A Secure Power System Dispatch Using the DFP(Davidon-Flitcher-Powell)

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Abstract:

A large scale optimum dispatch ,using the DFP(Davidon-Flitcher-Powell) procedure ,is presented for system in both normal as well as emergency states. Optimum rescheduling of control variables for system in amulet –contingency state includes minimization of the operating cost. A Satisfaction is made for system constraints for all selected line-outages .single line outage is also dispatched . Results obtained for the 5-bus and 30-bus test system indicate that single as well as multi-contingency dispatch converge after four DFP-iterations. Compared with optimum operating cost of system in its healthy (normal) condition , results obtained show an increase in the fuel cost for both the single and multi-contingency states . However, optimum cost for system operation during some of the single line-outages selected, is lower than that of a multicontingency operation . This encourages the dispatcher to reschedule control operation . This encourages the dispatcher to reschedule control variables during each contingency. However, if security is preferred on cost-minimization the dispatcher will depend on the results of a multicontingency optimum schedule , and no reschedule is required for control variables during emergency.

Keywords: DFP, Economy Dispatch, Single-Contingency, Multi-Contingency

الاختبار الآمن لنظام القوى الكهربائية باستخدام طريقةDFP

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المستخلص:
تستخدم طريقة (DFP دافيرون فليتشر بول) في إيجاد الاختبار الأمثل للمتغيرات لنظام القوى الكهربائية في حالتي الكمال والإصابة في حدوث الأعطال .يجرى إيجاد توزيع أمثل لمتغيرات التحكم للنظام ذات العطل المتعدد من اجل تقليل تكلفة التشغيل مع ضمان الحفاظ على شروط التشغيل في إثناء حدوث الأعطال المتوقعة جميعا يجرى أيضا اختبار أمثل للمتغيرات في حالة حدوث عطل منفرد . وتشير النتائج التي تم الحصول عليها من التطبيق على نظامي خمسة قضبان وثلاثين قضيبا ،إن الاختبار الأمثل في حالتي العطل المفرد والعطل المتعدد يصل إلى نهايته بعد أتمام أربعة خطوات تكرارية DFP. وتوضح النتائج أيضا أن القيمة الصغرى لتكلفة التشغيل في كل من العطل المفرد والعطل المتعدد اكبر من ن ظيرتها عندما يكون النظام سليما (من دون عطل) لكن التكلفة الصغرى لتشغيل النظام في حالة إي عطل منفرد اقل من ن ظيرتها في حالة النظام ذات العطل المتعدد وهذا من شانه إن يدفع المنظم إن يعيد توزيع متغيرات التحكم وضبطها عند حدوث كل عطل منفرد .ومن ناحية أخرى فان أمان تشغيل النظام يكون أفضل في كثير من الأحيان و لاسيما من ناحية تقليل تكلفةالتشغيل ، وهذا يتطلب من المنظم إن يعتمد على النتائج التي يحصل عليها من الاختبار الأمثل ذات العطل المتعدد ،متجنبا إعادة توزيع متغيرات التحكم وضبطها في إثناء حدوث إي عطل منفرد.

1. Introduction

Static power dispatching is an important constituent in planning and operation of electric power system. This requires solution of the optimal load flow problem which includes solution of a set of nonlinear load power flow equations under large number and type of constraints, together with minimizing the operating cost [1].

Results of the optimum dispatch usually give active powers of generators, reactive powers of var sources, controllable generator voltages, as well as setting of the tap-changing transformers[1,2].

Steady state security is a participating aspect for power system planning . The computation of system security usually involves some

selected contingencies of which unplanned equipment-outages have a major role. Acceptable steady state bus voltages and satisfied constraints of an optimal dispatch following a contingency is imperative to the secure and reliable operation of a power system[3,4].

Combining the optimal rescheduling of a power system and security, has been early developed [5], and a linear programming was used to obtain optimum dispatch of power for system security .

In a previous paper [6], the author presented a reliable convergent optimal load flow algorithm. It was based on the definition of a suitable step length for the control variable by the aid of the DFP-method [7] of unconstrained minimization .In the each step ,Powell's quadratic interpolation was utilized to determine the minimum value of the operating cost. System nonlinear load flow constraints were included in the minimization procedure [8].

In this paper the DFP-procedure , presented in [6], is used to optimally-dispatch the IEEE 30-bus system . Results obtained are in a close agreement to those obtained by Alsac Stott[1].

A selected number of contingencies for both the 5-bus [6] and 30=bus [1] system are individually studied .

Rescheduling of control variables is made for a system with single line-outage . This reschedule what is started with values of control variables resulted from optimum dispatch of a healthy system. Results show that the optimum operating cost is contingency-dependent.

However, multicontingency state is dispatched for each of the two test system . The results obtained for the control variables are valid for operating a power system with the relatively minimum fuel cost and without any load-interruption when any contingency occurs. It is the optimum secure operation .

2. Mathematical Aspects:

The DFP-procedure , previously explained [6] optimizes the quadratic cost function c(x p), the sum of the fuel costs of all generators connected to the system . X is the set of active powers of generators , other control variables are; the generator bus voltages x , and transformer tap-ratios x . the set of control variables x is given by:

$$[x]=[X_p \;\; X_v \;\; X_t]^T \quad \ldots(1)$$

The total cost function of a system , c (x) ,1s givenby:

$$c(x)=\sum_{i=2}^{ng} C1\,(X\,pi) + C1(X\,p1) \qquad \ldots(2)$$

Xp1 the active power of generator connected at bus 1.
C1 (Xp1) cost of generator connected at bus 1.
Xp1 active power of slack generator .
NG number of generator .
The quadratic form of generator cost includes three cost coefficients Ai ,bi ,and ci for generator at bus i ;
Ci (Xpi) = ai + bXpi + CiXpi … (3)
The gradient of the system total cost function is ;

$$\frac{\partial c\,(x)}{\partial x} = \sum_{i=2}^{NG} \left(\frac{\partial ci}{\partial X\,i}(Xpi) + \frac{\partial c1}{\partial Xi} + (Xpi) \right) \ldots(4)$$

$$\frac{\partial Ci}{\partial Xi}(Xpi) = bi\ 2ciXpi \ldots \ldots xi = xpi \qquad = 0 \qquad \text{otherwise.}$$

Xi is the control variable at bus 1 .

The gradient ∂Ci (Xp1) /∂Xi of the cost of the slack generator ,can be computed through the load flow solution .
The load flow solution obtained through the adopted DFP-procedure satisfies the following functional constraints.
1-Upper and lower limits for both active power of generators and reactive power of generator and other reactive power sources ,are preserved
2-A bus voltage is to be within 0.95-1.05.
3-Upper limits of MVA-flow in each line is specified.
4-Tap-ratio of a tap changer transformer is allowed to vary from -10 to 10 percent .
Those constraints are enforced on the economic dispatch of test system in both healthy (normal) as well as emergency states.

3. Results

Two test systems are handeled; the 5-bus system described elsewhere[6] and the standard IEEE 30-bus system.
The 5-bus system has no tap –changing transformers. At each of the load buses;2 and 3is connected a reactive power source . While

generators are connected to buses 1,4 and 5, the 30 bus system has tap-changing transformers at buses ; 11,12,15 and 36 with the respective tap-ratios of t11 ,t12 ,t15 and t36.Generators are connected to buses 1,2,5,8,11 and 13[1].

4. Base Case Optimum Dispatch

The results of an optimum dispatch of the healthy(normal) no contingency, 5-bus and 30-bus systems are first computed so that it can be used as a base for comparison when contingencies are considered.

Fortunately ,the 5-bus system was previously dispatched by author[6] and by the aid of the DFP-procedure , and its results are presented here in table(1),under the name "base case" dispatch. The results of the base case dispatch of healthy(normal) 30-bus system are evaluated and presented in table(2).

5. Cost-Minimisationof a Single-Contingency State

It is important to search for the optimum dispatch of a system during the time of occurrence of a contingency .Reasons leading to an outage of a line may continue for some time before reclosing . The time elapsing before reclosing can be exploited to operate the system in an optimum rescheduled state . Each contingency will then have its own dispatch. Fig .1 shows steps of the DFP-procedure for dispatching a system will single line outage.

5.1 Five Bus System:

Starting with the base case values for control variables, Table (1),each contingency is optimally-dispatched alone .Table (3) shows the minimum cost for each of the selected line-outages.

Compared with the cost of the base case dispatch , Table (1) , the additional cost to be paid ranges from 1.22$/hr (outage of line 1-3) to 6.121$/hr (outage of line 2-3).

5.2 Thirty Bus System

Four contingencies for the 30-bus system are individually tested . The DFP-procedure is applied for each contingency. Four iterations were sufficient for each dispatch to converge . Table (4) illustrates the results of the four dispatches . Compared with the optimum cost of the base case dispatch ,Table (2), an additional cost is required to economically-operate the system during each line-outage. This

additional cost ranges from 1.53$/hrduring outage of line 30 to 11.75$/hr for the outage of line 33.

6. Cost –Minimization Of The Multi-Contingency State

A more useful for system operation is the search for an optimum dispatch of the system when it is assumed to be equally subjected to any of the selected contingencies . This necessitates a large scale dispatch that includes , in addition to control variables , all state variables of all contingencies involved . This dispatch should result in adjusted value of control variables suitable for economically-supplying the loads connected to the system , without any load-shedding during the occurrence of a one or more contingencies. In this search .however , the dimension of the state variable will increase by c-times , where c is the number of contingencies studied. The results of a multi-contingency dispatch for the 5-bus system are outlined in Table (5).Table(6) give similar results of the 30-bus system.

7. Cost Of Security

Comparing the fuel cost for operating apower system in both :healthy (normal) and contingency conditions , it is clear that additional cost must be paid for security attainment . As for the 5-bus system, the base case (healthy condition) fuel cost is 1000.37$/hr, Table (1).But , to guarantee adequate continuous supply for the connected loads during a contingency state , the cost has to be increased to 1999.65$/hr, with an increase of 9.28$/hr or 0.93%. The 30-bus system requires , also a 7.26$/hr or 0.91% of its base cost (805.3$/hr). The additional cost to be paid in order to avoid load-shedding during contingency can , however , be lowered when the results of the optimum dispatch of a single-contingency , Table (3,4), are considered . For example, during the outage of line 1-2 in the 5-bus system, the optimal fuel cost is 1002.5$hr , which means a saving of (1009.65-1002.5)or 7.15$/hr in the hourly cost . Similar example can be extracted , also for other contingencies in both , the 5-bus and 30-bus system , through examination of tables (3,4) and tables (4,6) respectively .

8. Discussion and Conclusions

The DFP-procedure [6] is used to economy dispatch of the 5-bus and 30-bus test systems. Four iterations were sufficient for convergence . The optimum dispatch program [6],Fig (1) had proved to be reliably efficient in solving the optimum dispatch problem .Two types of dispatches are begin made;

(i) A dispatch for the healthy system (no contingency is considered),

(ii) A dispatch for the system when one or more of the selected contingencies are involved.

Considering a number of selected contingencies , the optimum dispatch was carried out through two categories;

1- Rescheduling of control variables was made for the system with single line-outage. The results indicted an increase in the optimum fuel cost during emergency.

2- A system dispatch which includes the satisfaction of system constraints of all the selected contingencies is computed .It is called the "multi-contingency "dispatch , and it gives values of control variables necessary for operating the system without any load-shedding during the time of emergency .It is the optimum secure dispatch .

Comparison of the fuel cost of a system for both ;multi-contingency and single contingency states clarifies:

(i)Both states require an operating cost larger than the optimum cost of the system in its healthy (normal) condition.

(ii) The optimum cost of any of the single-contingency operations is lower than that of a multi-contingency operation. This encourages the dispatcher to reschedule control variables during each contingency .However , if security is preferred on cost-minimization, the dispatcher will depend on the results of multi-contingency schedule and no reschedule he has to make during emergency.

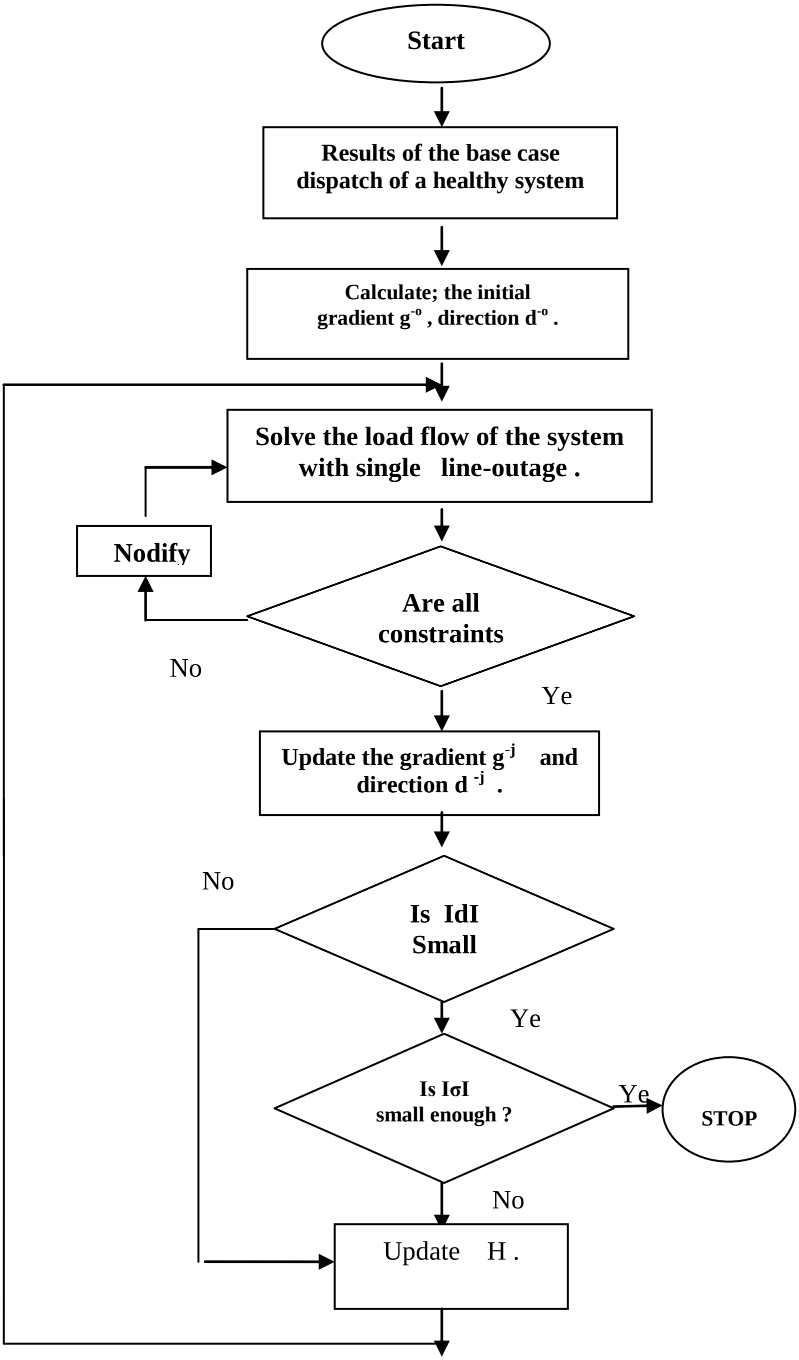

Figure1 DFP Procedure for Single Contigency Disptch

Table (1) Base Case Optimum Dispatch of the 5-Bus System [6] .

Case	Optimum Cost $/ hr	CONTROLVARIBALE								
		Generated power at bus on				Generator voltage at bus on				
		2 MVARA	3 MVARR	4 MW	5 MW	1	2	3	4	5
Healthy system	**1000.37**	**-30**	**-30**	**103.5**	**86.6**	**1.04**	**1**	**.987**	**1.03**	**1.02**

Table (2) .Base Case Optimum Dispatch of the 30-Bus System.

Case	optimum Cost $/hr					VARIABLES CONTROL										
		Tap – ratio %				Generated MW at bus no					Generated Voltage at bus no					
		t 11	t 12	t 15	t 36	2	5	8	11	13	1	2	5	8	11	13
Healthy system	805.3	1.1	-2.8	o.9	-4.15	54.4	25.6	28.2	16.5	19	1.05	1.03	1.02	1.01	1.05	1.05

Tabl (3) single- contingency dispatch for the 5-bus system

Outage Of line	Optimum Cost $/ hr	Control variables								
		Generated power at bus no				Generated Voltage at bus no				
		2 mvar	3 mvar	4 mw	5 mw	1	2	3	4	5
1-2	**1002.5**	**-21.7**	**-8.9**	**89.5**	**89.5**	**1.04**	**0.96**	**0.96**	**1.04**	**1.02**
2-3	**1006.5**	**-32**	**-30**	**100**	**92**	**1.04**	**1.05**	**0.965**	**1.05**	**1.024**
3-1	**1001.6**	**-28**	**-35**	**99.6**	**90.2**	**1.05**	**1.04**	**1.03**	**1.05**	**1.022**

Table (4) .Singel –Conting Ency Dispatch of the 30-Bus System.

Outage of line	Optimum cost $/ hr	Control variables														
		Tap-ratio %				Generated MW at bus no					Generator voltage at bus on .					
		t 11	t 12	t 15	t 36	2	5	8	11	13	1	2	5	8	11	13
1	**817.05**	**o.6**	**-3.8**	**1.1**	**-4.6**	**65.3**	**20.4**	**35.4**	**18.2**	**19**	**1.05**	**1.03**	**1.02**	**1.01**	**1.04**	**1.05**
5	**813.85**	**0.8**	**-3**	**0.35**	**-5.1**	**71.4**	**28.1**	**32.2**	**17.6**	**16**	**1.05**	**1.04**	**1.03**	**1.02**	**1.04**	**1.04**
30	**806.83**	**0.95**	**-2.4**	**-.6**	**-4.2**	**57.4**	**30.7**	**33.1**	**17.1**	**14.2**	**1.05**	**1.04**	**1.02**	**1.05**	**1.05**	**1.05**
33	**816-30**	**-1.05**	**-2.6**	**-1.5**	**-4.5**	**70.4**	**29.2**	**30.7**	**19.5**	**13.6**	**1.05**	**1.04**	**1.03**	**1.05**	**1.05**	**1.04**

Table(5) Multi –Contingency Dispatch of the 5-Bus System

Outage of Line	Optimum cost $/ hr	Control				variables				
		Generated power at bus no				Generator voltage at bus no .				
		2 mvar	3 mvar	4 mw	5 mw	1	2	3	4	5
1-2,2-3,3-1	1009.65	-27	-33	98.3	88.2	1.04	.99	.97	10.3	1.02

Table (6) .Multi –Contingency Dispatch of the 30-Bus System.

Outage of Line	Optimum Cost $/hr	Control									variable					
		Tap-ratio %				Generated MW at bus no					Generator voltage at bus N0 .					
		t 11	t 12	t 15	t 36	2	5	8	11	13	1	2	5	8	11	13
1,5,30,33	812.56	1.53	-3.2	1.27	-4.4	71	28	32.3	17.7	16.1	1.05	1.03	1	1.02	1.05	1.05

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