the greatest rotor point is set to be 500 degrees. In the event that the framework is steady, at that point reset the begin time $t_0 = t_m$; something else, reset the end time $t_e = t_m$. In conclusion, cycle the procedure until $t_0 - t_e$ achieves the assigned exactness scope. Since the underlying pursuit run is set cautiously, the quantity of cycles is substantial in this strategy and the count speed is low for investigation of vast scale control framework.

4. RUEP Method [14-15].

In the RUEP method, the transient energy is defined as follows:

$$V = V_{ke} + V_{pe} = \sum_{i=1}^{n} \frac{1}{2} M_i \omega_i^2 + \sum_{i=1}^{n} \int_{\theta_l^1}^{\theta_l} -\left(P_{mi} - P_{ei} - \frac{M_i}{M_T} P_{col}\right) d\theta_i \quad (2)$$

Where V_{ke} and V_{pe} are kinetic energy and potential energy respectively.

$$V_{ke=\sum_{i=1}^{n}\frac{1}{2}M_i\omega_i^2} \quad (3)$$

$$V_{pe} = \sum_{i=1}^{n} \int_{\theta_l^1}^{\theta_l} -\left(P_{mi} - P_{ei} - \frac{M_i}{M_T} P_{col}\right) d\theta_i \quad (4)$$

The mode of system instability is that these two groups lose synchronism with each other defining the equivalent speed of the two centers as follows:

$$\dot{\omega}_k = \sum_{i=1}^{k} \frac{M_i \dot{\omega}_\iota}{M_k}$$

(5)

$$\theta_k = \sum_{i=1}^{k} \frac{M_i \theta_i}{M_k} \quad (6)$$

$$M_k = \sum_{i=1}^{k} M_i$$

$$\omega \dot{}_{T-k} = \sum_{i=1+k}^{n} \frac{M_i \dot{\omega}_1}{M_{T-k}}$$

$$\dot{\theta}_{T-k} = \sum_{i=1+k}^{n} \frac{M_i \dot{\theta}_1}{M_{T-k}}$$

$$M_{T-k} = \sum_{i=1+k}^{n} M_i$$

The following equation can be derived:

$$M_k \theta_k + M_{T-K} \theta_{T-k} = 0 \quad (7)$$

$$M_k \dot{\omega}_k + M_{T-K} \dot{\omega}_{T-k} = 0 \quad (8)$$

In the equivalent two –machine system ,the kinetic energy causing the separation of the two groups is the same as that of an equivalent (OMIB) One Machine Infinite Bus system having inertia constant M_{eq} and angular speed ω_{eq} given by :

$$M_{eq} = \frac{M_k M_{T-k}}{M_T} \quad (9)$$

$$\omega_{eq} = \omega_k - \omega_{T-k} \quad (10)$$

And the corresponding kinetic energy is given by :

$$V_{ke} = \frac{1}{2} M_{eq} \dot{\omega}_{eq} \quad (11)$$

From (4)

$$V_{pe} = \sum_{i=1}^{n} \int_{\theta_l^1}^{\theta_l} -\left(P_{mi} - P_{ei} - \frac{M_i}{M_T} P_{col}\right) d\theta_i = -\sum_{i=1}^{n} P_i(\theta_i - \theta_i^s) - \sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\left[C_{ij}\left(\cos\theta_{ij} - \cos\theta_{ij}^s\right)\right] - \sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\int_{\left(\theta_i^s+\theta_j^s\right)}^{(\theta_i+\theta_j)} D_{ij}\cos\theta_{ij}\, d\left(\theta_i+\theta_j\right)$$

(12)

Where:

$$P_i = P_{mi} - E_i^2 G_{ii} \quad (13)$$

$$P_{ei} = E_i^2 G_{ii} + \sum_{j=1, j\neq i}^{n} (C_{ij}\sin\theta_{ij} + D_{ij}\cos\theta_{ij} \quad (14)$$

The linear route is assumed, which supposes that all the rotors move from θ^s to θ at a constant speed. Under this assumption, the power angle in the integration route satisfies the following equations:

$$\theta = \theta^s + \alpha(\theta - \theta^s) \quad (15)$$

This means all the machines move to the stable equilibrium point at a constant speed .This assumption is strictly untrue in the practical view but it makes the RUEP (Relative Unstable Equilibrium Point) method feasible and gets satisfied accuracy in most of the cases. Under this supposition, the integration term that depends on the actual trajectory can be calculated. Equation (12) can be changed into the following:

$$V_{pe} = -\sum_{i=1}^{n} P_i(\theta_i - \theta_i^s) - \sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\left[C_{ij}\left(\cos\theta_{ij} - \cos\theta_{ij}^s\right)\right] - D_{ij}\left(\frac{\theta_i+\theta_j-\theta_i^s-\theta_j^s}{\theta_{ij}-\theta_{ij}^s}\right)\left(\sin\theta_{ij} - \sin\theta_{ij}^s\right) \quad (16)$$

The critical energy is defined as the potential energy of the RUEP

$$V_{cr} = V_{pe}|\theta = \theta^u = -\sum_{i=1}^{n} P_i(\theta_i^u - \theta_i^s) - \sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\left[C_{ij}\left(\cos\theta_{ij}^u - \cos\theta_{ij}^s\right)\right] - D_{ij}\left(\frac{\theta_i^u+\theta_j^u-\theta_i^s-\theta_j^s}{\theta_{ij}-\theta_{ij}^s}\right)\left(\sin\theta_{ij}^u - \sin\theta_{ij}^s\right) \quad (17)$$

Where θ^s is the stable equilibrium point of the post fault system which can be derived from equations (18) by Newton's iteration method calculating the $P_{ei}(\theta)$ from the post fault topological parameter, and using the stable equilibrium point of the pre-fault system as the initial value .θ^u is the relative unstable equilibrium point, and can also be obtained from equation (18) by Newton's iteration method if choosing appropriate initial values.

$$f(\theta) = P_{mi} - P_{ei}(\theta) - \frac{M_i}{M_T}Pcol(\theta) = 0$$

$$\theta_n = \frac{\left(\sum_{i=1}^{n-1} M_i\theta_i\right)}{M_T} \quad (18)$$

In the relative uneven balance idea technique, the transient energy V of the scheme at the responsibility clearance period is calculated by equation (14), and the system critical energy V_{cr} can be obtained from formula (12). The stability of the system is assessed by the comparison of transient energy and critical energy:

$V < V_{cr}$ the system is stable

$V = V_{cr}$ the system is critical stable

$V > V_{cr}$ the system is unstable

A stability index can be derived in the following way:

$$\Delta V = \frac{(V - V_{cr})}{V_{ke|t=t_{cl}}} \quad (19)$$

Where:

$V_{ke|t=t_{cl}}$ Is the kinetic energy of the system at the fault clearing time.

Using equation (12), the critical clearing time can be obtained by calculating the potential energy along the fault-on trajectory until the potential energy reaches its maxi mum. Then the time corresponding to the maximum potential energy is the critical clearing time.

5-Flowcharts: The flow chart of the RUEP method is given at figure 2.

6. Scenario analysis

The following system is used test the RUEP and TDS. The test system shown in (1), Iraqi Super Grid System**.**

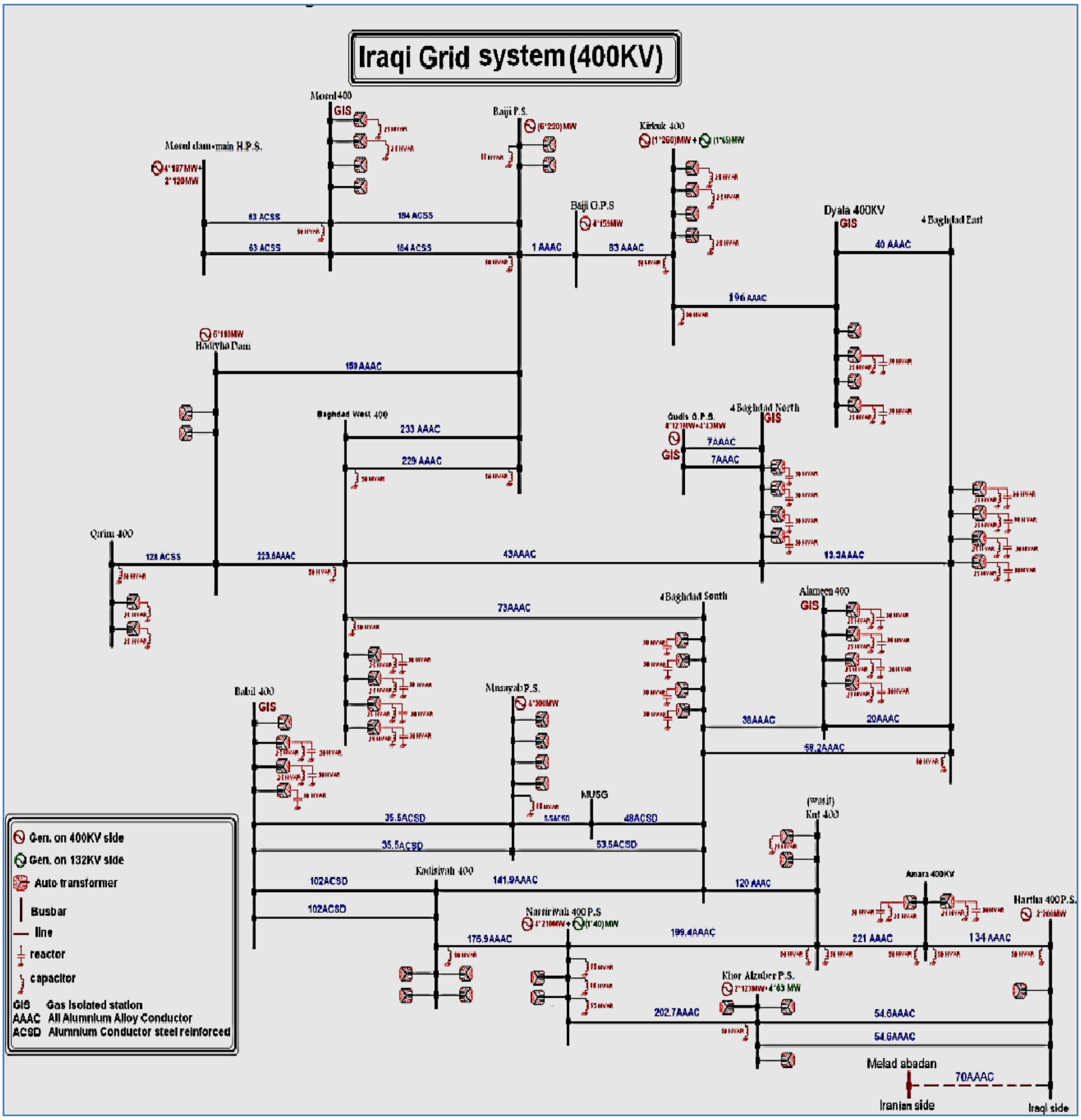

Fig. 1.Test System Iraqi Super Grid [17]

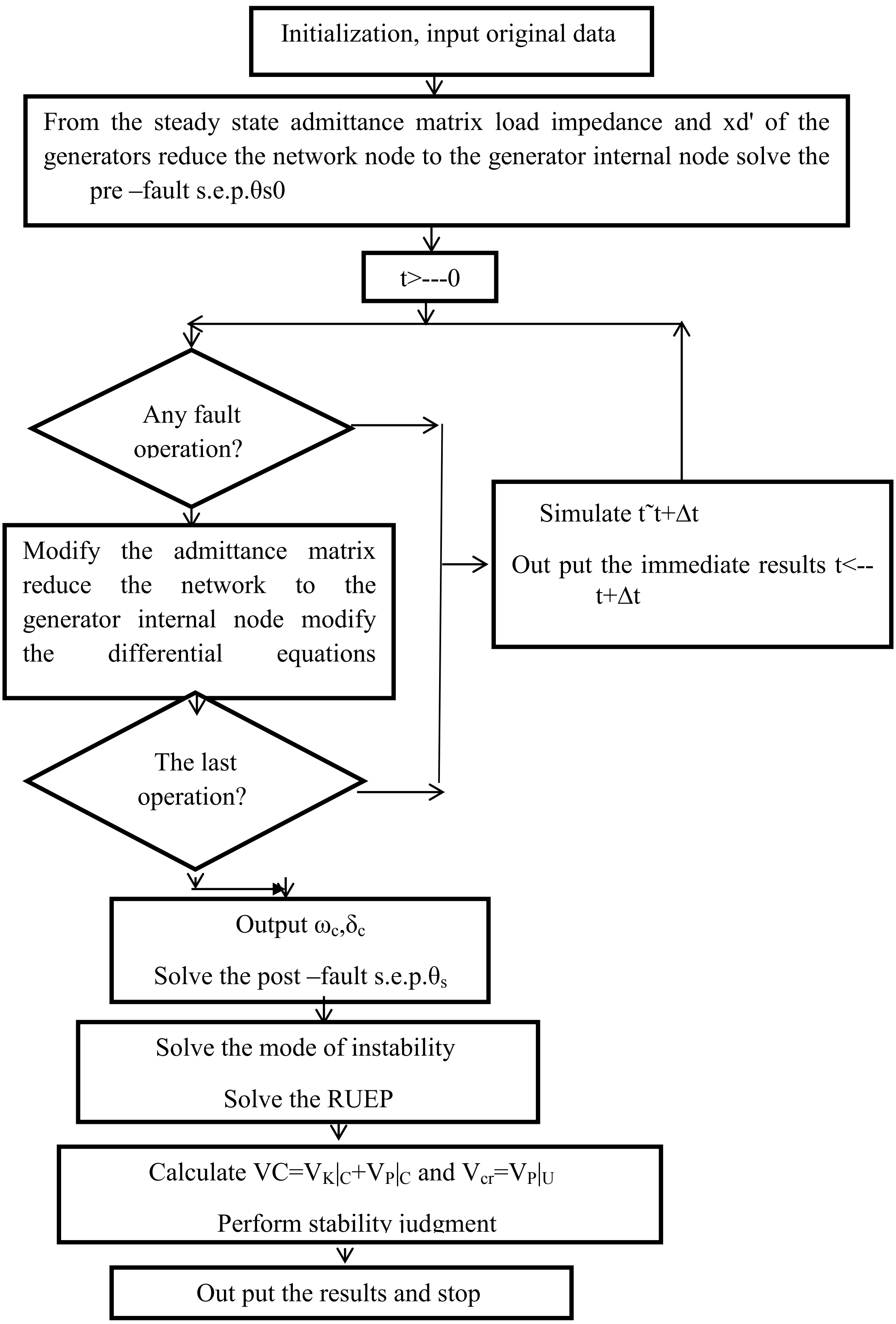

Fig. 2 Flow chart of CCT calculation by RUEP method[16]

In the RUEP method, the conservation property of transient energy counts on the precision of the energy expression. The calculation of V_p needs the constant impedance model and the classic generator model, and this simplification of models will bring error. To study this error the test system example is scanned and the CCT at every possible bus is calculated. The result is shown in Table1.

Table 1 Error analysis of CCT calculation by the RUEP method on the test system example.

"Fault bus number"	CCT(RUEP)	CCT(TDS)	Error (100%)
2	0.1	0.103	-2.9
6	0.11	0.093	7.5
7	0.15	0.122	9.4
18	0.15	0.124	5.6

In this table, TDS method means the time-domain simulation method whose results are used as the criteria of CCT calculation. Only the top seven buses with the least CCT is listed for the sake of brevity. From table 1, it is revealed that the error of RUEP method is acceptable and keeps below 10%. In this paper, the one-fold redundancy is adopted and thus the error is set to be 20%.

Contrast to the condition of the simple 10 machine example, in practical projects, the first task of CCT calculation by RUEP method is to simplify models and due to the complexity of modern power grid this simplification will conceal some important parameters. Thereby, there are some divergent points and points with oversize error where the further time-domain simulation will be in need for recalculation.

7. Crossbred technique

7.1Critical clearing time of three-phase short circuit fault

The fault clearing time is the time between the occurrence of the fault and its complete abscission. The critical clearing time t_{cr} is the maximum clearing time to keep the system stable, which meets the following conditions:

$$\begin{cases} t < t_{cr} \ \ stable \\ t = t_{cr} \ \ critical\,stable \\ t > t_{cr} \ unstable \end{cases} \qquad (19)$$

The three-phase fault is the most serious kind of fault, and its critical clearing time can reflect the transient stability of power system. Generally, the longer the CCT is, the stronger the system is in resisting the fault and the larger the corresponding stability margin. The CCT can be calculated by the TEF method or the time-domain simulation method: the former concentrates on calculation of the critical energy or the critical rotor angle and the later needs to modify the clearing time several times to successively approximate the CCT.

7.2 Crossbred method

The crossbred method, as specified above, is really the time-domain simulation method with the underlying ascertained by the RUEP strategy, whose point by point as appeared in stream outline in figure 3:

8. The Application of the Crossbred Method on Iraqi Super Grid:

Iraqi Super Grid System which is shown in figure (2) has been examined with its data (as shown at appendix A) by applying Crossbred Method at faulted buses (2,3,5,6,9,12,13,14,16,&19).

Table (2) illustrates the differences in the execution time CPU; time enhancements using RUEP method crossbred fast method. In order to reduce the total execution time and determine the CCT with a three-phase to ground fault at any fault location in order to setting the relays. This achieved by using crossbred method.

In this paper, the simulation is carried out on the 400kv Iraqi Super Grid System consists of 22 bus bars and 35 400 kV overhead transmission lines. Ten generating stations with different types of turbines are connected to the grid. They are of different kinds of generating units: thermal non-reheat, thermal single reheat, Gas turbine, and hydro-turbine types. The configuration of the network is given in the Appendix. Loads are represented by static admittance and transmission lines by the nominal π sections. All network data expressed in per-unit referred to a common base power of 100MVA and common base voltage of 400kV. This table lists the ten top buses with the least CCT and compares the accuracy of the RUEP method with that of the Crossbred method. From this table, among the then buses, only bus BSB4 has the RUEP result with an error over 20%, that is to say only one bus needs a second search. Moreover, based on the principle of the crossbred method, thanks to the same convergence condition, the result of this new method has the same accuracy with the time-domain simulation method.

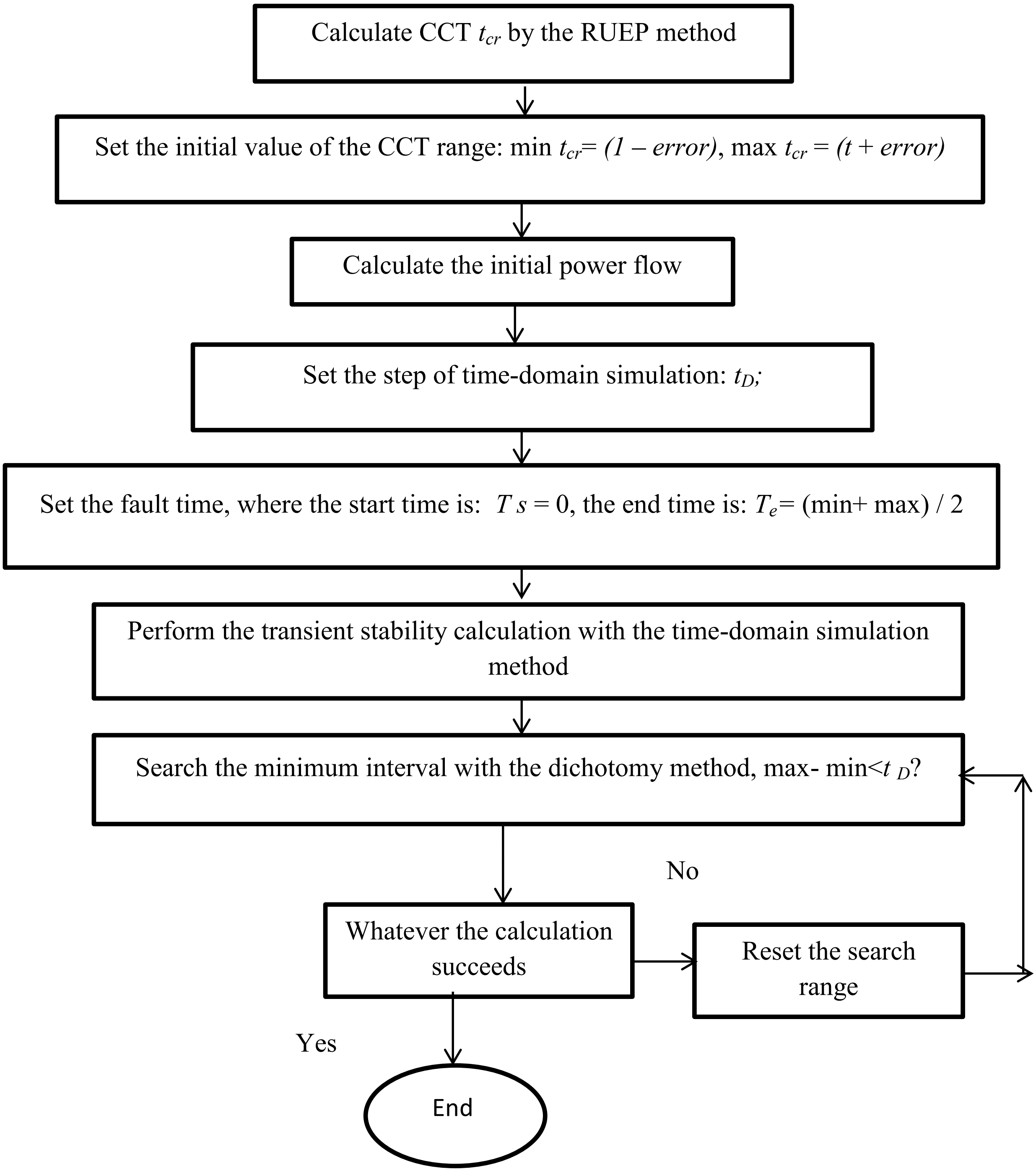

Fig. 3. Flow chart of CCT calculation by the Crossbred method

Table 2. Result of CCT calculation on the 400kV power grid of Iraq

Faulted Bus No.	Faulted bus name	Remove line	RUEP method CCT(second)	Crossbred method CCT(second)	Error (%)
2	MOS4	MOS4-KRK	0.11	0.12	-8.33
6	HAD4	HDTH- QAM4	0.12	0.13	-7.7
3	BAJ4	BAJ4-HAD4	0.12	0.12	0
9	BCN4	BCN4-BCE4	0.13	0.11	18.2
5	QAM4	QAM4-HAD4	0.14	0.17	-17.6
13	BSB4	BSB4-BCS4	0.15	0.20	25
14	BAB4	BAB4-MSB4	0.16	0.15	6.67
16	NAS4	NAS4-KDS4	0.16	0.19	-15.8
12	KUT4	KUT4-NAS4	0.17	0.18	-5.56
19	HRTP	HRTP-KAZ4	0.17	0.19	-10.5

The calculation time is shown in Table 3:

Table 3. CCT calculation time on the 400kV Iraqi super grid

	Time-domain simulation	crossbred method	Saving (%)
Computing time (minute)	29.34	10.75	29.34

This table compares the computing time of the time-domain method and the crossbred method on the 400kV power grid of Iraqi. Since the new method reduces the search range, the number of circulation decreases and the simulation shows that the crossbred method can save nearly 2/3 of the computing time compared with traditional method. With the increase of the magnitude of studied power grid, this merit will be more evident.

9. Conclusion

The aim of this research is improving the performance of the Iraqi Super Grid (400 KV). As a common tool for simple analysis of power system, the RUEP method is limited by the accuracy of its models and the statistic shows the error can basically keep below 20%; the Crossbred method mentioned in this paper can combine the merits of the RUEP method (fast speed) and the time-domain simulation method (high accuracy), and simulation results demonstrate that it is more competent application.

After the CCT was calculated for both methods and the error %rate calculated, for example the faulted bus number 2 **,** remove line MOS4-KRK,the CCT for RUEP method 0.11sec and Crossbred method 0.12sec the error rate-8.33%. Thus for all faults, compares the computing time of the time-domain method was29.34minute and the crossbred method 29.34 minute this comparison shows that the crossbred method can save nearly 2/3 of the computing time compared with traditional method.

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Appendix

Table (1) Data of Iraqi super grid generators [18].

Gen No	Node name	H (sec.)	$X`_d$ (p.u)	D (p.u)
1	BAJP	132	0.03	33
2	BAJG	23.16	0.058	15.44
3	MMDH	101.508	0.049	25.96
4	HDTH	36.096	0.063	15.36
5	QDSG	29	0.74	11.6
6	MUSP	104	0.0687	32
7	NSRP	99.94	0.075	21.04
8	HRTP	47.5	0.127	10

Table (2) Bus-data of Iraqi super grid[18]

Bus No	B-B Name	Bus Type	V(p.u)	P_g (p.u)	P_L(p.u)	Q_L(p.u)
1	BAJP	Slack	1.01	0.0	2.000	0.98
2	BAJG	Gen	1.01	2.000	0.90	0.10
3	MMDH	Gen	1.02	6.000	0.50	0.20
4	HDTH	Gen	1.0	5.000	1.000	0.60
5	QDSG	Gen	1.01	2.370	0.60	0.70
6	MUSP	Gen	0.96	6.000	1.20	0.70
7	NSRP	Gen	0.98	6.500	1.00	0.54
8	HRTP	Gen	1.03	3.800	0.38	0.22
9	MSL4	Load	0.0	0.0	3.00	1.80
10	KRK4	Load	0.0	0.0	0.70	0.40
11	DAL4	Load	0.0	0.0	1.50	0.80
12	BGE4	Load	0.0	0.0	5.000	3.600
13	BGN4	Load	0.0	0.0	3.000	2.000
14	BGW4	Load	0.0	0.0	5.000	3.60
15	QIM4	Load	0.0	0.0	0.600	0.40
16	BGS4	Load	0.0	0.0	1.000	0.50
17	AMN4	Load	0.0	0.0	3.500	0.47
18	KUK4	Load	0.0	0.0	1.000	0.60
19	QRNA	Load	0.0	0.0	0.70	0.30
20	KAZG	Load	0.0	0.0	3.50	2.00
21	BAB4	Load	0.0	0.0	1.00	0.50
22	KDS4	Load	0.0	0.0	2.000	1.000

Table (3) Transmission lines parameters of the Iraqi super grid system [18].

From Bus	To bus	Line's name	R(p.u)	X(p.u)	B(p.u)
3	9	MMDH-MSL4 (1+2)	0.001436	0.011768	0.364392
9	1	MSL4-BAJP (1+2)	0.004195	0.034371	1.064256
1	2	BAJP-BAJG	0.000022	0.000197	0.005837
2	10	BAJG-KRK4	0.001799	0.016351	0.484471
1	14	BAJP-BGW4	0.004832	0.043931	1.301651
1	14	BAJP-BGW4	0.004962	0.045113	1.336673
1	4	BAJP-HDTH	0.003446	0.031323	0.928083
4	15	HDTH-QIM4	0.002918	0.02391	0.740352
4	14	HDTH-BGW4	0.004845	0.044049	1.305153
14	13	BGW4-BGN4	0.000932	0.008471	0.250991
14	16	BGW4-BGS4	0.001582	0.014383	0.426101
12	13	BGE4-BGN4	0.000288	0.00262	0.077632
13	5	BGN4-QDSG (1+2)	0.000152	0.001379	0.040859
12	11	BGE4-DAL4	0.000867	0.00788	0.23348
12	16	BGE4-BGS4	0.001261	0.011465	0.339713
16	6	BGS4-MUSP (1+2)	0.00122	0.010149	0.318967
16	18	BGS4-KUT4	0.000433	0.00394	0.11674
16	22	BGS4-KDS4	0.003075	0.027954	0.82827
6	21	MUSP-BAB4 (1+2)	0.000809	0.006734	0.211651
21	22	BAB4-KDS4 (1+2)	0.002326	0.019349	0.608124
22	7	KDS4-NSRP	0.003833	0.034849	1.032565
18	7	KUT4-NSRP	0.004321	0.039282	1.163898
18	19	KUT4-QRN4	0.006284	0.05713	1.69273
18	20	NSRP-KAZG	0.004393	0.039932	1.18316
20	8	KAZG-HRTP	0.001183	0.010756	0.3187
8	19	HRTP-QRNA	0.0013	0.01182	0.35022
11	10	DAL4-KRK4	0.001625	0.014775	0.457775
16	17	BGS4-AMN4	0.000823	0.007486	0.221806
17	12	AMN4-BGE4	0.000433	0.00394	0.11674

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 5.77351e-006
No. of Iterations = 10

Bus No.	Voltage Mag.	Angle Degree	------Load------		---Generation---		Injected
			MW	Mvar	MW	Mvar	Mvar
1.	0.982	0.000	195.000	158.000	981.000	-338.281	0.000
2.	0.986	-0.544	576.000	387.000	0.000	0.000	0.000
3.	0.992	1.013	0.000	0.000	360.000	-540.490	0.000
4.	0.967	-23.081	281.000	189.000	220.000	17.223	0.000
5.	1.049	0.906	70.000	10.000	0.000	0.000	0.000
6.	1.040	0.994	119.000	74.000	190.000	-586.121	0.000
7.	0.984	-26.487	110.000	46.000	0.000	0.000	120.000
8.	0.978	-26.059	192.000	91.000	0.000	0.000	90.000
9.	0.974	-26.488	387.000	100.000	0.000	0.000	90.000
10.	0.948	-31.296	500.000	322.000	0.000	0.000	90.000
11.	0.982	-27.278	125.000	100.000	0.000	0.000	90.000
12.	1.001	-26.868	181.000	100.000	0.000	0.000	0.000
13.	0.982	-26.981	210.000	161.000	720.000	-565.952	0.000
14.	0.985	-27.074	187.000	131.000	0.000	0.000	60.000
15.	0.988	-27.129	194.000	175.000	0.000	0.000	0.000
16.	0.972	-24.431	252.000	228.000	480.000	-74.457	0.000
17.	0.969	-23.323	132.000	139.000	220.000	116.957	0.000
18.	0.990	-26.219	175.000	75.000	0.000	0.000	60.000
19.	0.963	-23.504	127.000	94.000	300.000	-142.576	0.000
	Total		4013.000	2580.000	3471.000	-2113.697	600.000