MENOUFIYA UNIVERSITY
FACULTY OF ENGINEERING
ENG. RESEARCH BULL.
Vol. 17 Part I, 1994

PP : 171 : 190
Received at : 22 / 3 / 1994
Accepted at : 16 / 4 / 1994

OPTIMAL PLANNING FOR RING DISTRIBUTION POWER SYSTEMS

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ABSTRACT

This paper presents an efficient planning technique for ring distributed power systems. The mixed integer programming is performed to optimize the capacitance location in substations and new primary feeders for the existing or future expansion loads.The feeder flow patterns of the distribution network model is also optimized. The technique takes into account objective functions to minimize the fixed charges of new primary feeder and substation facilities, the cost charges variables and the energy losses cost in primary feeders. The costs minimization has been achieved considering the maximum flow limits in both feeders and substations capacity, the power balance limits as well as the voltages limits.

The feasibility of the proposed technique is tested using a typical power system.

1 INTRODUCTION

The optimal design of distribution system is very important to supply electric energy in a secure and economic manner considering the voltage drop and the thermal current constraints. The planning of substations and primary feeder facilities in electric power distribution systems [1] involves the optimal selection of the installation time, location and capacity of new and/or expanded facilities. In an optimal plan the forecast demand is met over the planning period, while the security constraints are satisfied and the overall installation and operating cost is minimum. This problem has been addressed and formulated by several authors [2-5] as optimization schemes in which a cost function representing the fixed and variable charges was associated with building. Wall et al [6] developed a model, representing nonuniform loads and feeder segments, having variable distribution costs and limited capacitances.A highly efficient transshipment code is used to solve the model. However, the model neglected the fixed charges of feeder segments. Several algorithms have been published [7,8] which can treat the discreteness and the necessity of multi-term planning through dynamic programing.

2 MATHEMATICAL MODEL FORMULATION

The primary distribution feeder was represented by many mathematical models such as the feeder voltage drop, thermal current carrying capacity, energy loss cost, growth factor, energy cost and feeder cost . The following assumptions has been made in formulating the mathematical models :

i) All consumers have the same maximum demand and power factor.
ii) The system is balanced under steady state operating conditions and having no loss or voltage drop in the neutral wire.
iii) All feeders are of radial type.
iv) The reactance per unit length of distribution conductor with different cross sectional area is constant.

In order to study the optimal conductor sizing of a distribution system, some variable items should be mathematically modeled.These items are the voltage drop across the feeder, cost of energy loss, cost of feeder material, cost of area changing along the feeder and cost of substation as given in the following sections:

2.1 Voltage Drop Across The Feeder

In many planning applications, firm constraints on voltage at various demand nodes are set in the following form:

$$V_d^{min} \le V_d \le V_d^{max} \qquad (1)$$

where V_d is the voltage at the demand node.

The well known approximate formula for voltage drop (VD) in a simple radial feeder with n segments, feeding loads with lagging power factors , can be written as:

$$VD = \sum_{i \in n} [\; I_i \, (\rho_i l_i / a_i) \cos \phi_i + I_i \, x_i l_i \sin \phi_i \,] \qquad (2)$$

where

I_i = load current taken from the radial feeder at point i,

ϕ_i = power factor angle of the load current at point i,

R_i = resistance in ohms of feeder i,

x_i = reactance in ohms of feeder i,per unit length,

l_i = length of feeder i in Km,

a_i = cross sectional area of feeder i in mm^2,

ρ_i = specific resistance of feeder i in(ohm mm^2/Km),

n = total number of feeders along the main feeder

Egyptian standard tables of feeders manufacture show that the reactance per Km of aluminum is 0.0951 ohm and 0.0816 ohm for cross section areas of 30 & 95 mm^2 respectively. This shows that the reactance is slightly decreased with the increase of the cross sectional area of feeder. Therefore, taking the reactance to be constant independent of the cross sectional area of the segment does not affect the solution accuracy. Eqn(2) becomes:

$$VD = \sum_{i \in n} [(B_i' / a_i) + B_i''] \qquad (3)$$

where

$$B_i' = I_i l_i \rho_i \cos \phi_i \quad , \qquad B_i'' = I_i l_i x_i \sin \phi_i$$

2.2 Cost Of Energy Loss

The energy loss across the n feeders for the base year (8760 hours) is given by [9]:

$$P_L = \sum_{i \in n} 26.28 \; I_i^2 \; R_i \; (LLF) \qquad (4)$$

where LLF is the loss of load factor which is a function of load factor (LF) and is defined [9] as:

$$LLF = A (LF)^2 + B (LF) \quad \text{for} \quad A+B = 1 \qquad (5)$$

The total energy loss has to be calculated on the basis of percent worth cost for the period of conductor assumed life time (D years) for a discount rate of annual percentage r which be written as

$$C_o = \sum_{i \in n} 26.28 \; I_i^2 \; R_i \; (LLF) \; h \sum_{d \in D} [1 / (1+r)^d] \qquad (6)$$

where h is the cost of energy per Kwh. The effect of load factor on the LLf as given by Eqn(5), and consequently its effect on the cost of energy C_o

To consider the effect of load growth, Eqn(4) has to be multiplied by a factor $(1+g)^{2d}$, $d = 1, 2, .., y$ where y is the plan period up to which the feeder can take load growth , and g is the annual load growth rate . The effect of growth in load factor is given by Scheer [10] through obtaining the yearly value of LF , i.e. $(LF)_d$ within the planning period y as :

$$LF_d = LF_\mu - (0.5)^{d/1.6} (LF_\mu - LF_p) \qquad (7)$$

where LF_μ and LF_p are the ultimate and percent values of load factors respectively .

The cost of energy is not constant as it always increases with time as the cost of erection, labor, equipments and maintenance increase with time. Then the cost of energy per Kwh, h in Eqn(6) must be variable with time as h_d, (d=1,2 ,..,D). Substituting these factors in Eqn(6), it becomes:

$$C_D = \sum_{i=1}^{n} 26.28 (l_i I_i^2 / a_i) \{ \sum_{d \in y} (1+g)^{2d} (LLF)_d h'_d /(1+r)^d + (1+g)^{2y} (LLF)_y \sum_{d=M+1}^{D} h'_d/(1+r)^d \} \qquad (8)$$

2.3 Cost Of Feeder

The actual cost of the distribution factor involves a fixed cost as well as a variable cost. The fixed cost component involves cost for conductor's pole, accessories, labor and erection. The variable cost component reflect the cost of conductor material and is a function of cross - sectional area. The total cost over the life period of the feeder can be written as :

$$C_f = \sum_{i \in n} (b_{1i} a_i + b_{2i}) l_i \qquad (9)$$

where b_{1i} and b_{2i} are the cost constants of feeder per unit length.

2.4 Cost Of Area Changing

Most of distribution feeders have different values of the cross-sectional area as a result of economic graduation. Changing the area of a feeder for two adjacent segments will involve more cost.

This excess cost includes labor cost and the cost of welding or connecting the two different areas to each other. This cost can be expressed as :

$$C_w = H\ c_w \tag{10}$$

where C_w is the total cost for changing the areas along the feeder, H is the number of changing areas across the feeder and c_w is the cost of one change in feeder area .

2.5 Cost Of Substation

The substation cost depends on the substation location and type of supply. In this paper , all substations are considered to be of the same type, (step - down three - phase transformers). The annual cost equation model can be written as :

$$C_s = \sum_{i \in NS} a_{si} + b_{si}\ S_i^2 \ \ \text{L.E/year} \tag{11}$$

where a_{si} represents the construction and the capitalized no-load loss costs. The second part presents essentially copper loss costs. NS is the number of substation and S_i is the injected power (source) at node i in Kw.

3 PROBLEM FORMULATION

3.1 Objective Function

The objective function in this problem is to minimize the total percent worth expenditure containing the conductor costs, the substation costs and the energy loss cost. The total combined cost can be written as :

$$\min\ F = W_1\ (\ C_f + C_w + C_{sub}) + W_2\ C_D \tag{12}$$

where W_1 is the weighting factor for feeders and substations cost and W_2 is the weighting factor for energy loss cost.

The objective cost function of substations to be minimized can be written as :

$$C_s = \sum_{i \in NS} f_i\ (\ S_i\ ) \tag{13}$$

where $f_i(S_i)$ is the cost function of the ith substation unit $= a_{si} + b_{si}\ S_i^2$

This objective function can be linearized about an operating point as shown in Fig(1). The incremental cost at each generation level can be approximated by constant values around each operating point as shown in Fig(2), hence,

$$df_i / dS_i \Big|_{S_i = S_{io}} = 2\ b_{si}\ S_i = f_i'(S_{io}) \qquad (14)$$

Using Taylor series expansion Eqn(14) can be written as :

$$f_i(S_i) = f_i(S_{io}) + f_i'(S_{io})\ \Delta S_i \qquad (15)$$

where , $\Delta S_i = S_i - S_{io}$ (16)

starting with certain operating point , Eqn(15) can be rearranged as :

$$f_i(S_i) = f_i'(S_i) \cdot S_i + f_{io} \qquad (17)$$

also , Eqn(13) is rewritten as :

$$C_s = \sum_{i \in NS} f_i'(S_{io})\ S_i + \sum_{i \in NS} f_{io} \qquad (18)$$

where f_{io} is a cost parameter for each substation and depends on the chosen operating point. This parameter is considered approximately constant when ΔS_i lies within certain tolerance. The value of this tolerance depends on the, required accuracy of the linear solution. Also, $f_i(S_{io})$ is considered approximately constant on the condition that the solution is close enough to the initial operating point O. If this solution is out of tolerance, e.g., with S_{i1} at point 1 shown in Fig(2), the incremental cost and the cost parameter of each generator are not accurate enough and hence the solution obtained using this operating point is not necessarily the optimal one. The procedure may be repeated with new incremental and parameter costs adaptive to the previous solution to have more accurate results.

3.2 System Constraints

i. Power Balance

The total power generation should meet the system load demand , network transmission losses and the net power interchange with the interconnected power system ;

$$\sum_{i \in NS} S_i - P_L - P_{in} = P_D \qquad (19)$$

where, P_L is the transmission losses, P_{in} is the system net interchange which is positive for power out, and P_D is the power system load demand.

ii. Substation Capacity

The substation output power must be within its maximum and minimum limits as :

$$S_i^{min} \leq S_i \leq S_i^{max} \tag{20}$$

iii. Transmission Line Security

The resulting flows through any line should not violate the imposed limits due to thermal capabilities. This limits can be written as :

$$PF_k^{min} \leq PF_k \leq PF_k^{max} \tag{21}$$

where , PF_k is the power flow in line k.

iv. Voltage Drop Constraint

The voltage level at the consumer in the distribution system is the main constraint in distribution system planning. The distribution voltage level is a function of two variables. One of them is dependent on the equipment in use such as transformers, its tap settings and the voltage level received from the generating stations. The other is the voltage drop in the feeder segments [11].The voltage in the distribution feeder depends on the choice of its cross-sectional areas , loading level, power factor and circuit operating voltage. The choice of high value of feeder voltage drop leads to less conductor size and consequently less investment and higher system losses. On the contrary, small value of feeder voltage drop leads to higher conductor size and consequently more investment and less system losses.Therefore,the choice of the optimal economical value of feeder voltage drop is a trade-off between the capital investment and the annual recurring expenditure due to energy losses.

v . Thermal Limit constraint

The maximum allowable conductor temperature at which the conductor can be operated is called the thermal limit or thermal rating of that conductor. For a given feeder loading , the thermal current carrying capacity sets a lower limit on the conductor cross-sectional area A^{min} [12],i.e.,

$$a_i \geq A^{min} \tag{22}$$

vi. Conductor Size constraint

The cross-sectional areas of the conductors vary in a discrete manner and there are only a few standard sizes used in practice. Therefore,the feeder areas are assumed in a priori. Due to the discrete values of the conductor size, the following constraint is to be adopted here :

$$a_i > 0 \tag{23}$$

4. PROPOSED TECHNIQUE

The objective of the proposed planning technique is to find a subtransmission system that capable of supplying given loads and offering a high security level of supply, with minimum overall cost. This problem has mainly two objective functions, first objective is the fixed and variable costs of the substations and primary feeders, while the second objective is the cost of the energy losses. These functions can not be optimized simultaneously due to the inherent conflict between these objectives. The sequence of the solution begins with optimization for the first objective, $W_1 = 1$ and $W_2 = 0$. Then, given the boundary of the first objective, that objective is relaxed by some percentage to be constrained within some bounds and the second objective is achieved $0<W_1<1$ and $0<W_2<1$. This process is repeated until $W_1=0$ and $W_2=1$. This means that the second objective has been optimized by sacrificing the first objective optimization .

The choice of the optimal solution is closed to the ideal line (IL), as shown in Fig(4), and dependent on power system planners meeting their own requirements, based on system considerations. Hence, the optimization problem can be formulated as to minimize the objective function given by Eqn(12) subjected to the three constraints of voltage drops, thermal limit and conductor size given by Eqns(3), (22) and (23) respectively.

The mixed integer programming technique is performed to optimize the location and capacities of substations and the routes of the feeders and their sizes.

5. APPLICATION

5.1 Test System

In order to test the proposed technique for the optimal location capacity of substation units and new primary feeder to be installed, the Suez distribution system of feeders with 19-transmission lines, three transformer substations, 18-buses is used. The single line diagram of the system is shown in Fig(3). The corresponding segments length, lines impedance, and the minimum allowable area for each corresponding feeder current are illustrated in Table(1). The minimum allowable area is decided according to the thermal current carrying capacity in each feeder. The complex injected power and the bus name are illustrated in Table(2).

The substations receive their power from the 220 KV unified grid of Egypt through 66/11 ,220/66/11 KV, 220/11 KV transformer substations at Suez No.1, Suez No.2,and Suez No.3 respectively. The capacity of the distribution substations are :

Suez substation No.1 at bus 1 = 2 x 10 = 20 MVA
Suez substation No.2 at bus 7 = 2 x 20 = 40 MVA
Suez substation No.3 at bus 13 = 2 x 60 = 120 MVA

The other important data that are used here are :
Resistivity of Aluminum = 29.75 ohm mm^2/Km
Constant reactance for the distribution feeder =0.1 ohm/Km.
Power factor = 0.87
Conductor cost of feeder = 10.5 LE/mm^2/Km
Energy cost of feeder = 0.02 LE/KWH
MVA base = 50 & KV base = 11
Permissible changes in voltage drop = ± 5 %

5.2 Results And Comments

Fig(4) shows the relationships between the percentage changes in the weighting factors W_1 and W_2 computed by the proposed technique for existing Suez network . However all the following results are dependent on the weighting factors W_1 and W_2 according to the ideal line (IL) as shown in Fig(4)

Table(3) shows the optimal location of substations and their capacities in order to supply the given loads with a minimum cost and without violating system security constraints . From this table substation No.3 (at bus 7) has the largest generation power in order to feed the loads at buses 5,8-12,14-17, compared with other substations.

Table(4) indicates the optimal conductors sizing of the existing Suez network. This table shows the number of cables, standard areas, cost of conductors, C_f, cost of power losses, C_D, the overall cost, C_T , and the voltage drop in each feeder.

Table(5) shows the sample of conductors sizing using the other standard areas for the feeders 1 - 9. From Tables(4)&(5), it is found that the conductors sizing calculations, using the proposed technique,are the optimal conductors sizing referred to the lowest costs and satisfy the voltage drop limit in each feeder. Table(6) shows lines impedance according to the optimal cross-section area, the current flows, and power flows in each line using Newton-Raphson load flow technique.

Table(7) shows the complex power injection, the complex voltage, the magnitude voltage for each bus according to the optimal cross-section area. From this table, the voltage drop has a maximum value at bus 6 and the maximum regulation equals 4.5 % while the system efficiency equals 91.6 %.

Also, the proposed technique is applied on Suez load demand up to year 2000. However, the Suez load demand has been predicted up to year 2000 using the End Use Forecasting method [13]. Fig(5) shows the expected load demand from year 1987 until year 2000.

Table(8) shows the optimal location of substations and their capacities using the proposed technique in order to supply the predicted load demand of Suez network up to year 2000 which is equal to 263 MVA.

Table(9) shows two another cases of substations capacities to supply the Suez load demand up to year 2000. From Tables (8)&(9), it is found that :

1-The total cost of the under ground cross-section areas, calculated by the proposed technique,equals 7,327,264 LE, the maximum voltage regulation equals 4.9 % and the efficiency equals 95.7 %.

2-The total cost of the cross-section areas,according to case No.1, equals 8,140,561 LE, the maximum voltage regulation equals 5% and the efficiency equals 95.5 %.

3-The total cost of the cross-section areas,according to case No.2, equals 7,484,672 LE, the maximum voltage regulation equals 4.9% and the efficiency equals 95.7 %.

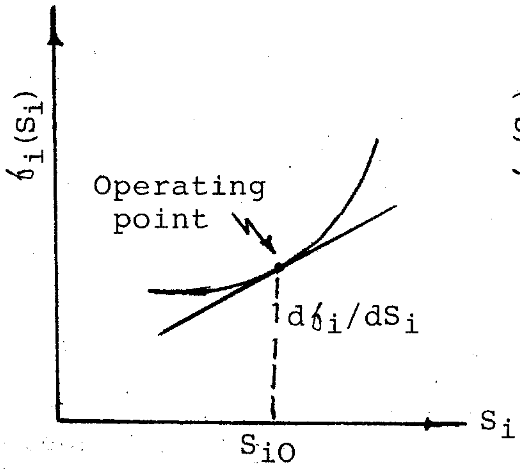

Fig.1 Substation cost function.

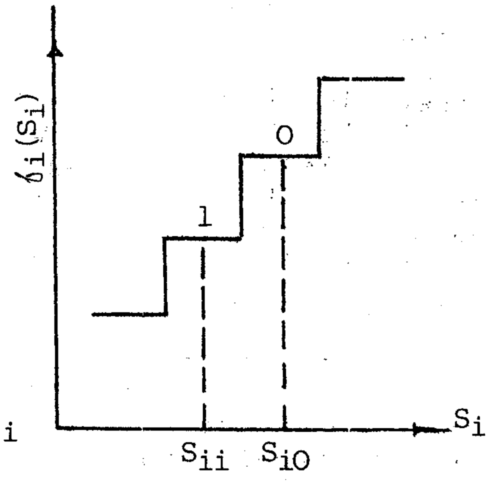

Fig.2 Incremental substation cost.

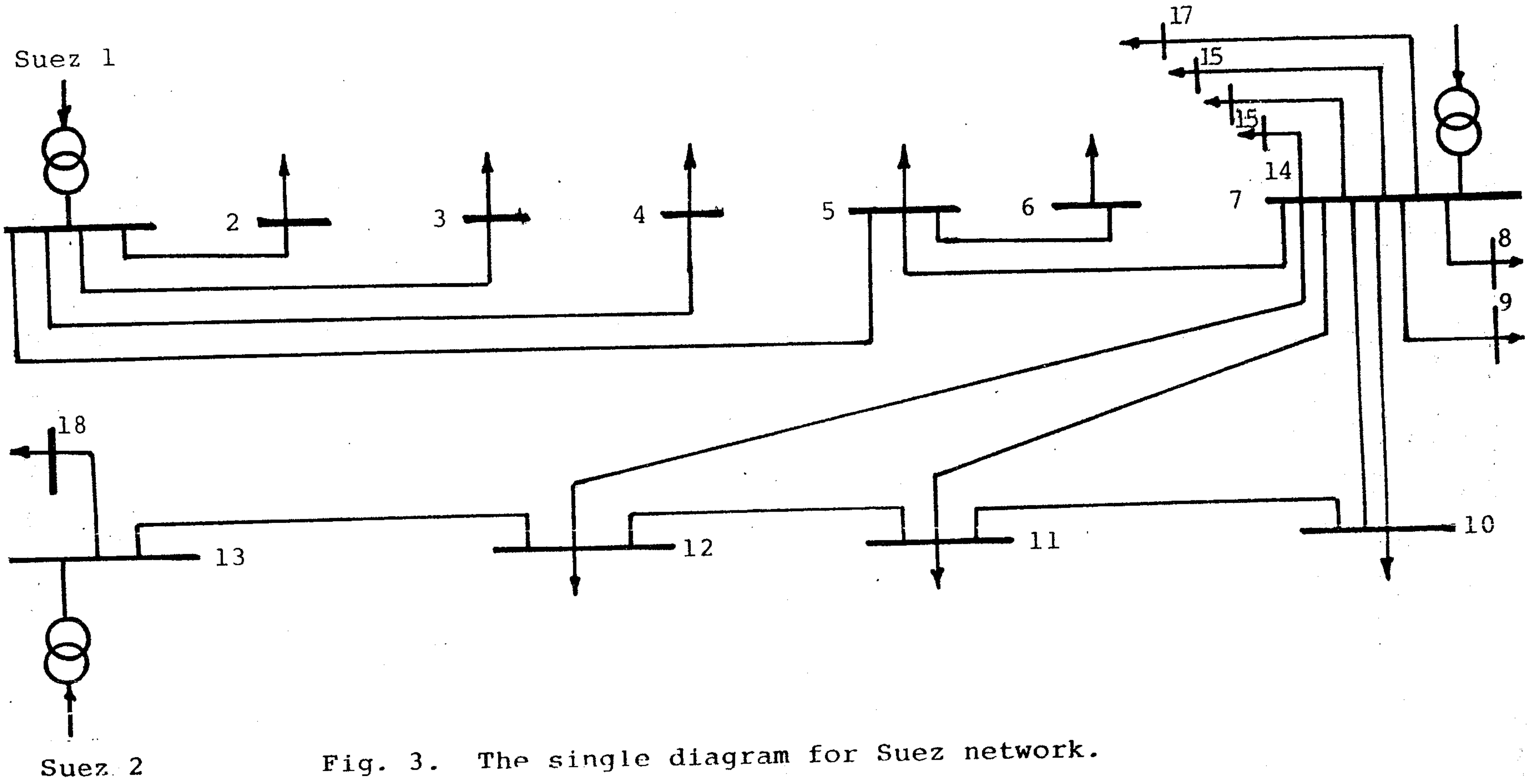

Fig. 3. The single diagram for Suez network.

6. CONCLUSIONS

This paper presented a simple, fast, reliable and efficient planning technique for ring distribution power systems. The location of substation units and their capacities optimal feeder routes and the corresponding suitable wire sizes have been optimized in order to supply the given loads with a total minimum cost and without violating system security constraints. Two weighting factors for the objective function have been achieved which give a wide range of alternative solutions for the power system planners. The percentage changes in the weighting factors help the system planners to choose the optimal operation and planning solution which is required to satisfy certain operating condition or philosophy design.The mixed integer programming technique has been efficiently applied to solve this problem considering two objectives related to both minimum planning cost (C_f + C_w + C_{sub})and minimum operation cost (C_D) for Suez network.

Numerical application has been efficiently carried out on Suez network for the existing load demand and the expecting load demand up to year 2000. Three cases of substations distribution up to year 2000 for Suez network have been applied. However, the proposed technique introduced the more efficient technique for obtaining minimum substation and cross-section costs, minimum voltage regulations and high efficiency operation for ring distribution power system.

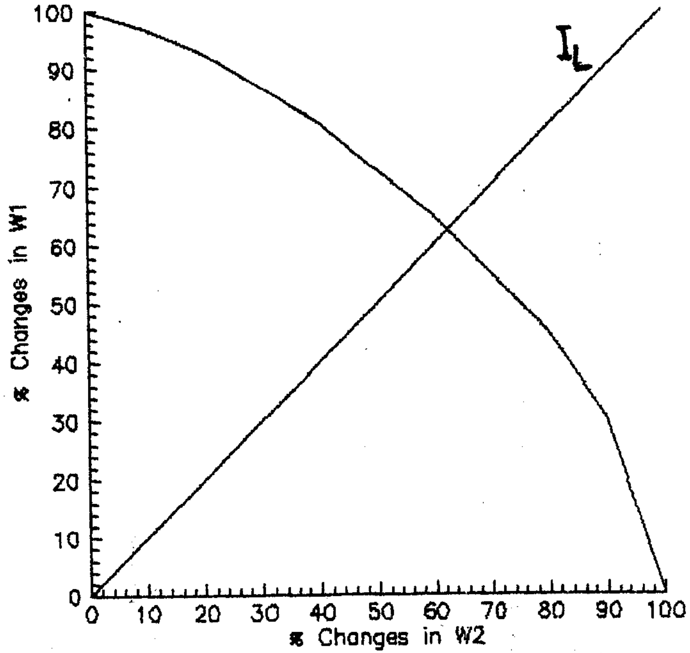

FIG. 4 PERCENTAGE CHANGES IN W1 AND W2

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Table 1: Lines impedance of the existing Suez Network.

Line No.	Bus code from	to	Impedance (ohms)	Impedance (p.u.)	Length (Km)	Min Area (mm^2)
1	1	2	0.508 + J 0.895	0.210 + J 0.370	11	70
2	1	3	1.137 + J 0.089	0.470 + J 0.450	7	70
3	1	4	0.617 + J 0.242	0.255 + J 0.106	6	120
4	1	5	1.597 + J 3.226	0.660 + J 0.333	15	70
5	5	6	0.358 + J 0.186	0.148 + J 0.077	5	70
6	5	7	1.290 + J 0.663	0.533 + J 0.274	9	70
7	7	8	0.218 + J 0.111	0.090 + J 0.046	3	70
8	7	9	0.131 + J 0.116	0.054 + J 0.048	7	120
9	7	10	0.242 + J 0.111	0.100 + J 0.046	9	95
10	7	11	0.063 + J 0.034	0.026 + J 0.014	2	120
11	7	12	1.452 + J 2.275	0.600 + J 0.946	8	70
12	7	14	0.218 + J 0.184	0.090 + J 0.076	5	120
13	7	15	0.073 + J 0.073	0.030 + J 0.030	2	120
14	7	16	0.116 + J 0.073	0.048 + J 0.030	1	185
15	7	17	0.007 + J 0.005	0.003 + J 0.002	1	150
16	10	11	0.702 + J 0.992	0.290 + J 0.410	8	150
17	11	12	0.714 + J 0.363	0.295 + J 0.150	5	150
18	12	13	0.646 + J 0.339	0.267 + J 0.140	9	120
19	13	18	0.285 + J 0.145	0.118 + J 0.060	4	185

Table 2: Injected bus powers for Suez network.

Bus No.	complex bus power (MVA)	Bus name
1	5.45 - J 3.3	Suez No. 1.
2	0.50 - J 0.283	El-Nafak
3	1.00 - J 0.55	El-Eman
4	3.42 - J 1.938	El-Mayah
5	1.00 - J 0.55	Port Tawfik
6	0.83 - J 0.45	Hod El-Dars
7	58.45 - J 36.4	Suez No. 3.
8	1.25 - J 0.65	El-Talaga
9	6.20 - J 0.45	El-Tamen
10	12.67 - J 7.15	El-Arbeen
11	0.05 - J 0.00	El-Ghazia
12	7.92 - J 3.355	Fesal
13	7.90 + J 0.50	Suez No. 2.
14	8.00 - J 4.534	El-Semad
15	1.83 - J 0.950	Petrol Tubes
16	5.05 - J 2.8	El-Naser Petrol
17	20.35 - J 10.45	El-Suez Petrol
18	2.60 - J 1.48	Akdema.

Table 3: Optimal location and capacities of the substations.

Substation location	Output of substation in (MVA)
Bus No. 1	5.75 - J 3.25
Bus No. 7	58.55- J 39.35
Bus No. 13	8.0 + J 3.35

Table 4: Optimal conductors sizing of the existing Suez Network.

Line No.	No. of Cables	Stand. Area (m/m^2)	Cable current (Amp)	C_f(£)	C_D(£)	Total Cost C_T(£)	V.D. (Volt)
1	1	70	31.0	2205	215	2420	230
2	1	70	60.0	15425	5629	21064	281
3	2	120	106.8	45360	17570	62930	299
4	1	70	43.0	33075	6195	39270	436
5	1	70	52.0	11025	3020	14045	176
6	1	70	81.0	19845	13190	33035	492
7	1	70	75.0	7088	3518	10606	152
8	3	150	125.3	39225	34368	133593	340
9	5	120	106.8	165100	66885	231985	416
10	6	126	110.0	45360	18918	64278	95
11	1	70	75.0	17640	10052	27692	405
12	4	150	124.0	94100	32056	126156	220
13	1	120	109.0	7560	3912	11472	37
14	2	185	152.0	11656	3906	15562	50
15	10	150	120.0	47250	15050	62260	43
16	1	150	123.3	37800	12678	50478	350
17	2	150	122.0	75600	15516	91116	216
18	3	150	128.0	126675	46113	172788	409
19	1	185	160.0	23310	8655	31965	193

Table 5: Sample of conductors sizing using the other Standard areas.

Line No.	No. of Cables	Stand. Area m/m^2	Cable Current(A)	C_f(£)	C_D(£)	Total Costs (£)	V.D. (Volt).
1	1	120	31	3780	125	3905	148
	1	95		2993	158	3151	177
2	1	120	60	26490	3284	29744	179
	1	95		20951	4148	25099	218
3	2	185	106.8	69930	11390	61326	226
	2	150	106.8	56700	14056	70756	245
4	1	120	43.0	56700	3614	60314	279
	1	95		44888	4565	49453	330
5	1	120	52.0	18900	1762	20662	113
	1	95		14963	2225	17188	135
6	1	120	81.0	34020	7694	41714	316
	1	95		26933	9719	36652	379
7	1	120	75.0	11340	2199	13539	97
	1	95		8978	2778	11756	117
8	2	300	18.8	132300	25790	158090	320
	4	120	94	105840	32240	138080	285
9	4	150.0	133.5	170100	66884	23984	428
	6	95.0	89	151598	70404	232002	416

Table 6: Line, impedance, the current flow and power flow of the optimal feeders for the existing Suez network.

Line No.	Line impedance (p.u.)	Current flow (p.u.)	Power flow (p.u.)
1	1.932 + J 0.381	0.010 - J 0.006	0.010 - J 0.006
2	1.229 + J 0.242	0.021 - J 0.011	0.021 - J 0.011
3	0.307 + J 0.099	0.070 - J 0.040	0.070 - J 0.040
4	1.941 + J 0.506	0.014 - J 0.008	0.014 - J 0.008
5	0.647 + J 0.169	-0.018 - J 0.009	0.017 - J 0.009
6	1.165 + J 0.303	0.024 - J 0.013	-0.023 - J 0.012
7	0.527 + J 0.104	0.025 - J 0.013	0.025 - J 0.013
8	0.191 + J 0.075	0.128 - J 0.071	0.127 - J 0.071
9	0.231 + J 0.074	0.143 - J 0.083	0.143 - J 0.083
10	0.033 + J 0.013	0.134 - J 0.211	0.134 - J 0.211
11	1.405 + J 0.277	0.008 - J 0.019	0.008 - J 0.019
12	0.103 + J 0.040	0.164 - J 0.092	0.164 - J 0.092
13	0.205 + J 0.066	0.037 - J 0.019	0.037 - J 0.019
14	0.033 + J 0.016	0.102 - J 0.056	0.101 - J 0.056
15	0.008 + J 0.003	-0.409 - J 0.209	0.409 - J 0.201
16	0.219 + J 0.086	0.122 - J 0.063	-0.116 - J 0.062
17	0.137 + J 0.054	0.012 - J 0.148	0.011 - J 0.147
18	0.246 + J 0.097	-0.102 - J 0.103	-0.102 - J 0.098
19	0.266 + J 0.126	0.055 - J 0.027	0.053 - J 0.031

Table 7: Complex powers injection, complex voltages and magnitude voltages for the existing Suez network according to the optimal cross-section areas.

Bus No.	Injected bus power (p.u.)	Bus voltage (p.u.)	Magnitude voltage (p.u.)
1	0.115 - J 0.065	1.000 + J 0.000	1.000
2	0.010 - J 0.006	0.978 + J 0.008	0.978
3	0.020 - J 0.011	0.072 + J 0.009	0.972
4	0.068 - J 0.039	0.975 + J 0.005	0.975
5	0.020 - J 0.011	0.968 + J 0.008	0.968
6	0.017 - J 0.009	0.955 + J 0.011	0.955
7	0.171 - J 0.787	1.000 + J 0.000	1.000
8	0.025 - J 0.013	0.985 + J 0.005	0.985
9	0.124 - J 0.069	0.970 + J 0.004	0.970
10	0.253 - J 0.143	0.961 + J 0.009	0.961
11	0.000 - J 0.000	0.993 + J 0.005	0.999
12	0.118 - J 0.067	0.983 + J 0.025	0.984
13	0.160 - J 0.067	0.998 + J 0.025	1.000
14	0.160 - J 0.910	0.979 + J 0.003	0.979
15	0.037 - J 0.019	0.991 + J 0.002	0.991
16	0.101 - J 0.056	0.996 + J 0.001	0.996
17	0.407 - J 0.209	0.996 + J 0.001	0.996
18	0.052 - J 0.030	0.980 + J 0.061	0.982

Table 8: Optimal locations and capacities of substation for Suez network up to year 2000.

Substation Location	Output of Substation (MVA)	Cost of Cond. (£)	Voltage Regul.	Efficiency
Bus No. 1	35.9 - J36.3	7,327,264	4.9 %	95.7 %
Bus No. 7	35.9 + J35.85			
Bus No. 13	165.85- J132.85			

Table 9: Two another cases of substations capacities for Suez network up to year 2000.

Substation Location		Output of Substation (MVA)	Cost of Cond. (£)	Votlage Regul.	Efficiency
Case 1	Bus No. 1	43.80 -24.9	8,140,561	5 %	95.5 %
	Bus No. 7	56.35 -69.85			
	Bus No. 13	139.5-176.55			
Case 2	Bus No. 1	48.65 -J 19.9	7,484,672	4.9 %	95.7 %
	Bus No. 7	44.35 +J53.05			
	Bus No. 13	145.95-J164.45			

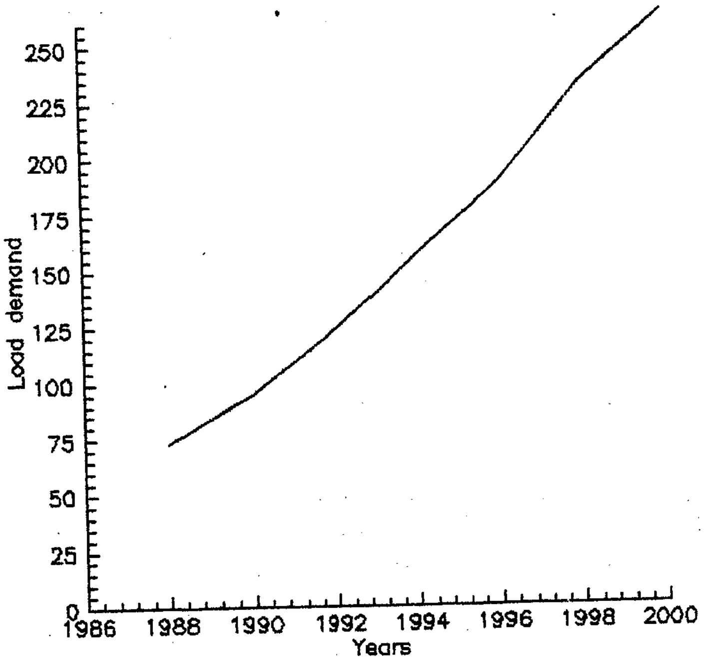

FIG. 5 EXPECTED LOAD DEMAND OF SUEZ GOVERNERATE UP TO YEAR 2000

" بسم الله الرحمن الرحيم "

- ملخص البحث -

يقدم هذا البحث طريقة مقترحة ذات كفاءة عالية للحصول على التوزيع الامثل والاقتصادى للقدرة الكهربية لنظم التوزيع الدائرية •
واستخدمت البرمجة الاختلاطيه Mixed Integer Programming للحصول على اماكن وسعات محطات المحولات المثلى اللازمة لتغذية الاحمال الكهربية بالاضافة الى مساحة مقطع المغذيات لنقل القدرة الكهربية لهذه الاحمال •
تم صياغة ذلك رياضيا آخذين فى الاعتبار التكاليف الثابتة والمتغيرة لمحطات المحولات ومغذيات التوزيع كدالة هدف اولى - بحيث تكون قيمتها اقل مايمكن وتحقيق اقل طاقة كهربية مستهلكة فى مغذيات التوزيع كدالة هدف ثانية •

وتم ذلك معتبرين الحدود المسموح بها فى التغيرات فى ضغوط قضبان الاحمال والحدود الحرارية فى المغذيات عن تيار معين كذلك حدود سريان القدرة الغير فعالة فى هذه المغذيات •

واقترحت طريقة للحصول على دالة هدف خطية ذات دقة عالية لمعادلة تكاليف محطات المحولات الغير خطية - مما امكن ادخالها بسهولة فى البرمجة الاختلاطيه •
كما تم ادخال معاملات تقدير لصياغة مشكلة تعدد الاهداف فى دالة هدف واحده مما اعطى فرص متعددة لاختيار الحل الامثل الاقتصادى اعتمادا على راى ومقترحات مشغل النظام وما يتطلبة النظام تبعا لحالة التشغيل •

تم التطبيق على شبكة التوزيع لمحافظة السويس المصرية واتضح من النتائج كفاءة الاستراتيجية المقترحة لايجاد الحل الامثل لتوزيع القدرة الكهربية للنظم الدائرية وذلك للاحمال الفعلية وكذلك مواجهة زيادة الاحمال المستقبلية حتى عام ٢٠٠٠ •