STEADY STATE VOLTAGE INSTABILITY STUDIES UNDER THE OPTIMAL CONDITIONS IN A POWER SYSTEM

M.M. Abdel-Aziz
Faculty of Engineering
Cairo University

M. M. Salama E.M. Saied S.M. Abdel-Maksoud
Faculty of Engineering (Shoubra)
Zagazig University

ABSTRACT

With the improved optimized operation and increase in loading of a power system, the problem of voltage stability and voltage collapse attracts more and more attention. The phenomenon of possible steady state voltage instability is creating serious concern among operators of large interconnected power system. Maintaining adequate system voltage has become a major problem as utilities are being forced to operate the system close to steady state voltage stability limit. A voltage collapse can take place in power systems or subsystems quite abruptly and that requires a continuous monitoring of the system state. There are different methods to study this phenomenon. In this work, it is suggested to use the modified multiple load flow and the voltage collapse proximity indicator methods to detect the voltage instability indicators and the weakest buses under optimal operating conditions.

The objective functions of optimal operating conditions are concerned with minimizing the operation costs or/and the transmission losses. The two suggested methods, which are based on the data that obtained from solving the optimization problem by first order gradient or Lagrangian multiplier algorithms, are applied on a simple 5-bus, 2-generator power system. The obtained results illustrate a complete view on the voltage profile on each bus, optimal generated power, optimal costs, transmission losses, voltage instability indicators and the weakest buses in each time interval.

KEYWORDS

Voltage collapse; Voltage instability; Proximity indicators; Economic operation; optimal load flow; Lagrangian multiplier.

INTRODUCTION

Stability of a power system are the major problems facing the power industry. The serious economic constraints preclude the conventional capital intensive approach of providing many redundant system elements. The voltage instability phenomenon occurs when the receiving end voltages are much lower values than the nominal ones. The effect of voltage instability ranges from post disturbance operation at low voltage profile to complete voltage collapse (Gupta et al 1990). The increasing interest in voltage collapse from researches due to the seriousness of the consequences of voltage collapse, which may lead to either a partial or total blackout in the system. Also due to the development of computer control (hardware and software such as economic dispatch, optimal power flows) which enables the economic exploitation of the existing transmission facilities results in operating the electric power system very close to its stability limit. The voltage instability is characterized by a progressive

decline of voltage, which can occur because of the inability of the network to meet increasing demand for reactive power. Some form of disturbance or change triggers the process of voltage instability in system operating conditions, which create increased demand for reactive power which is in excess of what the system is capable of supplying. As transmission systems become more stressed due to the increased loads and large inter-utility an efficient system operation is becoming increasingly threatened due to problems of voltage stability and collapse. If bus voltages ultimately fall in a more rapid decline, leading to loss of operations of the network, the term voltage collapses applied. These voltage related threats to system security are expected to become more severe over the next decade as demand for electric power rises, while economic and environmental concerns limit the construction of new transmission and generation facilities (Thomas and Dobson 1994).
Load characteristics and the available means of voltage control largely determine voltage instability. For true voltage instability, at least a part of the total load must be of the self-restoring (constant MVA) type (Pal 1992). In voltage stability, there are static and dynamic aspects involved. In static voltage stability, the purpose of index is to quantify how 'close' a particular operating point is to the point of steady state voltage collapse and consequently estimation of the steady state voltage stability limit for the examined operating point of the studied power system (Indulkar and Viswanathan 1983). For more accurate analysis of dynamic voltage stability, the system model includes excitation systems, under load tap-changers, capacitors and power system stabilizers in addition to network equations. For dynamic voltage stability enhancement, a parameter optimization technique with a model performance measure is used to determine optimal control parameters (Lee BH and Lee KY 1993). Methods for predicting voltage instability in power systems can be categorized into steady state and dynamic methods. The steady state methods use a static model such as power flow model or a linearized model for the dynamics of the system about the steady state operating point. On the other hand, dynamics methods use a model characterized by nonlinear differential and algebraic equations, which are solved by time domain simulations. The optimum operation and planning of electric power generation systems have occupied an important position in the electric power industry (Abdel-Kader 1995). The main concern of optimization problem is to minimize an objective function such as cost, transmission losses under some constraints. There are different methods to solve the optimization problem such as the Lagrangian multiplier method, first order gradient method and others (Abdel-Maksoud S.M. 1992).
In this research, the steady state (static) voltage instability methods are applied under the optimal operation conditions to estimate an proximity indicators which indicate the system is stable or not.

STEADY STATE VOLTAGE INSTABILITY ASSESSMENT

There are different methods for predicting the voltage instability in a power system. Some of these methods are.

1- Testing the eigen values of the Jacobian matrix of the load flow calculation.
2- Utilizing multiple load flow solutions to determine a measure to the proximity of the system to voltage collapse.
3- Solving an optimization problem to determine index to the voltage stability limit. The optimization problems involved are the optimal load flow (OLF).
4- **Finding a voltage collapse proximity indicators.**

In this research, the optimization method is used which includes the optimal load flow (OLF) as optimization problem.

OPTIMAL LOAD FLOW (OLF)

The optimal load flow is the operating condition in which the power flow in an electrical system occurs optimally (objective function is optimized under satisfied constraints). The objective function may be one of the following;

1. Optimal load dispatch, 2. Minimal transmission losses.

The operating constraints are represented by a set of inequality relations as below

$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max} \tag{1-a}$$

$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max} \tag{1-b}$$

$$V_i^{min} \leq V_i \leq V_i^{max} \tag{1-c}$$

where P_{Gi}, Q_{Gi} are the active and reactive powers of generator i and V_i voltage magnitude of bus i.

The load flow is a feasible load flow solution. Optimal load flow is achieved after solving a large number of load flow solutions corresponding to a set of specified values of the consumers demand. In this process, the control variables, such as voltage magnitudes of slack and generator buses, active generations of generator buses are not stated singularly but their ranges of variation are specified according to the objective to be optimized. In optimal load flow program, the initial values of the control variables are given from the given range. Therefore it checks whether the given objective has been optimized. If it has not been optimized it modified the values of control variables following some optimization technique and performs another load flow study. This process goes on automatically until the given objective is optimized. During the process, the computer also checks whether the operating constraints are violated.

Formulation of Optimal Load Flow and its Solution

Let u: control variables, x: controlled variables and p: fixed or uncontrolled variables

The optimal load flow can be summarized as:

Optimize the nonlinear function f(u,x), is the objective function subject to:

i- equality constraints (load flow equations)

$$G_i\ (u\ , x\ , p) = 0$$

ii- inequality constraints (operating limitations)

$$u_i - u_i^{max} \leq 0 \tag{2-a}$$

$$u_i^{min} - u_i \leq 0 \tag{2-b}$$

$$x_i - x_i^{max} \leq 0 \tag{2-c}$$

$$x_i^{min} - x_i \leq 0 \tag{2-d}$$

By ignoring the inequality constraints, the Lagrangian function reduce to (Murty P. 1984):

$$L = f(x\ , u) + \sum_i \lambda_i\ G_i\ (u\ , x\ , p) \tag{3}$$

$$\frac{\partial L}{\partial x} = \frac{\partial f}{\partial x} + \left(\frac{\partial G}{\partial x}\right)' \lambda = 0 \tag{4}$$

$$\frac{\partial L}{\partial u} = \frac{\partial f}{\partial u} + \left(\frac{\partial G}{\partial u}\right)' \lambda = 0 \qquad (5)$$

$$\frac{\partial L}{\partial \lambda} = G(u, x, p) = 0 \qquad (6)$$

$\left(\frac{\partial G}{\partial x}\right)'$ in Eq. (4) is the transposition of the Jacobian matrix obtained by differentiating Eq. (6). Eq. (6) can be satisfied by any feasible load flow solution. λ can be determined from Eq. (4) as;

$$\lambda = -\left(\frac{\partial G}{\partial x}\right)'^{-1} \left(\frac{\partial f}{\partial x}\right) \qquad (7)$$

Knowing λ, Eq. (5) can be evaluated. The algorithm to satisfy Eqs. (4), (5) and (6) is;

1- Assume a set of control variables.
2- Perform the load flow solution using the Newton-Raphson method and determine the value of the objective function.
3- Determine the value of the Lagrangian multiplier λ from Eq. (7).
4- Using the values of λ found in step 3, determine the gradient vector from Eq. (5). If its components are sufficiently small, the optimum solution has been obtained. Otherwise, go to the next step.
5- Find new values of the control variables as $u_{i\,new} = u_{i\,old} - \frac{\partial L}{\partial u_i}$
6- Return to step 2.

The above iterative procedure is terminated if the rate of decrease of the value of the objective function evaluated in step 2 is found to be less than a certain tolerance.

MATHEMATICAL MODEL OF OPTIMAL LOAD FLOW

Minimum Fuel Cost

The objective function in this case is minimizing the total cost (F_T), which in the form;

$$F_T = \sum_{i=1}^{N} F_i(P_i) = A_i P_i^2 + B_i P_i + C_i \qquad (8)$$

Where: A_i : cost constant (\$ / MW^2 h), B_i : cost constant (\$ / MWh), C_i : fixed cost (\$ / h), P_i : generated power for bus i (MW) and N : number of generating units.

The constraints are:

$$\sum_{i=1}^{N} P_i = P_D + P_L \qquad (9)$$

$$P_i^{min} \le P_i \le P_i^{max} \qquad (10)$$

The optimization method used to solve these Equations is the first order gradient method (Allen and Wollenberg 1984) which gives the optimal generated power P_i and the minimum total cost. Then the load flow solution is carried out under these conditions to obtain the OLF.

Minimum Transmission Losses

The objective function in this case is minimizing the transmission losses (P_L). Where

$$P_L = P^T\,[\,B\,]\,P + P^T B_o + B_{oo} \tag{11}$$

Where P: vector of generator bus power, [B]: square matrix of the same dimension as P, B_o: vector of the same length as P and B_{oo} : constant. Eq. (11) can be written as:

$$P_L = \sum_i \sum_j P_i B_{ij} P_j + \sum_i B_{io} P_i + B_{oo} \tag{12}$$

By neglecting the second and third terms of Eq. (12), P_L becomes:

$$P_L = \sum_i \sum_j P_i B_{ij} P_j \tag{13}$$

The constraints are the same in Eqs. (9) and (10).
By using the Lagrangian multipliers as sensitivity factors to determine the minimum losses. The optimal load flow solve these equations with the Lagrangian :

$$L = P_L - \lambda\,(\sum_{i=1}^{N} P_i - P_D - P_L) \tag{14}$$

$$\frac{\partial L}{\partial P_i} = \frac{\partial P_L}{\partial P_i} - \lambda\,(1 - \frac{\partial P_L}{\partial P_i}) = 0 \tag{15}$$

Thus, we can summarize the algorithm as follows:
1-Assume initial values for P_i
2- Calculate P_L
3- Calculate the value of λ which causes :

$\sum_{i=1}^{N} P_i = P_D + P_L$, and then calculate P_i

4- Recalculate P_L and compare it with the estimated in step 2
5- If a small tolerance is reached , the optimum solution has been obtained. Otherwise go to the following step
6- find new values of P_i such that $P_i^{new} = P_i^{old} - \frac{\partial L}{\partial P_i}$
7- Return to step 2.

Minimum Fuel Cost and Minimum Transmission Losses

In this case , the objective function is minimizing ($F_T + P_L$). Where

$$F_T + P_L = A_i P_i^2 + B_i P_i + C_i + \sum_i \sum_j P_i B_{ij} P_j \tag{16}$$

The Lagrangian multiplier is given by :

$$L = F_i(P_i) + P_L - \lambda\,(\sum_{i=1}^{N} P_i - P_D - P_L) \tag{17}$$

$$\frac{\partial L}{\partial P_i} = \frac{dF_i}{dP_i} + \frac{\partial P_L}{\partial P_i} - \lambda\,(1 - \frac{\partial P_L}{\partial P_i}) = 0 \tag{18}$$

$$\sum_{i=1}^{N} (2 A_i P_i + P_i) + \sum_j 2 B_{ij} P_j - \lambda\,(1 - \sum_j 2 B_{ij} P_j) = 0 \tag{19}$$

Thus, the algorithm of this method as follows.
1-Assume initial values for P_i
2- Calculate P_L and F_T
3- Calculate the value of λ which causes :

$$\sum_{i=1}^{N} P_i = P_D + P_L$$, and then calculate P_i from Eq. (19)

4- Recalculate P_L and F_T and compare them with the estimated values in step 2

5- If a small tolerance is reached, the optimum solution has been obtained. Otherwise go to the following step

6- find the new values of P_i such that $P_i^{new} = P_i^{old} - \frac{\partial L}{\partial P_i}$

7- Return to step 2.

VOLTAGE COLLAPSE PROXIMITY INDICATORS (VCPI)

Different indicators have been proposed to assess the proximity of the system to voltage collapse. One of them is used for the on line test of the power system (Salama M..M. et al 1998). Thereby an indicator which varies in the range between 0 (no load) and 1 (voltage collapse). The indicator uses information of load flow solution, which in this paper is optimal load flow solution. The advantage of this method lies in the simplicity of the numerical calculation and the expensiveness of the results. This indicator is given by:

$$L_j = |L_j| = \left| 1 - \frac{\sum_{i \in \alpha_G} C_{ji} V_i}{V_j} \right| \qquad j \in \alpha_L \tag{20}$$

Where α_l : set of load buses, α_G : set of generator buses, V_j : complex voltage at load bus j, V_i : complex voltage at generator bus i and C_{ji} : elements of matrix C determined by:

$$[C] = -[Y_{LL}]^{-1}[Y_{LG}] \tag{21}$$

Where $[Y_{LL}]$ and $[Y_{LG}]$ are submatrices of the Y-bus matrix.

The modification is produced on Eq. (21), such that the matrix C is given by:

$$[C] = -[B_{LL}]^{-1}[B_{LG}] \tag{22}$$

Where $[B_{LL}]$ and $[B_{LG}]$ are the imaginary parts of the matrices $[Y_{LL}]$ and $[Y_{LG}]$ respectively. With the help of these indicators critical load buses can be identified. For stable situations the condition $L_j \leq 1$ must not be violated for any of the nodes j.

APPLICATIONS AND RESULTS

The sample power system is shown in **Fig. 1** (Stagg and El-Abiad 1968). The load time intervals (In.) are given in **Table 1**.

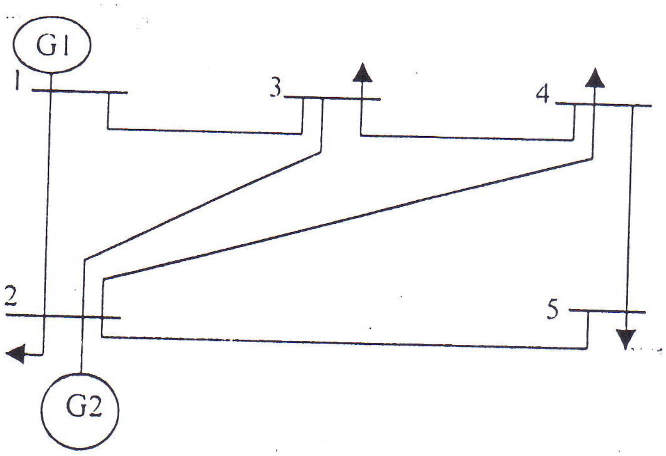

Fig. 1. One line diagram of the sample

Table 1 Load time interval

In.	Time (hrs.)	Load (MW)
1	2	850
2	2	500
3	2	350
4	2	450
5	4	550
6	4	700
7	4	950
8	2	600
9	2	1050

Minimum Fuel Costs Results

The optimal powers and costs of all generators are given in **Table 2**. The voltage profiles at all buses and the weakest buses at the load buses are in **Table 3**, while voltage indicators (Lj) are tabulated in **Table 4**.

Table 2 Optimal powers and costs without and with transmission losses (T.L.)

	Without Transmission Losses						**With Transmission Losses**						
In	P_1 MW	P_2 MW	P_T MW	F_1 ($)	F_2 ($)	F_T ($)	P_1 MW	P_2 MW	P_L MW	P_T MW	F_1 ($)	F_2 ($)	F_T ($)
1	393	357	750	3917	3360	7277	404	352	6	756	4024	3324	7348
2	230	220	450	2465	2165	4630	235	217.4	2.4	452.4	2505	2133	4638
3	156	144	300	1836	1478	3314	153	148.3	1.3	301.3	1790	1511	3301
4	205	195	400	2252	1933	5185	211	191.2	2.2	402.2	2298	1888	4186
5	252	248	500	2658	2402	5060	259	243.6	2.6	502.6	2722	2350	5072
6	322	278	600	3279	2641	5920	332	272.1	4.1	604.1	3362	3537	6899
7	440	360	800	4349	3389	7738	454	352.9	6.9	806.9	4477	3487	7955
8	276	274	550	2863	2632	5495	283	270	3.0	553	2930	2603	5533
9	459	441	900	4862	4145	9007	513	394.6	7.6	907.6	5035	3709	8744

Table 3 Bus voltages and weakest buses

In	**Without Optimal Flow**					**With Optimal Flow**					**Weakest Buses**					
	Bus1	Bus2	Bus3	Bus4	Bus5	Bus1	Bus2	Bus3	Bus4	Bus5	Without T.L.			With T.L.		
1	1.06	1.023	1.026	1.021	1.018	1.06	1.021	1.022	1.016	1.001	5	4	3	5	4	3
2	1.06	1.005	1.020	1.007	1.002	1.06	0.993	1.017	0.997	0.933	5	4	3	5	4	3
3	1.06	1.001	0.962	1.001	0.966	1.06	0.986	0.944	0.895	0.947	5	4	3	5	4	3
4	1.06	1.004	0.989	0.965	0.958	1.06	0.977	0.962	0.882	0.922	5	4	3	5	4	3
5	1.06	1.018	1.005	0.971	0.941	1.06	1.008	0.979	1.007	0.879	5	4	3	5	4	3
6	1.06	1.022	1.014	1.005	0.952	1.06	1.018	0.991	1.003	0.903	5	4	3	5	4	3
7	1.06	1.038	1.009	1.007	0.981	1.06	1.033	0.964	0.899	0.870	5	4	3	5	4	3
8	1.06	1.026	1.033	1.075	1.008	1.06	1.004	1.015	1.008	0.896	5	4	3	5	4	3
9	1.06	1.029	1.052	1.044	1.017	1.06	1.024	1.034	1.021	1.002	5	4	3	5	4	3

Table 4 Voltage indicators (Lj) with minimum fuel cost with and without T.L

	Without Transmission Losses						**With Transmission Losses**					
	Without modification			With modification			Without modification			With modification		
In	Bus3	Bus4	Bus5	Bus 3	Bus 4	Bus 5	Bus 3	Bus 4	Bus 5	Bus 3	Bus 4	Bus5
1	0.248	0.272	0.278	0.251	0.275	0.282	0.252	0.279	0.29	0.27	0.29	0.35
2	0.065	0.066	0.074	0.068	0.069	0.079	0.068	0.074	0.15	0.09	0.09	0.09
3	0.057	0.069	0.070	0.059	0.078	0.077	0.058	0.077	0.09	0.07	0.09	0.09
4	0.077	0.087	0.087	0.077	0.087	0.089	0.089	0.088	0.14	0.08	0.12	0.13
5	0.083	0.084	0.088	0.083	0.088	0.093	0.089	0.089	0.15	0.09	0.09	0.14
6	0.090	0.096	0.099	0.095	0.099	0.108	0.092	0.097	0.17	0.13	0.14	0.17
7	0.299	0.319	0.330	0.360	0.327	0.337	0.332	0.338	0.37	0.37	0.39	0.38
8	0.078	0.076	0.085	0.079	0.089	0.087	0.082	0.086	0.11	0.09	0.11	0.16
9	0.339	0.389	0.389	0.342	0.389	0.396	0.368	0.408	0.46	0.42	0.48	0.52

Minimum Transmission Losses Results

The generating powers, fuel costs and minimum losses are given in **Table 5**, while the voltages profiles at all buses, the weakest buses and the voltage indicators in this case are tabulated in **Table 6**.

Table 5 generating powers, fuel costs and minimum losses

In	P_1 MW	P_2 MW	P_L MW	P_T MW	F_1 ($)	F_2 ($)	F_T ($)
1	420.4	335.42	5.82	755.82	4166.6	3168.43	7335.03
2	239.04	212.83	1.87	451.87	2543.4	2110.73	4654.13
3	162.3	138.82	1.12	301.12	1887.5	1437.54	3325.04
4	206.41	195.53	1.94	401.94	2262.3	1947.65	4209.95
5	265	237.24	2.24	502.24	2769.5	2306.81	5076.31
6	334	269.37	3.37	603.37	3380.6	2572.30	5952.9
7	463.2	342.86	6.06	806.06	4564.6	3230.46	7795.06
8	291.6	260.69	2.29	552.29	3003.9	2513.21	5517.11
9	518.7	387.63	6.33	906.33	4993.1	3647.29	8640.39

Table 6 Bus voltages, voltage indicators and weakest buses

In	Bus Voltages					Voltage Indicators						Weakest Buses					
						Without modification			With modification			Without modification			With modification		
	Bus1	Bus2	Bus3	Bus4	Bus5	Bus3	Bus4	Bus5	Bus3	Bus4	Bus5						
1	1.06	1.025	1.027	1.002	1.008	0.265	0.287	0.298	0.256	0.277	0.297	5	4	3	5	4	3
2	1.06	1.016	1.023	1.004	0.995	0.066	0.068	0.079	0.070	0.074	0.084	5	4	3	5	4	3
3	1.06	1.007	0.968	0.975	0.952	0.059	0.076	0.078	0.069	0.075	0.082	5	4	3	5	4	3
4	1.06	1.009	0.982	0.985	0.943	0.081	0.093	0.096	0.088	0.094	0.098	5	4	3	5	4	3
5	1.06	1.028	0.999	0.991	0.923	0.087	0.087	0.094	0.089	0.092	0.107	5	4	3	5	4	3
6	1.06	1.035	1.018	1.001	0.922	0.095	0.109	0.156	0.105	0.142	0.162	5	4	3	5	4	3
7	1.06	1.042	1.000	0.899	0.901	0.329	0.361	0.374	0.343	0.360	0.374	5	4	3	5	4	3
8	1.06	1.026	1.042	1.064	0.897	0.079	0.085	0.091	0.082	0.086	0.096	5	4	3	5	4	3
9	1.06	1.029	1.057	1.033	0.994	0.393	0.403	0.435	0.387	0.411	0.460	5	4	3	5	4	3

Minimum Fuel Cost and Minimum Transmission losses Results

Table 7 tabulates the optimal powers, minimum costs and minimum transmission losses.

Table 7 Optimal generated powers, minimum costs and minimum transmission losses

In	P_1 MW	P_2 MW	P_L MW	P_T MW	F_1 ($)	F_2 ($)	F_T ($)
1	442.6	313.72	6.32	756.32	4372.37	2963.63	7336
2	252.4	199.57	1.97	451.97	2659.51	1953.89	4613.4
3	164.7	136.72	1.42	301.42	1907.79	1419.51	3327.3
4	210.3	191.79	2.09	402.09	2295.65	1886.91	4182.56
5	263.5	239.08	2.58	502.58	2756.37	2297.66	5054.03
6	361.8	241.83	3.63	603.63	3630.92	2321.82	5952.74
7	473.6	333.12	6.72	806.72	4662.26	3140.27	7802.53
8	296.2	256.46	2.66	552.66	3043.94	2450.80	5494.74
9	530.9	376.22	7.12	907.12	5205.98	3537.91	8743.89

The bus voltages at the buses, voltage indicators and the weakest buses are given in **Table 8**.

Table 8 Bus voltages, voltage indicators and weakest buses

In	Bus Voltages					Voltage Indicators						Weakest Buses					
	Bus1	Bus2	Bus3	Bus4	Bus5	Without modification			With modification			Without modification			With modification		
						Bus3	Bus4	Bus5	Bus3	Bus4	Bus5						
1	1.06	1.020	1.025	0.996	1.001	0.278	0.290	0.294	0.269	0.291	0.298	5	4	3	5	4	3
2	1.06	1.011	1.019	1.001	0.992	0.069	0.076	0.079	0.075	0.077	0.083	5	4	3	5	4	3
3	1.06	1.017	0.958	0.963	0.933	0.062	0.080	0.084	0.069	0.070	0.086	5	4	3	5	4	3
4	1.06	1.004	0.969	0.972	0.919	0.084	0.096	0.098	0.083	0.092	0.108	5	4	3	5	4	3
5	1.06	1.023	1.009	0.955	0.908	0.092	0.094	0.098	0.094	0.095	0.113	5	4	3	5	4	3
6	1.06	1.031	1.012	0.987	0.916	0.098	0.116	0.122	0.102	0.111	0.130	5	4	3	5	4	3
7	1.06	1.034	1.001	0.892	0.898	0.344	0.368	0.376	0.361	0.368	0.382	5	4	3	5	4	3
8	1.06	1.021	1.014	1.022	0.894	0.080	0.092	0.099	0.088	0.096	0.109	5	4	3	5	4	3
9	1.06	1.022	1.034	1.013	0.985	0.400	0.430	0.445	0.389	0.425	0.463	5	4	3	5	4	3

The relations between the voltage indicators and the time intervals in case of minimum fuel cost, minimum transmission losses and minimum cost with minimum transmission losses with the modified method are shown in **Figs**. (2),(3) and (4). From all the applied methods, bus 5 has the highest indicator (L_j), thus is the weakest bus.

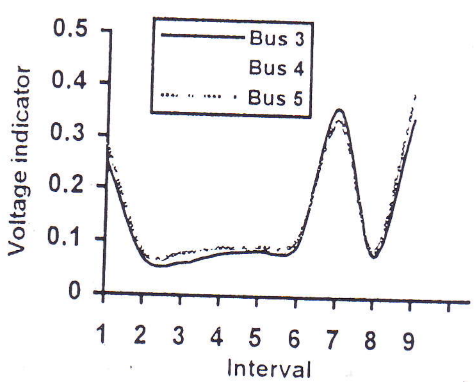

Fig. 2 Voltage indicator with interval in case of minimum cost

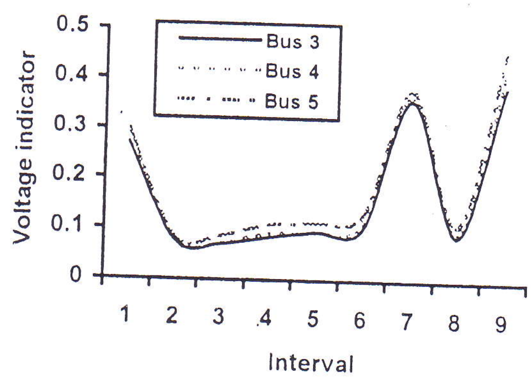

Fig. 3 Voltage indicator with interval in case of minimum transmission losses

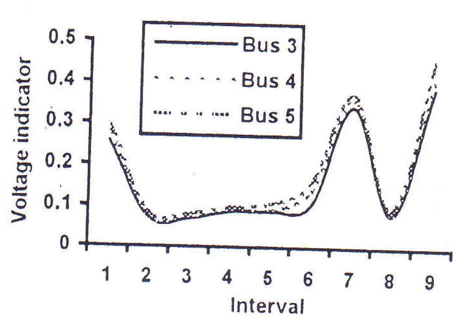

Fig. 4 Voltage indicator with interval in case of minimum cost with minimum T. L.

CONCLUSION

The methods of modified multiple load flow and voltage proximity indicators are suggested to detect the voltage stability assessment under optimal operating conditions of minimum costs or/and minimum transmission losses. The obtained results include the voltage profile on each bus, optimal generated powers, optimal operation costs and the transmission losses in each time interval. The voltage instability indicators and the weakest buses on each load bus are also presented. All the applied methods are agreeable in determination the highest values of voltage indicators and consequently the weakest buses are ranked.

REFERENCES

Gupta R.K., Alaywan Z..A., and Reece T.A. (1990), Steady State Voltage Operation Perspective, IEEE Transaction on Power Systems.

Thomas J and Dobson I (1994), Q-V Curve Interpretations of Energy Measures of Voltage Security, IEEE Transaction on Power Systems.

Pal M. K. (1992), Voltage Stability Conditions Considering Load Characteristics, IEEE Transaction on Power Systems.

Indulkar C and Viswanathan B (1983), Deterministic and Probabilistic Approach to Voltage Stability of Series-Compensated EHV Transmission Lines, IEEE Transaction on Power Systems.

Lee Ha and Lee Y (1993), Dynamic and Static Voltage Stability Enhancement of Power Systems, IEEE Transaction on Power Systems.

Abdel-Kader S.M. (1995), Security Assessments of Power Systems with Particular reference to Voltage Instability, Ph.D. Thesis, El-Mansoura University.

Abdel-Maksoud S. M. (1992), Short-Term Optimal Economic Operation of Hydrothermal Power Systems by Gradient Method, M. Sc. Thesis, Zagazig University.

Murty P.S.R. (1984), Power System Operation and Control, McGraw-Hill Publishing Company Ltd., New York, USA.

Allen J and Wollenberg B (1984), Power Generation, Operation and Control, John Wiley and Sons, New York, USA.

Salama M. M., Saied E.M. and Abdel-Maksoud S.M. (1998), Steady State Voltage Instability Assessment in a Power System, Journal of Eng. and Applied Science, Cairo University.

Stagg W. and El-Abiad A.H. (1968), Computer Methods in Power System Analysis, McGraw-Hill Kogakusha, Ltd.

AL-AZHAR ENGINEERING SIXTH INTERNATIONAL CONFERENCE
SEPTEMBER 1-4, 2000

AEIC 2000

مؤتمر الأزهر الهندسى الدولى
السادس
١ - ٤ سبتمبر ٢٠٠٠ م

TO WHOM IT MAY CONCERN

The Organizing Committee of the Al-Azhar Engineering Sixth International Conference hereby certify that the paper entitled :

STEADY STATE VOLTAGE INSTABILITY STUDIES UNDER THE OPTIMAL CONDITIONS IN A POWER SYSTEM

M. M. Abdel Aziz, M. M. Salama, E.M.Saied and S.M. Abdel Maksoud

has been refereed and presented in the course of the technical sessions of the conference .

Session Chairman

General Secretary

Prof. Ibrahiem Matrouk

AEIC 2000

٢/٩/٢٠٠٠

صورة طبق الأصل

١- م.د/ محمد مصطفى سالم
مدرس مساعد بقسم الهندسة الكهربية

2000 23/٩

د/ سعيد محمد عبد المقصود
مدرس بقسم

٢- السادة المذكورين من ضمن أعضاء هيئة التدريس دائمين

نجاة على الرمادى

المدير العام

AL-AZHAR UNIVERSITY, FACULTY OF ENGINEERING, NASR CITY - CAIRO - POST CODE NO. 11371
TEL : 4029873-2601702-2601703 FAX : 2601706
e-mail: aeic@gega.net