Urban Electric Power System Planning

By
The Joint Research Team
Electric Power System
Project
Cairo University/MIT

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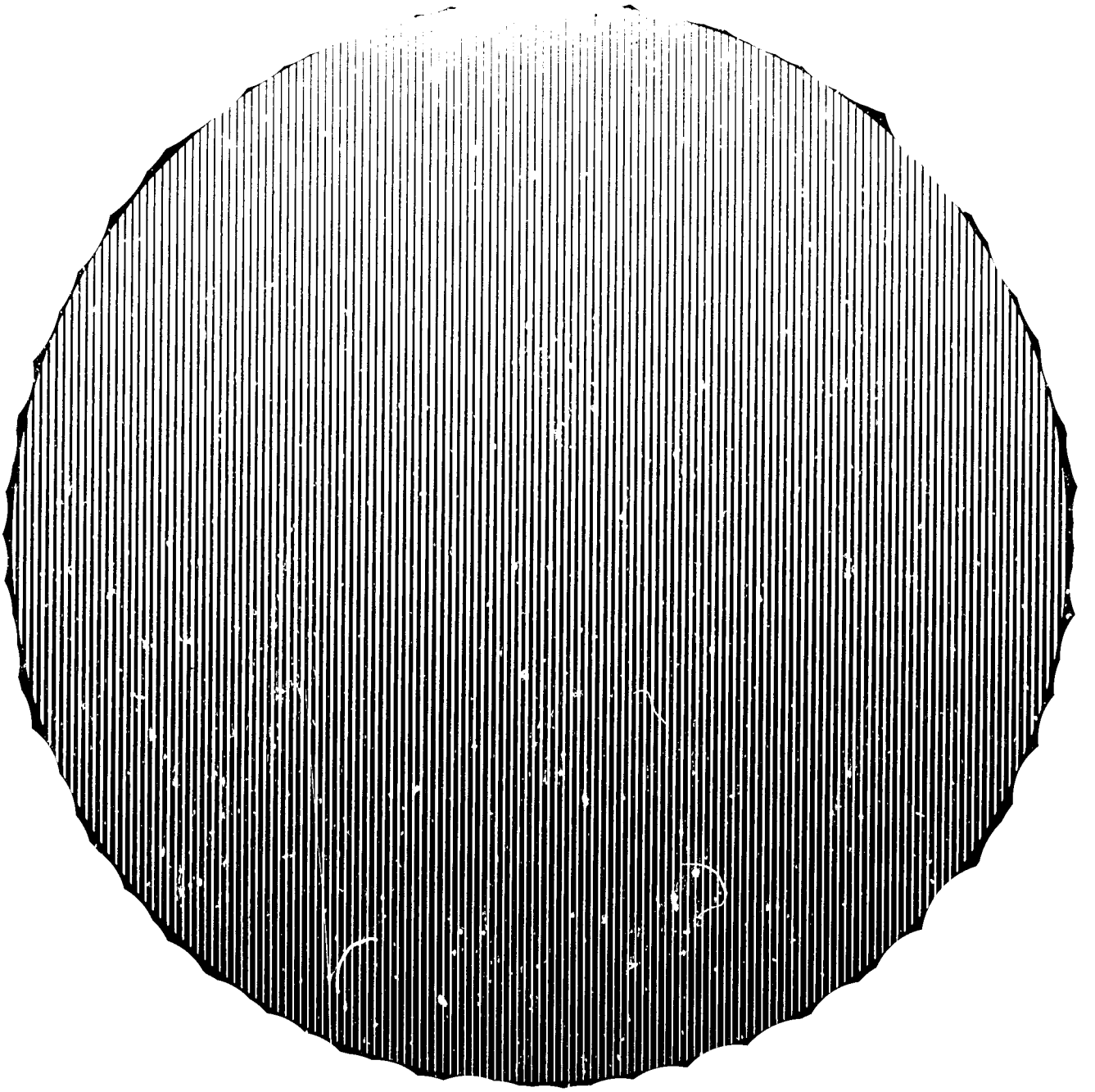

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URBAN ELECTRIC POWER SYSTEM PLANNING

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PROJECT ON

THE LONG TERM INVESTMENT PLANNING FOR

THE EGYPTIAN ELECTRIC POWER SYSTEM

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PREFACE

This report is one of a series of publications which describe various studies undertaken under the sponsorship of the Technology Adaptation Program at the Massachusetts Institute of Technology.

The United States Department of State, through the Agency for International Development, awarded the Massachusetts Institute of Technology a contract to provide support at M.I.T. for the development, in conjunction with institutions in selected developing countries, of capabilities useful in the adaptation of technologies and problem-solving techniques to the needs of those countries. This particular study describes research conducted in conjunction with Cairo University, Cairo, Egypt.

In the process of making this TAP supported study some insight has been gained into how appropriate technologies can be identified and adapted to the needs of developing countries per se, and it is expected that the recommendations developed will serve as a guide to other developing countries for the solution of similar problems which may be encountered there.

Fred Moavenzadeh

Program Director

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INTRODUCTION

This report presents the results of the work of the Urban Planning Subgroup of the MIT-CU project entitled: "Long Term Economic Planning of the Egyptian Electric Power System". The Subgroup operated during the period July 1978 to June 1980, and it concerned itself with the problems of the development of the electric distribution system in the greater Cairo area.

The distribution system in the Cairo area has grown rapidly over the years to meet the increasing load demand. The object of the urban subproject was to assess the cost impact of various types of interconnections on the Cairo distribution system both now and the future. A study of several options for network systems in Cairo has been completed. A "radial" system is one in which a load is connected to one and only one source. A "ring" system is made up of loops so that each load is connected to two different sources looking either way along the loop. Another network topology possible is a "grid", in which a load may be connected to several sources through a number of interconnections.

As more distribution lines and generators have been installed in the Cairo system to meet increasing demand, the levels of current that would be drawn by a short circuit have grown to the point where much of the circuit breaker capacity would be exceeded. Short circuits on many parts of the system would not be cleared by the primary breakers with all network interconnections closed. The solution to this has been to open network interconnections to reduce short circuit levels. But this has had the effect of decreasing the voltage supplied to many loads and to a reduction of circuit reliability. This condition is responsible for much of the loss of load in Cairo. A study is presented here comparing the cost of circuit breaker replacement with the cost of unserved demand, showing that even given the present Cairo system, circuit breaker replacement would result in large savings.

The present Cairo system is predominately radial in character, and a comparison between this type and three alternate configurations is given in this report. The three alternates, two loop variants and a grid type, can be implemented by changing the connections at substations. The study focuses on the effect of the various alternate schemes on voltage levels, transmission and transformer loading, power losses, levels of short circuit currents, and service continuity. It is found that the best maintenance of voltage levels occurs for the grid system, which is also optimal in terms of minimal number of overloaded lines and minimal power losses, whereas the radial system is the least favorable. However, the grid configuration requires a maximum number of replaced circuit breakers, whereas no circuit breaker replacement is necessary for the radial system. The loop systems are found to lie in an intermediate position between the radial and grid systems.

A discussion of growth of demand in the Cairo area is presented in which it is shown that growth will be about 9.9% per year, and that historically a major indicator of this is the results of polling industrial users. Based on this projection a study is presented of a Cairo electrical distribution expansion in which five network alternatives (radial, two loop types and two grid types) are tested. Conclusions similar to those of the above mentioned study of the present system are reached, and a summary table is presented showing for each configuration the required number of circuit breakers to be replaced, the range of voltage level for various demand points, the number of overloaded lines and transformers, and the transmission efficiency.

An examination of investment costs reveals among other things that for the expansion planned to meet the 1983 load demand the most expensive item will be substation construction and expansion, that a radial system would be the cheapest and least reliable, and that although a grid system is optimal for demand service, the cost of circuit breaker replacement would be extremely high.

The recommendation of the subproject on urban systems planning was that a loop system be adopted for the best compromise between level of service and capital costs.

URBAN SYSTEM PLANNING

Report 1

ASSESSMENT OF EXISTING CAIRO SUBTRANSMISSION NETWORK

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ASSESSEMENT OF EXISTING CAIRO SUBTRANSMISSION NETWORK

1. Introduction

The radial system (double circuit) is predominantly in use in Egypt at both subtransmission and distribution levels. The experiences of some other countries show a preference for the loop system as a more reliable, and possibly more economical alternative. For the subtransmission system large line expansions are expected to be carried out, especially in Cairo electricity zone, in the near future. In this chapter, a load flow and short circuit analysis is conducted in order to assess the capability of the existing 1978 network.

The configurations to be studied ,in order to asses their performance and service continuity, are:

1- Radial system.

2- Two-fed end system with sectionalized s/st.buses.

3- Two-fed end system with connected s/st. buses.

4- Grid system.

A comparison is set up between the above configurations taking into considerations the following aspects:

a- Voltages level.

b- Transmission lines loading.

c- Transformers loading and tappings.

d- Network losses.

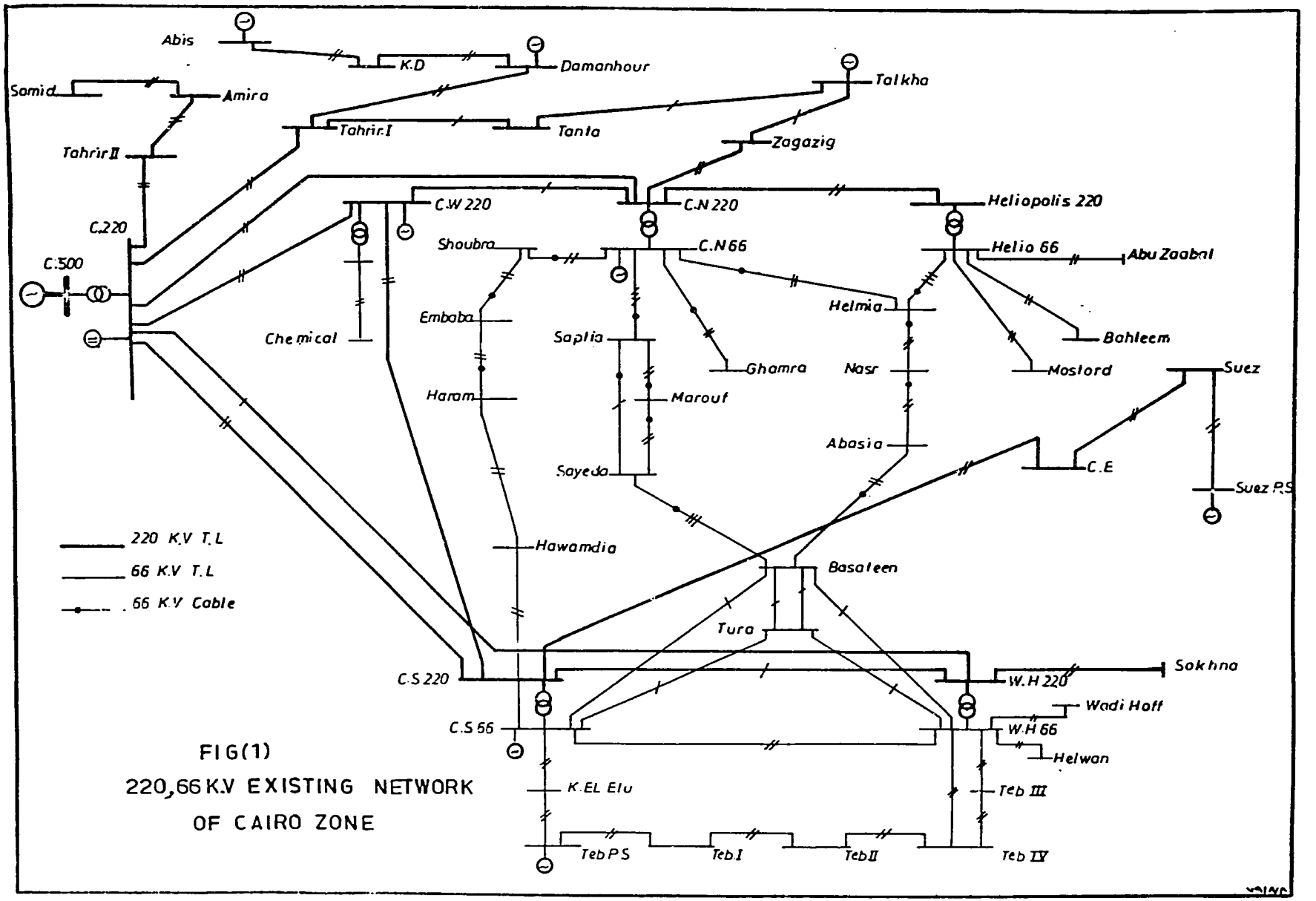
e- Short circuit level.

f- Service continuity.

A detailed study of the different proposed operating schemes is demonstrated in the following sections.

2. Existing network parameters and data of Cairo Electricity Zone

The existing configuration of the 220 KV Delta transmission network and of the 66 KV Cairo subtransmission network is shown in Fig. (1). The 220 KV transmission lines has a total length of 1783.6 km. The length of the 66 KV circuits amounts to 532.5 km in the Cairo Zone, of which 389.6 km are overhead and 142.9 km are underground The subtransmission system is supplied from the 220 KV system through four 220/66 KV substations at Cairo North, Heliopolis, Cairo South and Wadi Hoff.



FIG(1)
220,66 K.V EXISTING NETWORK
OF CAIRO ZONE

2.1 220 KV Transmission lines

The characteristics of the 220 KV lines are shown in Table (1). The Table shows the resistances, reactances and admittances per circuit in per unit on a base of 500 MVA. It is seen that the 220 KV network is a double circuit system except for six lines of single circuit. The longest and shortest lengths of the transmission lines are 130 km and 3 km respectively.

2.2 66 kv overhead transmission lines

The characteristics of the 66 kv overhead lines of the Cairo zone are given by Table (2). The resistances, reactances and admittances per unit on a base of 500 MVA per circuit are given. All lines are double circuits except for six lines which are single circuits. The longest length of the lines is 20.5 km while the shortest is 2 km.

2.3 66kv underground cables

The characteristics of the 66 kv cables are given by Table (3). The table gives the resistances, reactances and admittances per circuit in per unit on a base of 500 MVA. The cables are

Table (1) Existing 220 k.v. Transmission Lines

T.L.	No.of Ct.	Length km	R/ct./ km ohm	X/ct./ km ohm	B/ct./ km 10^{-6}	R/ct. (p.u.)	X/ct./ (p.u.)	B/ct./ (p.u.)
C500 - C.W.	2	11	0.0835	0.412	2.71	0.0095	0.046	0.0003
C500 - C.N.	1	24	0.0835	0.412	2.71	0.0207	0.102	0.0063
C500 - C.S.	2	40.3	0.08	0.392	2.85	0.0333	0.1632	0.011
C500 - T.B.	2	69	0.0835	0.412	2.71	0.059	0.294	0.0181
C500 - T.M.	2	130	0.0835	0.412	2.71	0.112	0.5555	0.033
C.S. - C.W.	2	46.6	0.0835	0.412	2.71	0.04	0.198	0.0122
C.S. - W.H.	1	3	0.08	0.392	2.85	0.004	0.0129	0.00105
C.S. - C.E.	2	30	0.0835	0.412	2.71	0.0259	0.1177	0.00786
C.W. - C.N.	1	16.4	0.0835	0.412	2.71	0.0131	0.0698	0.0043
C.N. - Heliopolis	2	19.2	0.13	0.418	3.56	0.0258	0.083	0.0067
C.N. - Zagazig	2	60	0.0835	0.412	2.71	0.051	0.2554	0.0157
W.H. - Sokna	2	100	0.0835	0.412	2.71	0.08626	0.425	0.0263
Damanhour - K.D.	2	34	0.0835	0.412	2.71	0.0296	0.1462	0.0089
K.D. - ABIS	2	20	0.0835	0.412	2.71	0.017	0.086	0.005
T.M. - Amiria	2	140	0.0835	0.412	2.71	0.035	0.172	0.001
Talkha - Zagazig	1	60	0.0835	0.412	2.71	0.0523	0.258	0.0157
Suez - Suez old	2	3	0.0835	0.412	2.71	0.0026	0.0127	0.0008
Tanta - T.B.	1	43	0.0835	0.412	2.71	0.0375	0.185	0.01126
Damanhour - T.B.	2	63	0.0835	0.412	2.71	0.055	0.271	0.0165
Tanta - Talkha	1	50	0.0835	0.412	2.71	0.04358	0.215	0.013
C.E. - Suez	2	130	0.0835	0.412	2.71	0.1033	0.559	0.034
P.L.L. - Amiria	2	34	0.0835	0.412	2.71	0.0296	0.1462	0.0089
C.S. - W.H.	1	[illegible]	0.13	0.418	3.56	[illegible]	[illegible]	0.00082
C 500 - W.H.	1	43.3	0.08	0.392	2.71	[illegible]	0.18	0.0115

Table (2) Existing Overhead Transmission Lines 66 KV

of Cairo Zone

T.L. Designation	No.of C t.	Length km	R/ct./ km	X/ct./ km	B/c t./ km x 10^{-6}	R/ct/ (p.u.)	X/ct/ (p.u.)	B/ct/ (p.u.)
Tebbin p.s. - Teb. I	2	2	0.134	0.38	3	0.0304	0.0800	0.00005
Tebbin I - Teb.II	2	1.3	0.134	0.38	3	0.02	0.0567	0.000034
Tebbin IV - Teb.III	2	3	0.134	0.38	3	0.046	0.131	0.000078
Tebbin III - Wadi Hoff	2	20.5	0.134	0.38	3	0.315	0.894	0.00053
Wadi Hoff - Teb. IV	2	18.5	0.134	0.38	3	0.284	0.807	0.00048
Tebbin IV - Teb. II	2	5.4	0.134	0.38	3	0.083	0.235	0.00014
Tebbin p.s. - Kafr E.E.	2	6.5	0.134	0.38	3	0.1	0.283	0.00017
Kafr El Elw. - C.S.	2	6	0.134	0.38	3	0.092	0.2617	0.00015
Cairo S. - Wadi Hoff	2	3	0.133	0.4	2.9	0.0458	0.1377	0.00076
Wadi Hoff - Helwan	2	2	0.133	0.4	2.9	0.03	0.0918	0.00051
Wadi Hoff - Basateen	1	18	0.134	0.38	3	0.277	0.785	0.00047
Cairo S. - Basateen	1	18	0.133	0.4	2.9	0.2748	0.826	0.000455
Cairo S. - Tura	1	9	0.133	0.4	2.9	0.137	0.413	0.000227
Wadi Hoff - Tura	1	9	0.134	0.38	3	0.1384	0.392	0.000225
Tura - Basateen	1	9	0.134	0.38	3	0.1384	0.392	0.000225
Tura - Basateen	1	9	0.133	0.4	2.9	0.1369	0.413	0.000227
Cairo - Hawamdia	2	7.6	0.134	0.38	3	0.1169	0.331	0.000199
Hawamdia - Haram	2	12	0.134	0.38	3	0.184	0.523	0.000314
Hawamdia - Embaba	2	13	0.134	0.38	3	0.2	0.567	0.00034
Shoubra - Embaba	2	12	0.133	0.4	2.9	0.1832	0.551	0.0003
Heliopolis - Abu Zaabal	2	20	0.133	0.4	2.9	0.3053	0.918	0.0005
Heliopolis Mostord	2	10	0.134	0.38	3	0.1538	0.436	0.00026
Heliopolis - Basateen	2	16	0.134	0.38	3	0.2461	0.698	0.000418

Table (3) Existing 66 KV Cables in Cairo Zone

T.L. Designation	No.of C t.	Length km	R/ct./ km ohm	X/ct./ km ohm	B/Ct km x 10^{-6}	R/Ct./ (p.u.)	X/Ct./ (p.u.)	B/Ct./ (p.u.)
Basateen - Sayeda	2	5.55	0.071	0.1	84.78	0.04523	0.0637	0.041
Sayeda - Saptia	1	4.78	0.071	0.1	84.78	0.0389	0.05486	0.00353
Saptia - Cairo North	2	7.34	0.071	0.1	84.78	0.0598	0.08425	0.0054
Cairo North - Helmia	2	5.59	0.071	0.1	84.78	0.0455	0.0641	0.00413
Helmia - Heliopolis	2	5.33	0.071	0.1	84.78	0.0434	0.06118	0.003937
Helmia - Nasr	2	4.29	0.0733	0.1	141.3	0.0361	0.0492	0.00528
Nasr - Abbasia	2	4.63	0.0733	0.1	141.3	0.03896	0.053	0.0057
Abbasia - Basateen	2	7.83	0.0733	0.1	141.3	0.06588	0.0899	0.0096
Cairo North - Shoubra	2	4.27	0.0733	0.1	141.3	0.03593	0.049	0.00525
Heliopolis - Helmia	1	5.5	0.0733	0.1	141.3	0.0463	0.063	0.00677
Cairo North - Saptia	1	7.9	0.0733	0.1	141.3	0.06647	0.0907	0.0097
Sayeda - Basateen	1	5.9	0.0733	0.1	141.3	0.04964	0.0677	0.0072
Haram - Imbaba	2	3.8	0.0733	0.1	141.3	0.0296	0.0367	0.0039
Saptia - Marouf	2	3	0.0733	0.1	141.3	0.0252	0.0344	0.0037
Marouf - Sayeda	2	1.78	0.071	0.1	84.78	0.0145	0.0204	0.00132
Cairo North - Gamra	2	6	0.075	0.09	84.78	0.048	0.0616	0.0037

double circuits except for three sections which are triplex and one section of a single circuit. The longest and shortest cable lengths are 7.9 km and 1.78 km respectively.

2.4 220/66 kv substations

The 220 kv transmission system supplies the 66 kv subtransmission system through four substations. The total installed capacity of these s/st,s is 1050 MVA and their characteristics are given by Table (4).

2.5 Generating power stations in Delta and Cairo zones

The existing 220 kv and 66 kv network are supplied from nine power plants, of which six plants are in the Cairo zone. The characteristics of these plants are given by table (5).

2.6 The step-up transformers

The step up transformers at Cairo electricity zone are found at Cairo North, Cairo South, and El-Tebbin. Table (6) shows the characteristics of these step up transformers.

Table (4) Characteristics of existing 220 kv Substations of the Cairo Zone

No	Designation of S.S.	Capacity and No. of trans. MVA	Voltage ratio allowed for regulation	X%
1	Cairo North	2 x 75	$\frac{220 \pm 10\%}{66}$	14
2	Cairc South	2 x 75	$\frac{220 \pm 10\%}{66}$	13.25
3	Heliopolis	3 x 125	$\frac{220}{66 \pm 6\%}$	9.67
4	Wadi Hoff	3 x 125	$\frac{220 \pm 12\%}{66}$	9.67
5	Cairo East	3 x 75	$\frac{220 \pm 10\%}{66}$	14.8
6	Cairo West	2 x 75	$\frac{220 \pm 12\%}{66}$	14

Table (5) Characteristic of Existing Generator power plants of National Grid.

No.	Power Plant	No. & Capacity of units MVA	Rated Voltage kv	Direct Axis Subtransient reactance x_d %
1	Cairo North	2 x 12.5 1 x 25 2 x 37.5	10.5 10.5 10.5	13 13.7 13
2	Cairo South	2 x 75 2 x 75	10.5 10.5	10.6 11.6
3	Old Tebin	3 x 20	10.5	8
4	Cairo West	3 x 105	13.8	11
5	Damanhour	2 x 18.75 3 x 81	10.5 10.5	12 11
6	Talkha	3 x 15.6 3 x 37.5	11.5 10.5	12 2
7	Alex. I up to 220 k.v.	4 x 16 2 x 30 + 2 x 26 2 x 14	-	182 based on 500 MVA
8	Suez old	4 x 37.5	11.5	14
9	Sync. Cond.	3 x 80	11	16.4

Table (6) Characteristic of existing step up transformers in the Cairo Zone

No	Transformer	Capacity and No. of trans. MVA	Voltage ratio for regulation	X%
1	Cairo North	2 x 12.5	10.5 / 66 ± 5%	10
		1 x 25		10
		2 x 37.5		10
2	Cairo West	3 x 100	220 / 13.8 ± 2.5%	13.67
3	Cairo South	2 x 80		9.85
		2 x 82	10.5 / 66 ± 5%	12
4	El Tebin	3 x 20	10.5 / 66 ± 2.5%	8.5

3. Load flow study

3.1 Radial Configuration

The loads at each bus are given in Table (7). The load flow study has revealed the following:

a- Voltage level

The voltage magnitudes of all buses are within the range $0.935 \leq |V| \leq 1.048$ p.u. In Table (8) and Fig. 2, the voltage level at each bus is shown where there are four buses of voltage level more than 1.03 p.u. and twelve buses with levels less than 0.97 p.u.

b- Lines loading

The electrical line loading is shown in Table (9). The lines carrying more than 100% of their capacity are:

Cairo North 66 - Shoubra	110%
Cairo South 66.2 - Basateen. 1	108%
Cairo South 66.2 - Tura. 1	108%
Tura 1 - Basateen. 1	105%

c- 220/66 kv Transformers loading and tapping

The transformers loading and tappings are shown in Table (10) where all the transformers are underloaded and all the tappings are of +10%.

Bus code	Load MW	Load MVAR	Bus code	Load MW	Load MVAR
220 KV Buses					
C 500	-	-	Gamra	8.4	6.3
C 220	-	-	Marouf	22.8	17.1
CW 220	5.5	4.125	Sayeda	40.5	30.375
CN 22	11.5	8.6	Basateen 1	14.95	11.21
Helio. 220	-	-	Basateen 2	14.95	11.25
Zagazig	69	51.75	Tura 1	0.0	0.0
Tanta	50	28	Tura 2	35	26.3
T.B.	44	33	Abasia 1	27.075	20.306
T.M.	45	25	Abasia 2	9.025	6.7687
Somid	10	7.5	Nasr	42	31.5
Amiria	70	45	Helmia	30	22.5
Abir	46	34.5	Helmia 66.1	36.5	27.37
K.D.	-	-	Helio. 66.2	-	-
Damanhour	80	60	Zaabal	44	33
Talka	120	80	Bohteen	24	18
C.S. 220	-	-	Mostord	32	24
C.E. 220	12	9			
Suez	-	-			
Suez p.s.	-	-			
W.H. 220	-	-			
Sokna	38	28.5			
66 KV Buses					
Helwan	20	15			
W.H. 66.1	-	-			
W.H. 66.2	9	6.75			
W.H. 66.3	-	-			
Teb. 3	20	15			
Teb. 4.1	18.25	13.6875			
Teb. 4.2	18.25	13.8			
Teb. 2	14.5	10.875			
Teb. 1.1.	13.5	10.125			
Teb. 1.2	13.5	10.125			
Teb. p.s.	-	-			
K-El-Wlae	2.4.5	18.375			
C.S. 66.1	-	-			
C.S. 66.2	-	-			
Hawamdia	10	7.5			
Haram	44	28			
Embaba 1	27.18	20.7			
Embaba 2	12.825	9.6187			
Shoubra	57.8	43.35			
C.N. 66	34	25.5			
Saptia 1	36	27			
Saptia 2	24	18			

Table (7) The loads for radial system

Bus code	Voltage mag. (p.u.)
Helwan	1.046
W.H. 66.1	1.00
W.H. 66.2	1.048
W.H. 66.3	1.047
Tib. 3	0.959
Tib. 4.1	0.956
Tib. 4.2	1.007
Tib. 2	1.00
Tib. 1.1	0.9997
Tib. 1.2	1.005
Tib. p.s.	1.006
K.El. Elwe	1.001
C.s. 66.1	1.004
C.s. 66.2	1.04
Hawamdia	0.97
Haram	0.95
Embaba 1	0.935
Embaba 2	1.02
Shoubra	1.03
Cairo N. 66	1.03
Saptia 1	1.03
Saptia 2	0.95
Ghamra	1.03
Marouf	0.95
Sayda	0.95
Basateen 1	0.96
Basateen 2	0.95
Tura 1	1.00
Tura 2	0.96
Abasia 1	0.95
Abasia 2	1.01
Nasr	1.01
Helmia	1.01
Heliopolis 66.1	1.02
Heliopolis 66.2	1.00
Zaahal	0.96
Bahteen	1.00
Mostord	0.99

Table (8) Voltage level for the existing 66 KV radial configuration

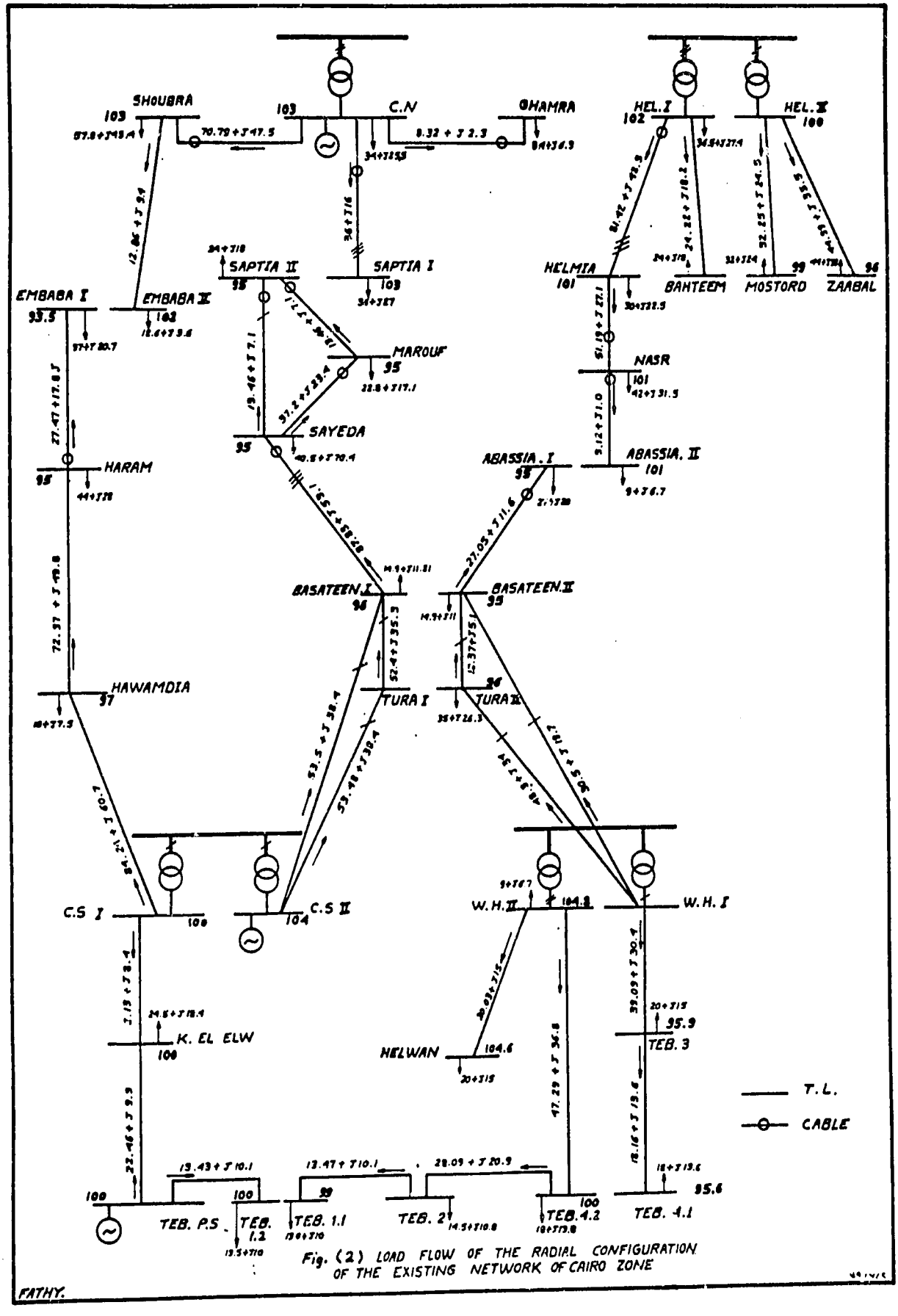


Fig. (2) LOAD FLOW OF THE RADIAL CONFIGURATION OF THE EXISTING NETWORK OF CAIRO ZONE

Line code		line capa-city MVA	Line Load MVA	Percentage loading	Trans. losses MW	MVAR
Hel. 66.2	Zaabal	120	57	47.5	0.99	2.49
Hel. 66.2	Mostord	120	40	33	0.25	0.45
Hel. 66.1	Basateen	120	30	25	0.22	0.21
Hel. 66.1	Helmia	120	91	75.8	0.25	-7.35
Helmia	Nasr	80	60	75	0.12	-5.3
Nasr	Abasia 2	80	11	13.75	0.0	-5.85
Basateen 2	Abasia 1	80	33	41.25	0.07	-8.62
Basateen 1	Sayida	120	105	87.5	0.33	-6.4
Sayda	Marouf	80	44	55	0.03	-1.14
Sayda	Saptia 2	80	13	16.25	0.01	-1.57
Marouf	Saptia 2	80	17	21.25	0.01	-3.36
CN 66	Saptia 1	120	44	36.6	0.07	-10.96
CN 66	Ghamra	80	10	12.5	0.0	-4
CN 66	Shoubra	80	88	110	0.25	-5.31
Shoubra	Embaba 2	120	16	13.3	0.04	-0.19
Haram	Embaba 1	120	34	28.3	0.3	-2.93
Hawamdia	Haram	120	88	73.3	1.52	4.03
CS 66.1	Hawamdia	120	103	85.8	1.25	3.35
CS 66.2	Basateen	60	65	108	2.18	6.32
CS 66.2	Tura 1	60	65	108	1.09	3.17
W.H. 66.1	Tura 2	60	59	98.3	0.96	2.62
W.H. 66.1	Basateen 2	60	36	60	0.73	1.84
W.H. 66.1	Tib. 3	120	25	20.8	0.02	0.0
W.H. 66.2	Helwan	120	49	40.8	0.78	1.64
Teb.3	Teb.4.1	120	22	18.3	0.03	0.0
W.H. 66.2	Teb.4.2	120	59	49.16	0.93	2.1
Teb. 4.2	Teb. 2	120	35	29.16	0.1	-0.07
Teb. 2	Teb. 1.1.	120	16	13.3	0.01	-0.02
Teb. p.s.	Teb. 1.2	120	16	13.3	0.01	-0.03
Teb. p.s.	K.el.-Elwe	120	24	20	0.06	0.02
Tura 2	Basateen 2	60	13	21.6	0.05	0.05
C.S. 66.1	K.El. Elwe	120	8	6	0.01	-0.13
Tura 1	Basateen 1	60	63	105	1.09	3.19

Table (9) Lines loading and losses of existing 66 KV radial configuration

Transformer code	Tr. capacity MVA	Tr. loading MVA	Percent. loading	%Tapping
C.N. 220 C.N. 66	150	78	52%	+ 10
Hel. 220 Hel. 66.1	250	172	68.8%	+ 10
Hel. 220 Hel. 66.2	125	102	82%	+ 10
W.H. 220 W H. 66.1	250	154	61.5%	+ 10
W.H. 220 W H. 66.2	125	98	80%	+ 10
C.S. 220 C.S. 66.1	75	58	77.5%	+ 10
C.S. 220 C.S. 66.2	75	18	24%	+ 10

Table (10) Transformers loading and tapping for the existing 66 KV radial configuration

d- Transmission losses

Transmission lines losses are given by Table (9). The total losses of the 66 kv lines as well as the 220 kv lines amounts to 25.21 MW. Since the total load is 1379.5 MW, then the efficiency amounts to 98.2%.

3.2 Two-fed end system with sectionalized s/st. buses

The loads at each bus are given in Table (11). The study has revealed the following:

a- Voltage level

The buses voltage are within the range $0.9 \leq |V| \leq 1.06$. The voltage level at each bus is shown in Table (12) and Fig. (3) where there are two buses with levels more than 1.03 p.u. and eleven bus less than 0.97 p.u.

b- Lines loading

The lines loading are given by Table (13) where the following lines are carrying over 100% of their capacities:

Cairo South 66.2 - Hawamdia	115%
Hawamdia - Haram	101.6%

c- Transformers loading and tapping

The transformers loading and tapping are given in Table (14). Only one transformer is carrying 110% of its capacity at Hel. 66-1 substation.

Bus code	Load MW	Load MVAR	Bus code	Load MW	Load MVAR
220 kV buses					
C 500	-	-	Ghamra	8.4	6.3
C 220	-	-	Helio. 66.1	36.5	27.375
CW 220	5.5	4.125	Helio. 66.2	-	-
CN 220	11.5	8.6	Helmia	30	22.5
Helio. 220	-	-	Nasr	42	31.5
Zagazig	69	51.75	Abasia	36.1	27.075
Tanta	50	28	Basateen 2	22.425	16.819
T.B.	44	33	Tura 1	34.8	26.1
T.M.	45	25	Zaabal	44	33
Somid	10	7.5	Bahteen	24	18
Amiria	70	45	Mostorid	32	24
Abis	46	34.5	Shoubra	37.8	38
K.D.	-	-	Embaba	40	23
Damanhour	80	60	Haram	44	28
Talkha	120	80	Hawamdia	10	7.5
Cs 220	-	-	Tura 2	-	-
CE 220	12	9			
Suez	-	-			
Suez p.s	-	-			
W.H. 220	-	-			
Sokna	38	28.5			
66 K V buses					
Helwan	20	15			
W.H. 66.1	-	-			
W.H. 66.2	9	6.75			
Tib. 3	20	15			
Tib. 4	36	26			
Tib. 2	14.5	10.875			
Tib. 1	27	20.25			
Tib. p.s.	-	-			
K.El-Elwe	24.5	18.375			
C.S. 66.1	-	-			
C.S. 66.2	-	-			
Basateen 1	7.475	5.606			
Sayida	40.5	30.375			
Marouf	22.8	17.1			
Saptia	60	35			
C.N. 66.1	-	-			
C.N. 66.2	34	25.5			

Table (11) Loads for two-fed end system with Sectionalized buses

Bus code	Voltage Mag. p.u.
Helwan	1.007
W.H. 66.1	1.048
W.H. 66.2	1.009
Teb. 3	0.967
Teb. 4	0.964
Teb. 2	0.956
Teb. 1	0.955
Teb. p.s.	0.956
K.El-Elwe	0.948
C.S. 66.1	0.98
C.S. 66.2	1.06
Basateen 1	0.97
Sayida	0.969
Marouf	0.9699
Saptia	0.97
C.N. 66.1	0.959
C.N. 66.2	0.9794
Ghamra	0.9792
Hel. 66.1	0.943
Hel. 66.2	1.02
Helmia	1.01
Nasr	1.01
Abassia	1.009
Basateen 2	1.01
Tura 1	1.01
Zaabal	0.9
Basateen	0.92
Mostord	0.927
Shoubra	0.956
Embaba	0.959
Haram	0.987
Hawamdia	1.03
Tura 2	0.976

Table (12) Voltage level for the existing sectionalized two fed end configuration

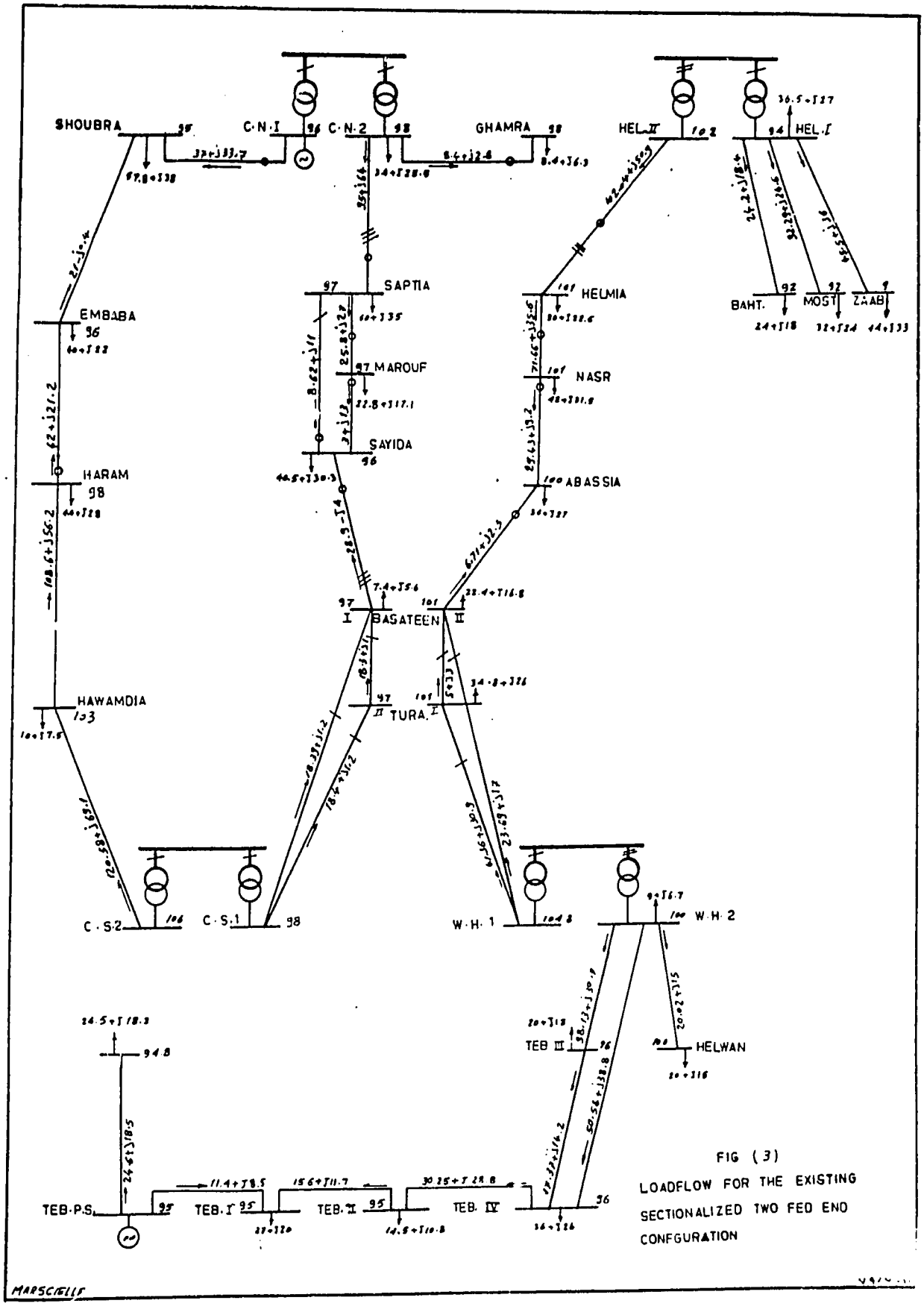


FIG (3)
LOADFLOW FOR THE EXISTING SECTIONALIZED TWO FED END CONFGURATION

Line code		Line Load MVA	Line rat. MVA	Percent. loading	losses MW	MVAR
Hel. 66.1	Zabaal	57.77	120	48%	1.15	3.04
Hel. 66.1	Basateen	30.44	120	25.3%	0.26	0.38
Hel. 66.1	Mostord	40.6	120	33.8%	0.29	0.59
Hel. 66.2	Helmia	114	120	..95 %	0.38	-7.14
Helmia	Nasr	80	80	100 %	0.23	-5.13
Nasr	Abassia	30.8	80	38.5%	0.04	-5.77
Basat. 2	Abassia	7	80	8.75%	0.01	-9.78
Basat. 1	Sayida	29.2	120	24.3%	0.02	-7.02
Marouf	Sayida	13.9	80	17.25%	0.0	-1.22
Saptia	Sayida	13.98	80	17.5%	0.02	-1.62
Saptia	Marouf	37.5	80	46.8%	0.04	-3.4
C.N. 66.2	Saptia	114.7	120	95.6%	0.59	-8.9
C.N. 66.2	Gamra	8	80	10%	0.0	-3.5
C.N. 66.1	Shoubra	50	80	62.5%	0.1	-4.6
Embaba	Shoubra	21	120	17.5%	0.09	-0.0
Haram	Embaba	65	80	81.2%	1.02	-1.3
Hawamdia	Haram	122	120	101.6%	2.58	7
C.S. 66.2	Hawamdia	139	120	115 %	1.98	5.3
C.S. 66.1	Basat 1	18.4	80	30.6%	0.19	0.37
C.S. 66.1	Tura 2	18.4	80	30.6%	0.1	0.2
WH 66.1	Tura 1	51.6	80	86%	0.67	1.78
WH 66.1	Basat.2	29	80	48.3%	0.43	0.96
WH 66.2	Helwan	25	120	20.8%	0.02	0.01
WH 66.2	Teb.3	48	120	40%	0.75	1.54
Teb. 3	Teb.4	22	120	18.2%	0.02	0.0
WH 66.2	Teb.4	63	120	52.5%	1.14	2.74
Teb. 4	Teb.2	37.9	120	31.6%	0.13	0.23
Teb. 2	Teb.1	19.5	120	16.25%	0.01	-0.01
Teb. p.s.	Teb.1	14.2	120	11.6%	0.01	-0.03
Teb.	K.El-Elve	30.8	120	25.8%	0.1	0.16
Tura 1	Basat. 2	6	60	10%	0.01	-0.08
Tura 2	Basat. 1	18.2	60	30%	0.01	0.2

Table (13) Lines loading and losses for the existing sectionalized two-fed end configuration.

Trans. code		Load. MVA	Rating MVA	Percentage loading	Percentage tapping	losses MW	MVAR
CN 220	CN 66.1	53.64	75	71.5%	05	0.0	5.09
CN 220	CN 66.2	58.87	75	78.5%	05	0.0	6.13
Hel 220	Hel 66.2	163.97	250	65.6%	10	0.0	9.4
Hel 220	Hel.66.1	138.35	125	110%	06	0.0	14.8
WH 220	WH 66.1	83.6	125	66 %	10	0.0	4.6
CS 220	C.S 66.1	37.1	75	49 %	05	0.0	2.5
CS 66.2	C.S 22	57.05	75	76	0.00	0.0	5.03

Table (14) Transformers loading and tapping for the existing sectionalized two-fed end configuration

d- Transmission losses

The lines losses are given by Table (13). The total losses of the network including the 220 kv lines amounts to 23.79 MW. The transmission efficiency is 98.3%.

3.3 Two-fed end with connected substation buses

The loads at each bus are given in Table (15). The load flow study has revealed the following:

a- Voltage level

The buses voltages are within the range of $0.963 \leq |V| \leq 1.048$. The voltage level at each bus is shown in Fig. (4) and Table (16) where there are two buses with voltage level more than 1.03 p.u. and two buses with voltage level less than 0.97 p.u.

b- Lines loading

The lines loading are given by Table (17) where it is shown that only one line (CN.66 - Shoubra) is carrying 110% of its rated capacity.

c- Transformers loading and tapping

All the transformers are loaded below their rated capacity as shown in Table (18). Transformers tapping are also given by the Table.

Bus code	Load MW	Load MVAR	Bus code	Load MW	Load MVAR
220 KV buses					
C 500	-	-	C.N. 66.1	-	-
C 220	-	-	C.N. 66.2	34	25.5
CW 220	5.5	4.125	Ghamra	8.4	6.3
CN 220	11.5	8.6	Helio. 66.1	36.5	27.375
Helio. 220	-	-	Helio. 66.2	-	-
Zagazig	69	51.75	Helmia	30	22.5
Tanta	50	28	Nasr	42	31.5
Teb.	44	33	Abassia	36.1	27.075
T.M.	45	23	Basateen 2	22.435	16.819
Somid	40	7.5	Tura 1	34.8	26.1
Amiria	70	45	Zaabal	44	33
Abis	46	34.5	Basateen	24	18
K.D.	-	-	Mostord	32	24
Damanhour	80	80	Shoubra	57.8	38
Talka	-	-	Embaba	40	23
C.S 220	12	9	Haram	44	28
Suez	-	-	Hawamdia	10	7.5
Suez p.s	-	-	Tura 2	-	-
W.H. 220	-	-			
Sokhna	38	38.5			
66 KV buses					
Helwan	20	15			
W.H. 66.1	-	-			
W.H. 66.2	9	6.75			
Teb. 3	20	15			
Teb. 4	36	26			
Teb. 2	14.5	10.875			
Teb. 1	27	20.25			
Teb. p.s.	-	-			
K.El-Elwe	24.5	18.375			
C.S. 66.1	-	-			
C.S. 66.2	-	-			
Basateen 1	7.475	5.606			
Sayida	40.5	30.375			
Marouf	22.8	17.1			
Saptia	60	75			

Table (15) The load for two fed end system (connected Buses)

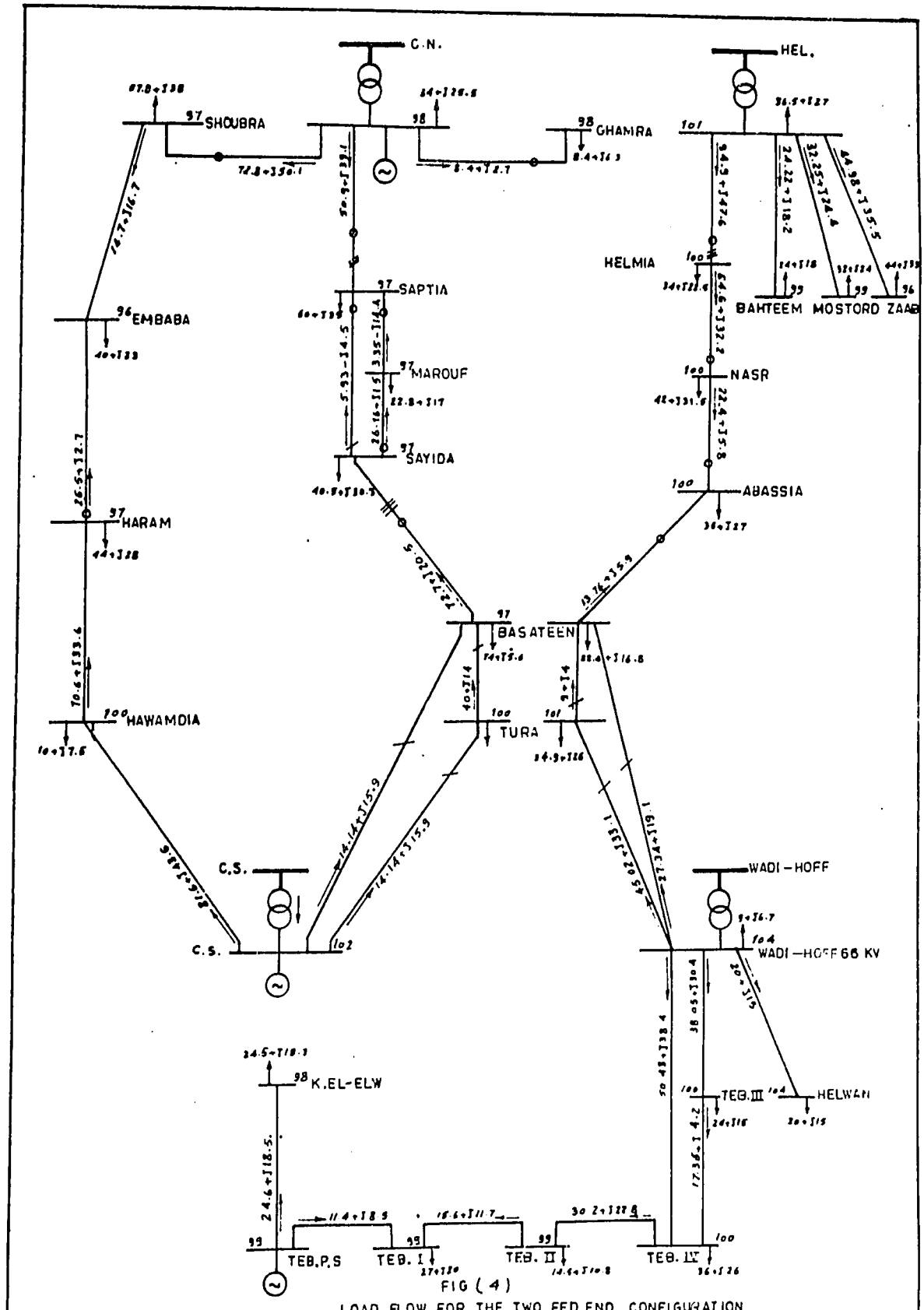


FIG (4)

LOAD FLOW FOR THE TWO FED END CONFIGURATION
FOR THE EXISTING NETWORK OF CAIRO ZONE

Bus code	Volt. mag. p.u.
Hel. 66	1.0136
Zaabal	0.9682
Mostord	0.9982
Basateen	0.9951
Helmia	1.0088
Nasr	1.0088
Abassia	1.0088
Basateen 2	1.0088
Tura 1	1.0088
Wadi Hoff 66	1.0088
Helwan	1.0088
Teb. 3	1.0088
Teb. 4	1.0088
Teb. 2	1.0088
Teb. 1	1.0088
Teb. p.s.	1.0088
K.El-Elwe	1.0088
C.S. 66	1.0088
Tura 2	1.0088
Basateen 1	1.0088
Sayida	1.0088
Marouf	1.0088
Saptia	1.0088
C.N. 66	1.0088
Shoubra	1.0088
Ghamra	0.9803
Embaba	0.1963
Haram	0.9719
Hawamdia	1.002

Table (16) Voltage level for the existing two-fed end configuration.

Line code		Line flow MVA	Line rat. MVA	percent. loading	losses MW	MVAR
Hel.	Zaabal	57.27	120	47.7	0.98	2.46
Hel.	Mostord	40.46	120	33.7	0.25	0.44
Hel.	Basateen	30.3	120	25.25	0.22	0.23
Hel.	Helmia	106.16	120	88.4	0.33	-7.1
Helmia	Nasr	72.14	80	90.17	0.19	-5.11
Nasr	Abassia	23.12	80	28.9	0.02	-5.72
Basat.2	"	14.98	80	18.75	0.02	-9.66
Tura 1	Basateen	10.64	60	17.7	0.03	-0.03
Wadi H.	"	33.37	60	55.6	0.56	1.33
Wadi H.	Tura 1	55.9	60	93	0.79	2.11
Wadi H.	Helwan	25.01	120	20.8	0.02	0.0
Wadi H.	Teb. 3	48.73	120	40.6	0.69	1.28
Teb.3	Teb. 4	63.39	120	52.8	0.02	-0.02
Teb.4	Teb. 2	37.84	120	31.5	0.12	0.18
Teb.2	Teb. 1	19.51	120	16.25	0.01	-0.01
Teb.p.s	Teb. 1	14.22	120	11.85	0.01	-0.03
Teb.p.s	K.El-Elwe	30.78	120	25.65	0.1	0.12
C.S. 66	Tura 2	44.11	60	73.3	0.51	1.43
"	Basateen	44.09	60	73.3	1.02	2.83
"	Hawamdia	92.5	120	77	0.95	2.5
Tura 2	Basateen 1	43.14	60	71.6	0.51	1.43
Basat.1	Sayida	75.59	120	63	0.17	-6.92
SaYida	Marouf	26.2	80	32.5	0.01	-1.22
"	Saptia	7.44	80	9.3	0.0	-1.66
Marouf	Saptia	14.76	80	12.3	0.0	-3.52
C.N.	Saptia	84.23	120	53.3	0.19	-9.54
C.N.		8.84	80	9	0.0	-3.55
C.N.	Shoubra	88.42	80	110	0.3	-4.61
Shoubra	Embaba	22.3	120	18.3	0.1	0.01
Haram	Embaba	25.66	80	32.35	0.16	-3.6
Hawamd.	Haram	78.22	120	65	1.13	2.9
H.W.	Tib. 4	49.4	120	42	1.05	2.44

Table (17) Lines loading and losses for the existing two-fed end configuration.

Trans.		power flow MVA	rated power MVA	Percent. loading	% Tapping	losses MW	MVAR
CN 220	CN 66	97.76	150	65	05	0.0	8.42
Hel 220	Hel 66	289.92	375	77	10	0.0	19.65
W.H.220	W.H. 66	245.79	375	65	10	0.0	13.25
C.S.220	C.S. 66	43.26	150	28.8	0.0	0.0	1.7

Table (18) Transformers loading and tapping for the existing two-fed end configuration.

d- Transmission Losses

The losses are given by Table (17). The total losses of the network including the 220 kv. lines amounts to 21.42 MV. The efficiency of transmission is 98.47%.

3.4 Grid system

The loads at each bus are given in Table (19). The load flow study has revealed the following:

a- Voltage level

The voltage magnitudes of all buses are within the range of $0.969 \leq |V| \leq 1.049$ p.u. The voltage level at each bus is given by Fig. (5) and Table (20) where there are three buses having voltage levels more than 1.03 p.u. and one bus less than 0.97 p.u.

b- Lines loading

The lines loading are given by Table (21) where it is seen that C.N.66- Shoubra line is carrying 115% of its rated capacity.

c- Transformers loading and tapping

Transformers loading and tapping are given by Table (22). It can be seen that all transformers are underloaded.

Bus code	Load MW	Load MVAR	Bus code	Load MW	Load MVAR
220 K.V. buses					
C 500	-	-	Sayida	40.5	30.375
C 220	-	-	Basateen	29.5	22.2
CW 220	5.5	4.125	Tura	34.8	26.1
CN 220	11.5	8.6	Abassia	36.1	27.075
Heliopolis 220			Nasr	42	31.5
Zagazig	69	51.75	Helmia	30	22.5
Tanta	50	28	Helio. 66	36.5	27.375
Feb.	44	33	Mostord	32	24
T.M.	45	25	Bahteem	24	18
Somid	10	7.5	Zaabal	44	33
Amiria	70	45	Ghamra	8.4	6.3
Abis	46	34.5			
K.D.	-	-			
Damanhour	80	60			
Talkha	120	80			
Cs 220	-	-			
CE 220	12	9			
Suez	-	-			
Suez p.s.	-	-			
W.H. 220	-	-			
Sokhna	38	28.5			
66 K.V. buses					
Helwan	20	15			
W.H. 66	9	6.75			
Teb. 3	20	15			
Teb. 4	36.5	27.375			
Teb. 2	14.5	10.875			
Teb. 1	27	20.25			
Teb. p.s.	-	-			
K.el-Elwe	24.5	18.375			
C.s. 66	-	-			
Hewamdia	10	7.5			
Haram	44	28			
Embaba	40	23			
Shoubra	57.8	38			
C.N.	34	25.5			
Saptia	60	35			
Marouf	22.8	17.1			

Table (19) Loads for the grid system

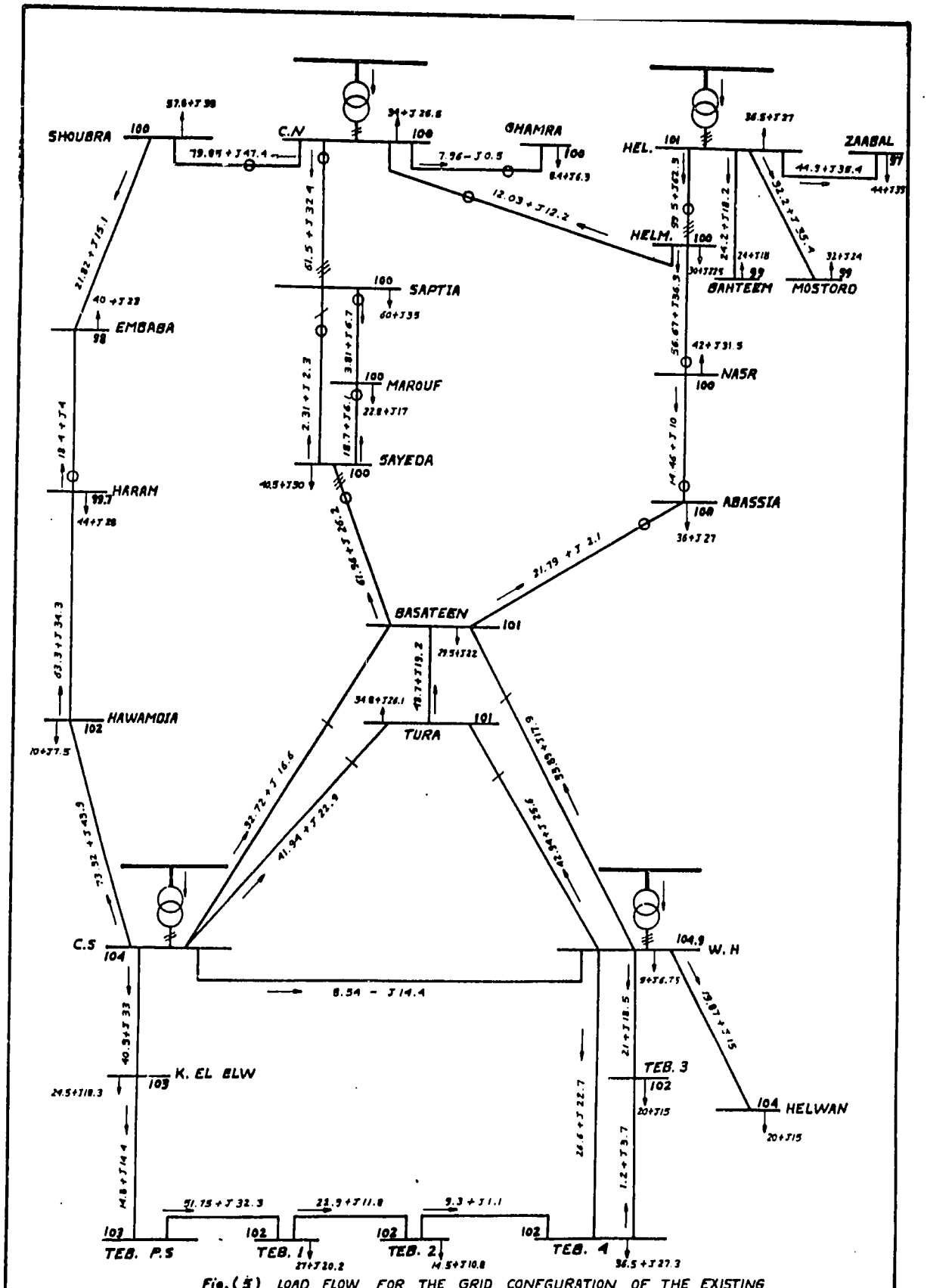


Fig. (5) LOAD FLOW FOR THE GRID CONFGURATION OF THE EXISTING NETWORK OF CAIRO ZONE

Bus code	volt. mag. p.u.
Helwan	1.047
W.H. 66	1.049
Teb. 3	1.0255
Teb. 4	1.0250
Teb. 2	1.026
Teb. 1	1.0271
Teb. p.s.	1.031
K. El-Elwe	1.036
C.S. 66	1.04
Hawamdia	1.02
Haram	0.997
Embaba	0.9898
Shoubra	1.002
C.N. 66	1.007
Saptia	1.002
Marouf	1.002
Sayida	1.003
Basateen	1.005
Tura	1.01
Abasia	1.00
Nasr	1.00
Helmia	1.00
Hel. 66	1.01
Mostord	0.998
Zaabal	0.969
Bahteem	0.995
Ghamra	1.00

Table (20) Voltage level for the existing grid configuration

Line code		Load. MVA	Rating MVA	Percent. Loading	Losses MW	MVAR
Hel. 66	Zaabal	57.2	140	47.6	0.98	2.45
Hel. 66	Bahteem	30.29	140	25.2	0.22	0.22
Hel. 66	Mostord	40.44	140	33.7	0.25	0.44
Hel. 66	Helmia	117.4	120	97.5	0.41	-7
Helmia	Nasr	67.3	80	83.7	0.17	-5.14
Nasr	Abasia	17.6	80	22	0.01	-5.73
Basateen	Abasia	21.9	80	27.4	0.03	-9.64
Basateen	Sayida	67.3	120	56	0.13	-7.38
Sayida	Marouf	19.66	80	25	0.01	-1.3
Sayida	Saptia	3.29	80	4	0.0	-1.76
Saptia	Marouf	7.73	80	9.6	0.0	-3.72
C.N. 66	Saptia	69.54	120	58	0.21	-10.06
C.N. 66	Gamra	7.98	80	10	0.0	-3.75
C.N. 66	Shoubra	92.86	80	105	0.32	-4.87
Shoubra	Embaba	26.5	120	22	0.13	0.09
Haram	Embaba	26.5	120	23.5	0.09	-4.07
Hawamdia	Haram	72	120	60	0.91	2.27
C.S 66	Hawamdia	86	120	71.6	0.79	2.02
C.S. 66	Basateen	36.7	60	61.1	0.68	1.9
C.S. 66	Tura	47.8	60	79.6	0.57	1.61
W.H. 66	Tura	50	60	83.3	0.63	1.66
W.H. 66	Basateen	38	60	63.3	0.74	1.84
W.H. 66	Helwan	25	120	20.8	0.02	0.0
W.H. 66	Teb. 3	28.04	120	23	0.23	-0.19
W.H. 66	Teb. 4	34.94	120	29	0.0	-0.08
Teb. 3	Teb. 4	3.87	120	3	0.32	0.37
Teb. 2	Teb. 4	9.37	120	7.8	0.01	-0.14
Teb. 1	Teb. 2	25.8	120	21.5	0.01	0.0
Teb. p.s.	Teb. 1	61.02	120	50.8	0.1	0.23
K.El-Elwe	Tep. P.S.	20.72	120	17.2	0.04	-0.05
Tura	Basateen	52.4	60	87	0.37	0.83
C.S. 66	K.El-Elve	52.1	60	87	0.23	0.49
C.S. 66	W.H. 66	16.72	120	13.7	0.01	-0.05
Helmia	C.N. 66	17.15	80	21.4	0.01	-1.0

Table (21) Line loading and losses for the existing grid configuration

Transformer code		Power flow MVA	Tr.capacity MVA	%Load.	%Tapping	Loss MW	MVAR
C.N. 220	C.N. 66	103	150	68.66	8	0.0	8.84
Helio.220	Helio.66	303	375	80.5	11	0.0	21.17
W.H. 220	W.H. 66	194	375	51	10	0.0	8.34
C.S. 220	C.S. 66	50	150	33.33	08	0.0	1.82

Table (22) Transformer loading and tapping for the existing grid configuration

d- Transmission losses

The lines losses are given by Table (21). The total losses amounts to 20.8 MW. The transmission efficiency is 98.51%.

4. Short circuit analysis

4.1 Radial system

The short circuit level at each bus is given by Table (23) and Fig. (6). All the values are within the rupturing capacity of the existing circuit breakers, and hence no replacement is required.

4.2. Two-Fed End System With Sectionalized Substation Buses

The short circuit level at each bus is given by Table (24) and Fig. (7). 108 circuit breakers are required to be replaced as shown by the table.

4.3 Two-Fed End System With Connected Substation Buses

The short circuit level at each bus is given by Table (25) as well as Fig. (8). It is seen that there are 144 circuit breakers are to be replaced.

4.4 Grid system

The short circuit level at each bus bar is given by table (26) as well as Fig. (5). It is

Bus code	MVA S.C. Without tapping	MVA S.C. With tapping	C.B. capacity (MVA)
220 K.V. buses			
C 500	5784	5801	15,000
C 220	6884	6934	15,000
CW 220	6411	6454	10,000
CN 220	5433	5464	10,000
Hel. 220	3755	3757	10,000
Zagazig	2904	2898	7 000
Tanta	2356	2347	7 000
T.B.	3963	3956	7 000
T.M.	1444	1436	5 000
Somid	999	993	5 000
Amiria	2495	2488	5 000
Abis	2495	2488	5 000
K.D.	2996	2988	5 000
Damanhour	3604	3595	5 000
Talka	2462	2453	10,000
C.S. 220	4888	4942	5 000
C.E. 22	3264	3272	10,000
Suez	1586	1578	5 000
Suez p.s.	1574	1565	5 000
W.H. 220	4605	4649	10,000
Sokna	1580	1571	5 000
66 K.V. buses			
Helwan	956	1000	1 500
W.H. 66.1	1701	1730	2 000
W.H. 66.2	1045	1089	2 000
W.H. 66.3	763	796	2 000
Teb. 3	638	695	2 000
Teb. 4.1	588	624	3 000
Teb. 4.2	572	608	3 000
Teb. 2	504	537	1 500
Teb. 1.1	490	522	1 500
Teb. 1.2	871	897	1 500
Teb. p.s	937	964	1 500
K.El-Elwe	1015	1046	1 500
C.S. 66.1	1134	1170	1 500
C.S. 66.2	849	884	1 500

Table (23) Short circuit level in MVA for the existing radial configurations

Table (23) cont'd.

Bus code	MVA S.C. Without tapping	MVA S.C. with tapping	C.B. capacity (MVA)
Hawamdia	824	853	1 500
Haram	572	593	2 000
Embaba 1	422	439	1 500
Embaba 2	784	800	1 500
Shoubra	1372	1395	1 500
CN 66	1470	1493	1 500
Saptia 1	1356	1379	1 500
Saptia 2	480	503	1 500
Ghamra	1400	1424	1 500
Marouf	485	508	1 500
Sayida	489	512	1 500
Basateen 1	499	523	1 500
Basateen 2	795	837	1 500
Tura 1	559	585	1 500
Tura 2	875	918	1 500
Abasia 1	738	779	1 500
Abasia 2	1273	1299	1 500
Nasr	1370	1391	1 500
Helmia	1472	1488	1 500
Hel. 66.1	1568	1578	2 000
Hel. 66.2	993	1029	2 000
Zaabal	522	554	1 500
Bahteem	752	788	2 500
Mostord	696	732	2 500

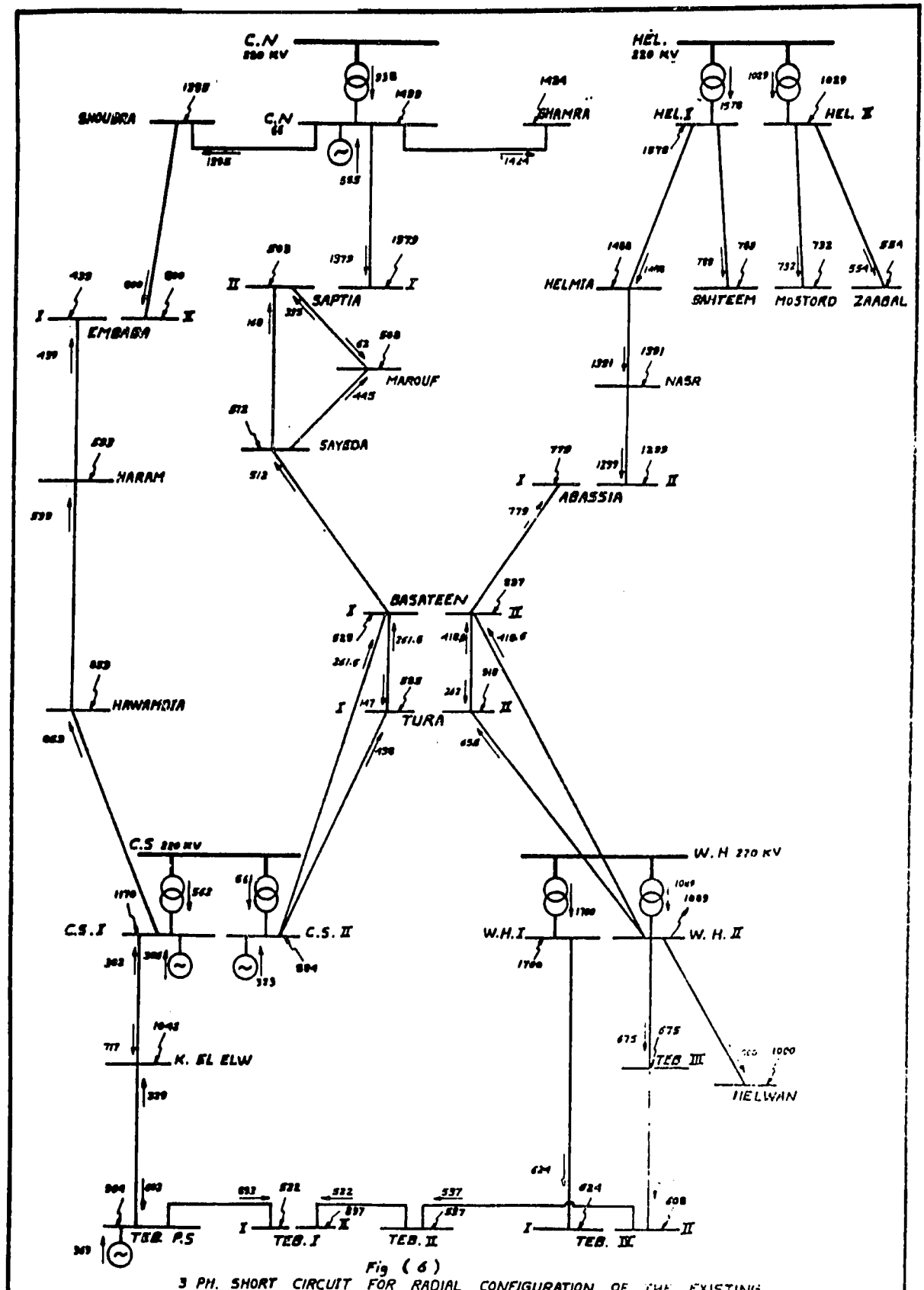


Fig (6)

3 PH. SHORT CIRCUIT FOR RADIAL CONFIGURATION OF THE EXISTING NETWORK OF CAIRO ZONE

FATHY.

Bus code	MVA S.C. With tapping	C.B. capacity MVA	Bus code	MVA S.C. With tapping	C.B. capacity MVA
220 K.V. buses					
C 500	5861	15 000	C.N. 66.1	1272	1 500
C 220	7033	15 000	C.N. 66.2	1889	1 500
CW 220	5644	10 000	Gamra	1769	2 500
CN 220	5610	10 000	Hel. 66.1	949	3 500
Hel. 220	3965	10 000	Hel. 66.2	1895	3 500
Zagazig	2931	7 000	Helmia	1832	1 500
Tanta	2357	7 000	Nasr	1705	1 500
T.B.	3977	7 000	Abasia	1705	1 500
T.M.	1444	5 000	Basateen 2	1623	1 500
Somid	997	5 000	Tura 1	1188	1 500
Amiria	1161	5 000	Zaabal	521	1 500
Abis	2492	5 000	Bahteem	584	2 500
K.D.	2993	5 000	Mostord	684	2 500
Damanhour	3604	5 000	Shoubra	1226	1 500
Talka	2466	10 000	Embaba	1041	1 500
CS 220	5167	5 000	Haram	1096	2 000
CE 220	3366	10 000	Hawamdia	1466	1 500
Suez	1595	5 000	Tura 2	1231	1 500
Suez p.s.	1582	5 000			
W.H. 220	4907	10 000			
Sokna	1605	5 000			
66 K.V. buses					
Helwan	1806	1 500			
W.H. 66.1	1695	2 000			
W.H. 66.2	2135	2 000			
Teb. 3	1281	2 000			
Teb. 4	1344	3 000			
Teb. 2	1178	1 500			
Teb. 1	1148	1 500			
Teb. p.s.	1112	1 500			
K.El-Elwe	851	1 500			
C.S. 66.1	1983	1 500			
C.S. 66.2	2180	1 500			
Basateen 1	1708	1 500			
Sayida	1752	1 500			
Marouf	1755	1 500			
Saptia	1799	1 500			

Table (24) Short circuit level in MVA for the existing sectionalized two-fed end configuration.

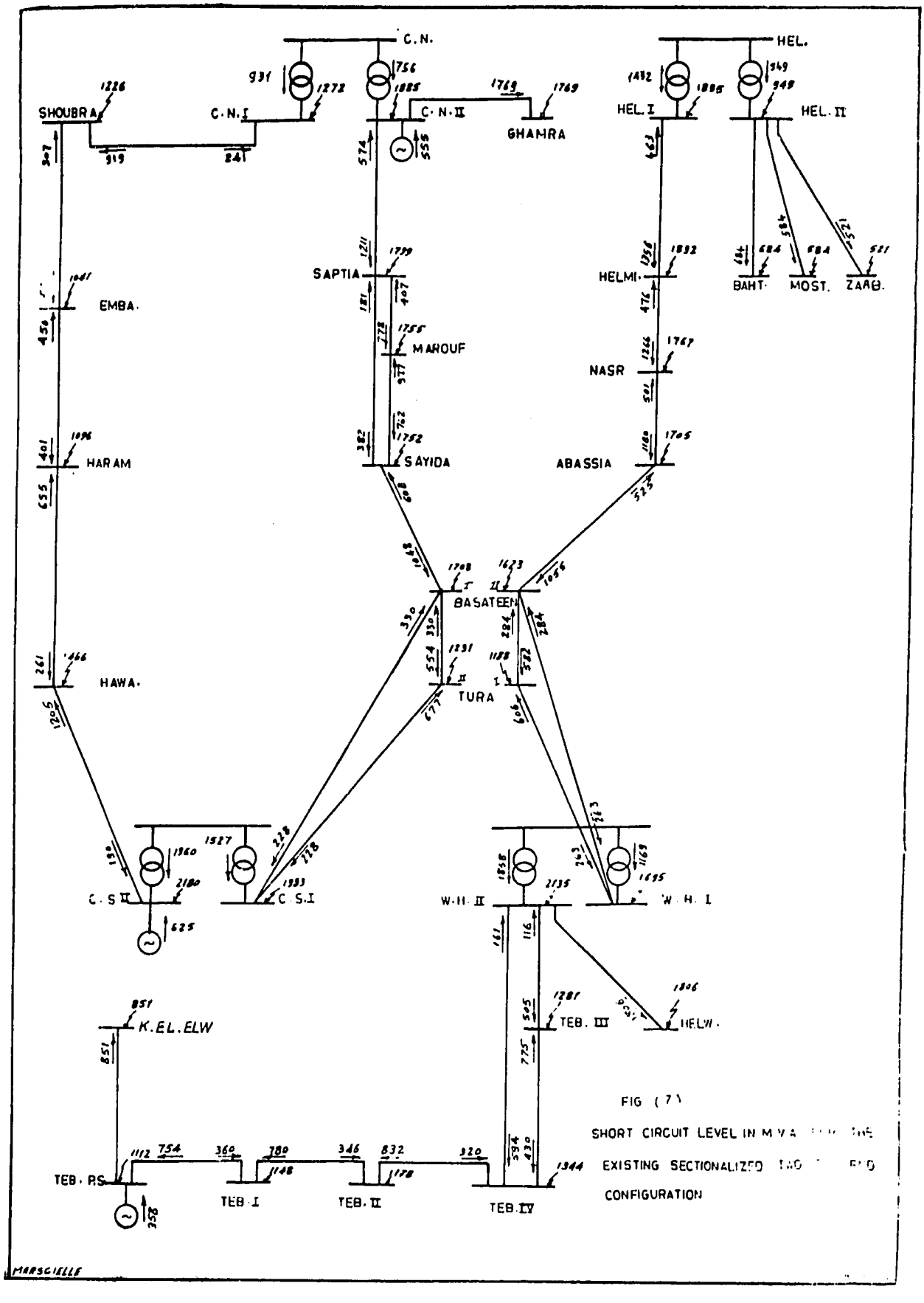


FIG (7)

SHORT CIRCUIT LEVEL IN M.V.A. FOR THE EXISTING SECTIONALIZED TWO [illegible] CONFIGURATION

Bus code	MVA S.C. Without tapping	MVA S.C. With tapping	C.B. capacity. (MVA)
220 K.V. buses			
C 500	5860	5871	15,000
C 220	7018	7052	15,000
CW 220	6532	6561	10,000
CN. 220	5611	5654	10,000
Hel. 220	3997	4037	10,000
Zagazig	2940	2939	7,000
Tanta	2364	2358	7,000
T.B.	3984	3980	7,000
T.M.	1449	1444	5,000
Somid	1001	997	5,000
Amiria	1166	1162	5,000
Abis	2496	2492	5,000
K.D.	2999	2994	5,000
Damanhour	3610	3605	5,000
Talka	2473	2468	10,000
C.S. 220	5137	5177	5,000
C.E.	3362	3370	10,000
Suez	1599	1595	5,000
Suez p.s.	1586	1582	5,000
W.H. 220	4878	4920	10,000
Sokna	1609	1606	5,000
66 K.V. buses			
Helwan	2204	2239	1,500
W.H. 66.1	2754	2752	3,500
W.H. 66.2	2754	2752	3,500
Teb. 3	1391	1449	2,000
Teb. 4	1464	1523	3,000
Teb. 2	1243	1298	1,500
Teb. 1	1205	1259	1,500
Teb. p.s.	1158	1211	1,500
K.El-Elwe	868	913	1,500
C.S. 66.1	2198	2206	1,500
C.S. 66.2	2198	2206	1,500
Basateen 1	1876	1893	1,500
Sayida	1936	1954	1,500
Marouf	1942	1961	1,500

Table. (25) Short circuit level in MVA for the existing two-fed end configuration

Table (25) cont'd.

Bus code	MVA S.C. Without tapping	MVA S.C. With tapping	C.B capacity (MVA)
Saptia	2000	2091	1,500
C.N. 66.1	2121	2141	1,500
C.N. 66.2	2121	2141	1,500
Ghamra	1974	1994	2,500
Hel. 66.1	2367	2355	3,500
Hel. 66.2	2367	2355	3,500
Helmia	2255	2257	1,500
Nasr	2144	2159	1,500
Abasia	2047	2073	1,500
Basateen 2	1927	1966	1,500
Tura 1	1376	1436	1,500
Zaabal	746	791	1,500
Bahteem	891	939	2,500
Shoubra	1964	1983	1,500
Embaba	1247	1260	1,500
Haram	1166	1176	2,000
Hawamdia	1478	1487	1,500
Tura 2	1253	1264	1,500

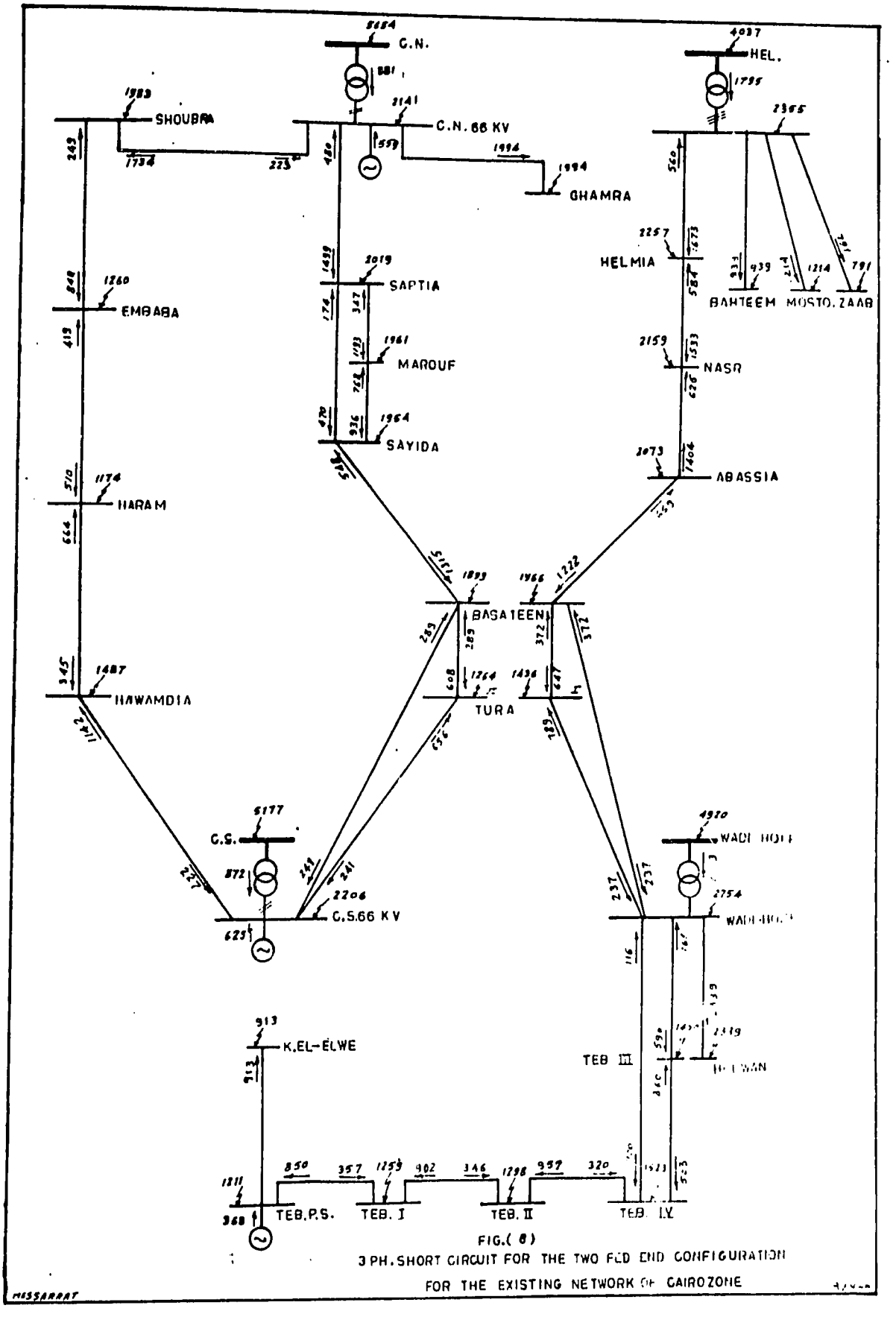


FIG.(8)
3 PH. SHORT CIRCUIT FOR THE TWO FED END CONFIGURATION
FOR THE EXISTING NETWORK OF CAIROZONE

Bus code	MVA S.C. With tapping	MVA S.C. Without tapping	C.B. capacity (MVA)
220 K.V. buses			
C 500	5967	5991	15,000
C 220	7208	7290	10,000
CW 220	6704	6773	10,000
CN 220	5782	5863	10,000
Hel. 220	4334	4432	10,000
Zagazig	2975	2965	5,000
Tanta	2375	2359	5,000
T.B.	4015	4001	5,000
T.M.	1457	1442	5,000
Somid	1005	993	5,000
Amiria	1171	1158	5,000
Abis	2500	2487	5,000
K.D.	3004	2990	5,000
Damanhour	3621	3604	5,000
Talka	2486	2470	18,000
CS 220	5337	5438	5,000
CE 220	3439	3451	10,000
Suez	1610	1596	10,000
Suez p.s.	1597	1583	10,000
WH. 220	5073	5174	10,000
Sokna	1629	1616	10,000
66 K.V. buses			
Helwan	2781	2804	1,500
W.H. 66	3724	3686	2,000
Teb. 3	1741	1793	2,000
Teb. 4	1927	1978	3,000
Teb. 2	1903	1955	1,500
Teb. 1	1942	1993	1,500
Teb. p.s.	2031	2083	1,500
K.El-El	2313	2360	1,500
C.S. 66	3744	3727	1,500
Hawamdia	1939	1992	1,500
Haram	1391	1444	2,000
Embaba	1518	1573	1,500
Shoubra	3000	3016	1,500
C.N.	3452	3438	1,500
Saptia	3213	3217	1,500
Marouf	3136	3146	1,500

Table (26) Short circuit level in MVA for the existing grid configuration

Table (26) cont'd.

Bus code	MVA S.C. Without tapping	MVA S.C. With tapping	C.B. capacity (MVA)
Sayida	3179	3186	1,500
Basateen	3241	3245	1,500
Tura	2377	2424	1,500
Abasia	3053	3063	1,500
Nasr	3164	3162	1,500
Helmia	3437	3409	1,500
Hel. 66	3361	3325	1,500
Mostord	1359	1409	2,500
Bahteem	999	1045	2,500
Zaabal	821	862	1,500
Ghamra	3069	3080	2,500

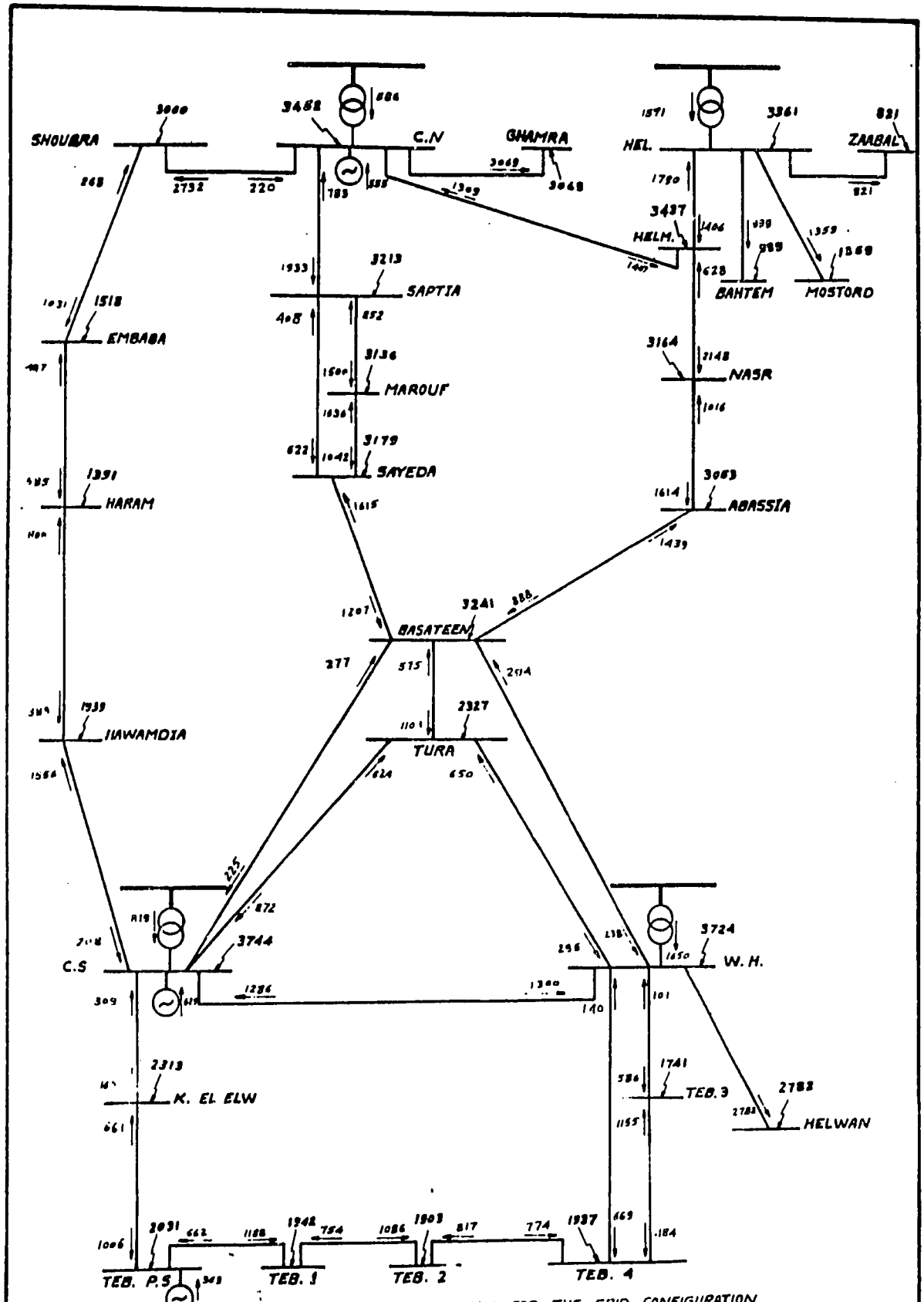


Fig. (9) 3 PH. SHORT CIRCUIT IN MVA FOR THE GRID CONFIGURATION FOR THE EXISTING NETWORK OF CAIRO ZONE

FATHY.

seen that 199 circuit breakers are required to be replaced.

5. Conclusions

The statistics given by table (27) leads to the following conclusions:

a) The number of network buses holding voltage magnitudes (in the range 0.97-1.03 p.u) is larger for "the grid", and "two-fed end and with connected substation buses" configurations than for the others.

b) The overloaded lines are less for "the grid" and the two-fed end with connected substation buses configurations. The radial configuration has more number of overloaded lines.

c) The grid configuration offers the best transmission efficiency since it has the lowest transmission losses. The radial system, on the other hand, is characterized by the largest transmission losses.

d) The grid configuration gives rise to higher short circuit level and hence the number and capacity of circuit breakers to be replaced is larger. On the other hand, no replacement is required for the radial configuration.

Comparison points	Radial system	Two-fed end with unconnected buses system	Two-fed end with connected system	grid system
1- No of buses with voltage level less than 0.97	12	12	2	1
2- No of buses with voltage more than 1.03	4	2	2	3
3- No of overload buses	4	2	1	1
4- No of lines loaded less than fifty recent	20	23	18	20
5- No of overload transformers	-	1	-	-
6- Lines losses	25.21	23.79	21.42	20.8
7- Line effeciency	98.2	98.3	98.47	98.51
8- No of C.B. S to replaced	-	108	144	199

Table (27) Comparison between different network configuration.

6. References

1- Report on Review and Analysis of the Transmission and Subtransmission Networkds in Great Cairo Zone up to the year 1985 (Egyptian Electricity Authority - EEA - Studies and Researches Sector, June 1979).

2- Report on Review and Analysis of the Unified Power System Network and Expected Energy and Load Requirements up to year 1990 (EEA, Studies and Researches Sector, Sept.1978.

3- Electrical Distribution System Rehabilitation and Expansions.Volume IV, Cairo (by Harza Overseas Engineering Company and Sabbour Associate, Nov. 1978).

4- Report on the Activities of the Task Group Studying the Development of Cairo Zone Network (EEA, Feb. 1977).

5- Power Sector Survey, Arab Republic of Egypt, System Planning Diagnostic Reports (by Sanderson & Porter, INC., Power Sector Survey Team, April 1977).

6- Report on Review and Analysis of the Unified Power System Network and Expected Energy and Load Requirements up to 1985 (EEA, Studies and Researches Sector, Dec. 1976).

7- Power System Planning (by Robert L. Sullivan Assoiate Professor of Electrical Engineering, University of Florida).

8- Electrical Transmission and Distribution Reference Book, by Central Station Engineers of the Westinghouse Electric Corporation.

URBAN SYSTEM PLANNING

Report 2

ECONOMICAL ASPECTS OF CIRCUIT BREAKERS REPLACEMENT FOR THE EXISTING SUBTRANSMISSION NETWORK OF CAIRO ZONE

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M. M. El-Metwally
L. Abdel-Kader

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Economical Aspects of Circuit Breakers Replacement for the Existing Subtransmission Network of Cairo Zone

1. Introduction:

The electrical network in Cairo Zone has grown during the past 30 years from small isolated systems to a completely integrated power grid to keep pace with the rapid increase in load demand.

In order to keep the short circuit level on substation bus-bars (66 KV) within the ruptuting capacity of the circuit breakers, the bus-bars are sectionalized and the network is opened at certain points. These actions had led to poor service continuity.

In this report, the economical aspects of circuit breakers replacement or up-grading (up to 3,500 MVA) for the existing Cairo subtransmission system are investigated. The analysis is carried out using two different methods. The capital cost of replacement is weighted against the cost of unserved energy.

2. Existing Circuit Breakers

a) The existing circuit breakers (quantity = 213) varies from 1000, 1500 to 2000 MVA.

b) 50% of the C.B.'s have been installed since 1955/1956, i.e., their expected life (20 years) have been exceeded.

c) The other 50% of the C.B.'s have been installed since 1968, i.e., the rest of their ages is about 40%.

d) From (b) and (c) only about 100 C.B.'s can be reused in other sub-transmission systems.

e) The present worth value of the 100 C.B.'s is then = 100 X 12,000 X 0.40 = 480,000 L.E.

f) On the other hand, it can be considered that all the existing C.B.'s can be reused assuming that the rest of their ages is about 30% , and hence present worth value is equal to about 720,000 L.E.

g) From (e) and (f), the average present worth value of existing circuit breakers = (480,000 + 720,000)/2 = 600,000 L.E.

3. Circuit Breakers Required for Replacement

Rupturing Capacity	Quantity	Type	Price/Unit (1978 price)
3,500 MVA	213	1) SF_6 C.B.	25,740 L.E.
		2) Other types	18,340 L.E.

a) Present cost of all C.B.'s using 100% of C.B.'s quantity of SF_6 type = 213 X 25,740 = 5,482,620 L.E.

b) Present cost of all C.B.'s using 100% of C.B.'s of other types = 213 X 18,340 = 3,906,420 L.E.

c) Present cost of all C.B.'s using 50% of C.B.'s of SF_6 type and 50% of other types = 4,694,520 L.E.

The present investment cost of the required C.B.'s are:

(i) Using SF_6 type only = 5,482,620 - 600,000 = 4,882,620 L.E.

(ii) Using other types only = 3,906,420 - 600,000 = 3,306,420 L.E.

(iii) Using 50% of SF_6 and 50% of other types

= 4,694,520 - 600,000 = 4,094,520 L.E.

4. Analysis using the benefit Cost Ratio Method

a) Assumptions

1) the expected life of a C.B. = 20 years
2) annual rate of escalation = 6%
3) the price of 1 KWh sold on 66 KV voltage level is constant (0.0062 L.E./KWh)
4) operation and maintenance costs are neglected.

b) Unserved energy (due to using the existing C.B.'s)

From statistical analysis of outages of year 1975, the total unserved energy has been found to be about 0.4% of total Cairo Zone energy consumption, as shown in table (1).

c) Tables (2), (3) and (4) show the energy forecast, unserved energy (due to using the existing C.B.'s), and the present worth value of unserved energy. Table (5) summarizes the obtained results. It can be easily seen that it is economical to replace or up-grade the existing circuit breakers to 3,500 MVA rupturing capacity level.

Table (1)

Outages of 1975

Line	Type	No. of Circuit Out	Time Hr.	P. loss MW	E. Loss MW hr.
Helip-Abu Zaabal		1	46.6	-	-
		2	5.38	44	237
Teb - Wadi Hoff	T.L.	2	3.33	41.5	138.3
Embaba - Shoubra		1	0.5	-	-
		2	4.2	-	-
Haram - Hawamdia		1	53	49	2597
		2	0.35	88	31
Teb I - Teb II	T.L.	2	30.2	-	-
Tura - C.S. - Basateen	T.L.	1	0.9	6	4.5
		2	0.116	46	5.336
C.S. Hawamdia		1	0.04	56	2.24
		2	0.3	98	29.4
Help- Bahteem		1	0.333	-	-
Help- Mostorod		1	0.333	-	-
		2	0.1	32	3.2
C.S. - W.H.	T.L.	2	0.4	-	-
Teb - W.H.K. - Elue	T.L.	2	1.2	25	30
W.H. - Helwan	T.L.	2	0.05	20	1
W.H. - Teb III	T.L.	1	.25.44	-	-
W.H. - Teb III	T.L.	2	1.44	-	-
Help- Helmia		2	113.5	40	4540
		3	0.15	40	6
C.N. - Helmia		1	15.1	-	-
		2	12.667	-	-
Saptia - Sayed	cable	1	27	-	-
Sayeda - Basateen		2	0.20	46	9.2
C.N. - Shoubra	cable	1	70.2	-	-
		2	43.1	54	2327
C.N. - Saptia	cable	1	15.8	16	253
Nasr - Helmia		2	0.1	10	1
Basateen - W.H.	T.L.	3	123.3	25	3082.5
		4	8.57	25	214.25

Total energy loss = 13511×10^3 K W H

Energy consumtion through year 1975 = 3811×10^6 K W H

Unserved energy/energy consumption = $\frac{13.511 \times 10^6}{3810 \times 10^6} = 0.0035 = 0.4\%$

Table (2)

Energy Forecast of Cairo Zone & Unserved Energy Cost Due to Using C.B.'s capacity less than 3500 MVA at 66 KV (Unserved Energy = 0.4% of total energy consumtion)

Year	Energy Consumption (million KWH)	Expected Unserved Energy (10^6 KWH)	Expected Unserved Energy Cost (10^3 L.E.)	Present Worth Value due to Escalation 6% (10^3 L.E.)
1980	6,529	24.516	151.999	151.999
1981	7,467	27.388	169.806	160.194
1982	8,462	32.128	199.194	177.282
1983	9,228	37.752	234.062	196.523
1984	10,631	42.524	263.649	208.835
1985	11,316	45.264	280.637	209.708
1986	12,070	48.280	299.336	211.020
1987	13,550	54.200	336.040	223.486
1988	14,460	57.840	358.608	224.995
1989	15,463	61.852	383.482	226.982
1990	17,467	69.868	433.182	241.887
1991	18,560	74.240	460.288	242.474
1992	19,750	79.000	489.800	243.416
1993	21,718	86.972	538.606	252.520
1994	23,132	92.528	573.674	253.737
1995	24,674	98.696	611.915	255.331
1996	26,855	107.42	666.004	262.170
1997	28,686	114.744	711.413	264.193
1998	31,183	124.732	773.338	270.934
1999	33,360	133.440	827.328	273.443

Total Present Worth Value of Unserved Energy Cost = 4,551.129

Table (3)

Energy Forecast of Cairo Zone and Unserved Energy Cost Due to Using C.B.'s Capacity Less Than 3500 MVA at 66 KV (unserved energy = 0.5% of Total Energy Consumption)

Year	Energy Consumption (million KWh)	Expected Unserved Energy (10^6 KWh)	Expected Unserved Energy Cost (10^3 L.E.)	Present Worth Value (10^3 L.E.)
1980	6,529	30.645	189.999	189.999
1981	7,467	34.235	212.257	200.242
1982	8,462	40.160	248.992	221.602
1983	9,228	47.190	292.578	245.654
1984	10,631	53.155	329.561	261.043
1985	11,361	56.580	350.796	262.135
1986	12,070	60.350	374.170	263.775
1987	13,550	67.750	420.050	279.357
1988	14,460	72.300	448.260	281.244
1989	15,463	77.315	479.353	283.728
1990	17,467	87.335	541.477	302.360
1991	18,560	92.800	575.360	303.092
1992	19,750	98.750	612.250	304.269
1993	21,718	108.920	673.258	315.650
1994	23,132	115.660	717.092	317.170
1995	24,674	123.370	764.894	319.164
1996	26,855	134.275	832.505	327.712
1997	28,686	143.430	889.26[illegible]	330.242
1998	31,183	155.915	966.673	338.668
1999	33,600	166.800	1,034.160	341.803

Total Present Worth Value = 5,688.909

Table (4)

Energy Forecast of Cairo Zone & Unserved Energy Cost Due to using C.B.'s Capacity less than 3500 MVA at 66 KV (unserved energy = 0.6% of total energy consumption)

Year	Energy Consumption (million KWh)	Expected Unserved Energy (10^6 KWh)	Expected Unserved Energy Cost (10^3 L.E.)	Present Worth Value (10^3 L.E.)
1980	6,589	36.784	229.837	229.837
1981	7,467	41.082	254.708	240.291
1982	8,462	48.192	298.790	265.922
1983	9,228	56.628	351.094	294.785
1984	10,631	63.786	395.473	313.252
1985	11,316	67.896	420.955	314.526
1986	12,070	72.42	449.004	316.531
1987	13,550	81.300	504.060	335.229
1988	14,460	86.760	537.912	337.493
1989	15,463	92.778	575.224	340.474
1990	17,467	104.802	669.772	362.829
1991	18,560	111.36	690.432	363.711
1992	19,750	118.500	734.700	385.123
1993	21,718	130.308	807.910	378.780
1994	23,132	138.792	860.510	380.604
1995	24,674	148.044	917.873	382.996
1996	26,855	161.130	999.006	393.255
1997	28,686	172.116	1,067.1192	396.290
1998	31,183	187.098	1,160.008	406.402
1999	33,360	200.160	1,240.992	410.164
Total				= 6,828.532

Table (5) Cost Analysis Using Benefit Cost Ratio Method

Unserved Energy as % of Energy Consumption	Present Worth Value of Unserved Energy (10^3 L.E.)	Benefit Cost Ratio		
		Using 100% of SF_6 type	Using 100% of other types	Using 50% of SF_6 type and 50% of other types
0.4%	4551.129	$\frac{4551.129}{4882.620}$ = 0.97	$\frac{4551.129}{3306.420}$ = 1.376	$\frac{4551.129}{4094.520}$ = 1.11
0.5%	5688.909	1.165	1.721	1.391
0.6%	6828.532	1.40	2.065	1.670

5. Cost Analysis Using Sinking Fund Method

The new price of the C.B. at the end of life is given by:

$$w = c_o (1+e)^n - s$$

where

w is the wearing value of C.B.'s

c_o is the original cost of C.B.'s

n is the expected life of C.B. in years

e is the annual rate of escalation

s is the salvage value

The annual deposit is given by:

$$A_d = w \times \frac{i}{(1+i)^n - 1}$$

where

A_d is the annual deposit

i is the rate of interest per year

The depreciation charge, D_r, for the "r th" year is calculated from:

$$D_r = A_d (1+i)^{r-1}$$

Assumptions:

a) The expected life of C.B. is 20 years

b) Annual rate of escalation is considered to be 6%, 7% and 8%.

c) Annual rate of interest is considered to be 8%, 10%, and 12%.

d) Salvage value at the end of C.B. life is negligible.

Therefore,

The present cost of all C.B.'s using SF_6 type

= 213 X 25,740 = 5,482,620 L.E.

The present cost of all C.B.'s using other types

= 213 X 18,340 = 3,906,420 L.E.

The present cost of all C.B.'s (using 50% SF_6 type + 50% others)

= 106 X 25,740 + 107 X 18,340 = 4,690,820 L.E.

Subtracting the present worth value of existing C.B.'s, yields:

C_{o1} = 5,482,620 - 600,000 = 4,882,620 L.E.,

C_{o2} = 3,906,420 - 600,000 = 3,306,420 L.E.,

C_{o3} = 4,690,820 - 600,000 = 4,090,820 L.E.

The wearing values are calculated as shown in the following table:

Annual rate of escalation (e)	Wearing value (W) L.E.		
	W_1	W_2	W_3
6%	15,659,224	10,604,137	13,119,814
7%	18,894,199	12,794,802	15,830,183
8%	22,757,682	15,411,082	19,067,137

The annual deposits are calculated as shown in the following table:

Annual Escalation and Interest Rates	Annual Deposit (L.E.)		
	A_{d1}	A_{d2}	A_{d3}
e = 6%			
i = 8%	342, 198	231, 724	286, 697
i = 10%	273, 404	185, 144	229, 007
i = 12%	217, 331	177, 172	182, 087
e = 7%			
i = 8%	412, 880	279, 595	345, 924
i = 10%	329, 886	223, 392	276,389
i = 12%	262,228	177,576	219,704
e = 8%			
i = 8%	497, 306	336, 766	416.659
i = 10%	397, 341	269. 072	332.905
i = 12%	315, 849	213, 887	264, 629

The present worth value of unserved energy and the net revenue (for unserved energy = 0.6% of total energy consumption and for e = 6%, and i = 10%) are shown in table (6). It is seen that a net revenue of 4.043 million Egyptian pounds is gained as a cost of unserved energy that will be saved by installing new circuit breakers.

The results obtained through this method and the benefit cost ratio method are in agreement.

Table (6)

Present Worth Value of Unserved Energy and Net Revenue (unserved energy = 0.6% of total energy consumption, e = 6%, and i = 10%)

Year	Unserved Energy (10^6KWh)	Unserved Energy Cost (10^3L.E.)	Annual Deposit (10^3L.E.)	Net Revenue (10^3L.E.)	Present Worth Value of Net Revenue (10^3L.E.)
1980	36.784	229.837	229.007	0.830	0.083
1981	41.082	254.78	229.007	25.701	24.246
1982	48.192	298.790	229.007	69.783	62.107
1983	56.628	351.094	229.007	122.087	102.507
1984	63.786	395.473	229.007	166.466	131.857
1985	67.896	420.955	229.007	191.948	143.435
1986	72.420	449.004	229.007	219.957	155.089
1987	81.300	504.060	229.007	275.053	182.926
1988	86.760	537.912	229.007	308.905	193.811
1989	92.778	575.224	229.007	346.217	204.925
1990	104.802	649.772	229.007	420.765	234.953
1991	111.360	690.432	229.007	461.425	243.073
1992	118.500	734,700	229.007	505.693	251.314
1993	130.308	807.910	229.007	578.903	271.412
1994	138.792	860.510	229.007	631.503	279.314
1995	148.004	917.973	229.007	688.866	287.440
1996	161.130	999.006	229.007	769.999	303.107
1997	172.116	1,067.119	229.007	838.112	311.245
1998	187.098	1,160.008	229.007	931.001	326.170
1999	200.160	1,240.922	229.007	1,011.985	334.474
Total Present Worth Value of Net Revenue				=	4,043.488

6. CONCLUSIONS

The cost analysis using benefit cost ratio and sinking fund methods indicates the following:

1- Benefit cost ratios vary from 1.4 to 2.065 depending on the types of C.B. replacement.

2- The present worth value of net revenue, due to C.B. replacement, amounts to a value of 4.043 million Egyptian pounds.

7. RECOMMENDATION:

It is economically recommended to replace or up-grade the rupturing capacity of the existing C.B.'s of the subtransmission network up to a level of 3500 MWA.

8. References

1- Report on Review and Analysis of the Transmission and Subtransmission Networks in Great Cairo Zone up to the year 1985 (Egyptian Electricity Authority - EEA - Studies and Researches Sector, June 1979).

2- Report on Review and Analysis of the Unified Power Network and Expected Energy and Load Requirements up to the year 1990 (EEA, Studies and Researches Sector, Sept. 1978).

3- Electrical Distribution System Rehabilitation and Expansions - Volume IV, Cairo (by Harza Overseas Engineering Company and Sabbour Associate, Nov. 1978).

4- Joint Egypt/United States Report on Egypt/United States Cooperative Energy Assessment (Vol. I, Executive Summary, Main Report and Appendices, Dec. 1978).

5- Annual Reports of Electric Statistics for Years 1972, 1975, 1976 and 1977 (issued by EEA)

6- Power Sector Survey, Arab Republic of Egypt, System Planning Diagnostic Reports (by Sanderson & Porter , INC., Power Sector Survey Team, April 1977).

7- Report on Review and Analysis of the Unified Power System Network and Expected Energy and Load Requirements up to 1985 (EEA, Studies and Researches Sector, Dec. 1976).

URBAN SYSTEM PLANNING

Report 3

LOAD AND ENERGY REQUIREMENTS FOR CAIRO ELECTRIC ZONE (1975 - 1985)

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LOAD AND ENERGY REQUIREMENTS FOR CAIRO ELECTRICITY ZONE (1979 - 1985)

1. Introduction:-

With the rapid increases in load demand, the electric network in Cairo Zone has been grown so fast such that the peak demand jumped in the last two decades from 156 MW in year 1958 to 920 MW in year 1978.

This chapter is devoted to give the up-dated electrical energy and load requirements for the next seven years plan in Cairo Zone from 1979 to 1985.

Calculation of the electrical energy required for the heavy industries in addition to the natural growth of the consumption for other utilities such light and medium industries, domestic, commercial and public services are estimated.

2. Historical Data

Statistical analysis of electrical energy consumption and peak demand in last 25 years in Cairo Zone is shown in table (1).

Year	Energy Consumption			Peak Demand		
	Million (KWH)	Average Rate %		MW	Average Rate %	
1956	636			115		
1958	836	15		156		
1960	1110.6			195	13.3	
1965	xx			353		
1970	xx			xx		
1971	xx			xx		
1972	2793			xx		
1973	2970			xx		
1974	3388	10.9	9.7*	xx		10*
1975	3810			653		
1976	4100			767		
1977	4514	8.8		855	9.5	
1978	4857			920		

Table (1) Energy Consumption And Peak Demand

* Average annual growth rate up to year 1977 = 9.9%

xx Data is not available

3. <u>Annual Energy Consumption and Peak Demand in Cairo Zone Compared to the total National</u>

Table (2) shows the percentage of the energy Consumption and peak load in the last two decades in Cairo Zone to the total consumption in the national grid.

Year	Energy Consumptopm (Million KWH)			Peak Demand (MW)		
	National grid	Cairo Zone	%	National grid	Cairo Zone	%
1956	1426	636	44.6	297	115	38.7
1960	3079	1110.6	36.1	533	195	36.6
1965	5000	xx	-	750	353	47.1
1970	6915	xx	-	1100	xx	
1971	7323	2572	35.1	1160	xx	
1972	7384	2793	37.8	1176	xx	
1973	7435	2970	39.9	1248	xx	
1974	8519	3388	39.8	1433	xx	
1975	9799	3810	38.9	1733	653	37.7
1976	11646	4100	35.2	1909	767	40.2
1977	13572	4640	34.2	2284	855	37.4
1978	15074	4857	32.2	2555	920	36

Table (2) A comparison of Annual Energy consumption and Peak Demand in Cairo Zone to the total national grid

xx Data is not available

.4. Annual Rates of growth with and without Heavy Industries

The statistical analysis of electrical energy consumption in Cairo Zone in the last decades as shown in Tables (3) and (4) indicates the following:

a) An average rate of growth of energy consumption within the last decade with heavy industries is 9.7% and without heavy industries is 9.1%.

b) An average rate of growth within the last 12 months (from Jan. 1978) is 7.6%*.

Year	Total Cairo Zone Energy consumption			Consumption Excluding Heavy Industries		
	Million KWH	Rate %	Average Rate %	Million KWH	Rate %	Average Rate %
1972	2793	-		2493		
1973	2970	6.3		2645	6.1	
1974	3388	14.1		2848	7.7	
1975	3810	12.5		3242	13.8	
1976	4100	7.6	9.6	3467	6.9	9.1
1977	4514	10.1		3979	14.8	
1978	4857	7.6		4196	5.5	

Table (3) Energy Consumption & Rate of Growth in the period from 1972 to 1978

* Electrical Energy Shed within year 1978 : 100 Million KWH

Month	Energy Consumption (Million KWH)		
	1977	1978	Growth Rate %
January	378	416	10.1
February	338	363	7.4
March	376	402	6.9
April	376	388	3.2
May	384	385	0.2
June	360	392	8.9
July	367	410	11.7
August	394	440	11.7
September	376	388	3.2
October	388	415	7.0
November	366	414	13.1
December	411	444	8.0
Total	4514	4857 *	7.6

Table (4) Comparison of Rate of Growth of last 12 Months of the year 1977 and 1978

* Energy Shed within year 1978 100 Million KWH

5. <u>Load and Energy Required for Cairo Zone Up to Year 1985</u>

Tables (5), (6) and (7) give the expected energy consumption and peak demand in Cairo Zone up to the year 1983, according to the 5 year plan (1979/1983) of different utilization sectors (industrial, construction public services,...etc).

Figs (1) and (2) show graphically the expected consumption. Since the plan of industrial sector and others beyond 1983 are not defined, therefore the expectation of electric energy and peak loads requirement in Cairo Zone up 1985 are based on the statistical consumptions by taking annual growth rate as 10% for energy consumption & 11% for peak demand. The following table gives the total energy required and peak demand up 1985.

Year	Peak Demand (MW)	Energy Consumption (TWH)	Annual Load Factor %
1983	1659	9.228	63.50
1984	1851	10.500	64.75
1985	2000	11.360	64.80

Project Name	1978		1979		1980		1981		1982		1983	
	TWH	MW	TWH	MW	TWH	MW	TWH	TW	TWH	MW	TWA	MW
Iron & Steel -	.250	36	.40	56	.40	56	.40	56	0.40	56	0.40	56
Rolling mill-	.070	22	.070	22	0.13	40	0.13	40	0.22	69	0.22	69
Integrated Mill	.25	36	0.25	36	0.25	36	0.35	50	0.35	50	0.35	50
Steel Industry	0.57	94	0.72	114	0.78	132	.88	146	0.97	175	0.97	175
Fertilizer	0.10	20	0.10	20	0.10	20	0.15	30	0.15	30	0.15	30
Cement Plants:												
Tora Existing	.08	12	0.08	12	.08	12	.08	12	.08	12	.08	12
Extension Tora I	-	-	-	-	.22	32	.22	32	.22	32	.22	32
Tora Plant	.08	12	.08	12	.30	44	.30	44	.30	44	0.30	44
Helwan Portland	0.14	20	.14	20	.14	20	.14	20	.14	20	.14	20
Extension H.P.(I)	-	-	-	-	.14	20	.14	20	.14	20	.14	20
" " (II)	-	-	-	-	-	-	0.32	46	.32	46	.32	46
Helwan P.	0.14	20	.14	20	.28	40	.60	86	.60	86	.60	86
Kawmia	0.1	15	0.10	15	0.1	15	0.1	15	0.1	15	0.1	15
Extension (I)	-	-	.29	41	0.29	41	0.29	41	0.29	41	0.29	41
" (VI)	-	-	-	-	-	-	-	-	0.39	55	0.39	55
" (III)	-	-	-	-	-	-	-	-	-	-	-	-
(Kawmia P.)	0.1	15	.39	56	.39	56	0.39	56	0.78	111	0.78	111
Maady Cement P.	-	-	-	-	-	-	-	-	-	-	0.20	28
Total Cement P.	0.32	47	0.61	88	0.97	140	1.29	186	1.68	241	1.88	289
Total Heavy Industry	0.99	161	1.43	222	1.85	292	2.32	362	2.8	446	3.0	474
Max. Demand (Using Diversity & Utilization Factors)	161		180		236		293		361		384	

Table (5) Electrical Energy and loads Requirements for Heavy Industries up to the year 1983

Year	1978	1979	1980	1981	1982	1983
Heavy Industr-ies (TWH)	0.99	1.43	1.85	2.32	2.8	3.0
Other Utili-ties (TWH)	3.867	4.254	4.679	5.147	5.662	6.278
Total (TWH)	4.857	5.684	6.529	7.467	8.462	9.228

Table (6) Energy Consumption up to the year 1983

Year	1978	1979	1980	1981	1982	1983
Heavy Indust-ies (MW)	161	180	236	293	361	384
Other Utilities includes large hotels & airport	759	840	940	1050	1160	1275

Table (7) Peak demand in Cairo Zone up to the Year 1983

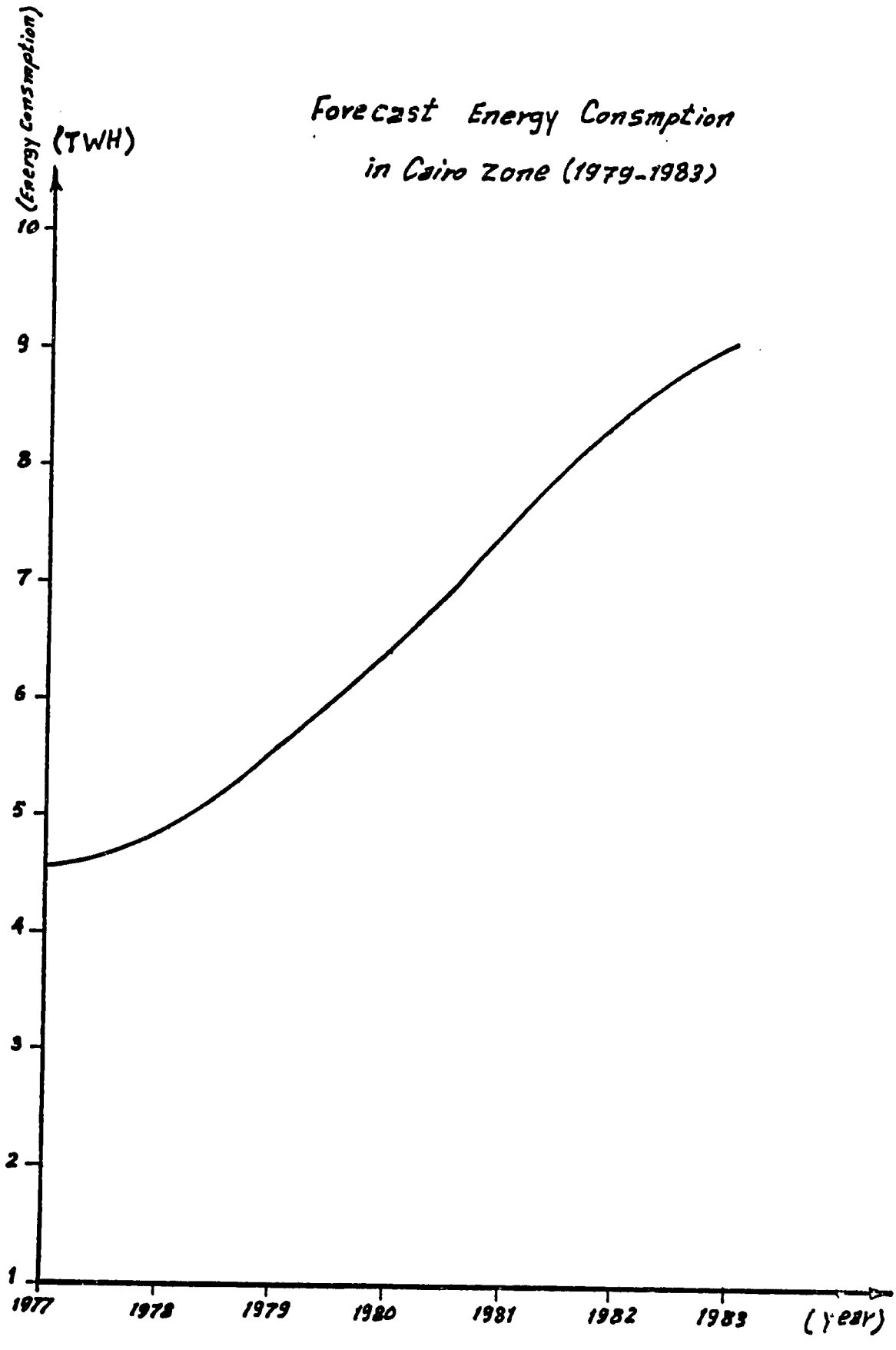
Forecast Energy Consmption
in Cairo zone (1979-1983)
(Energy Consmption)
(TWH)
10
9
8
7
6
5
4
3
2
1
1977
1978
1979
1980
1981
1982
1983
(year)

Fig. (1)

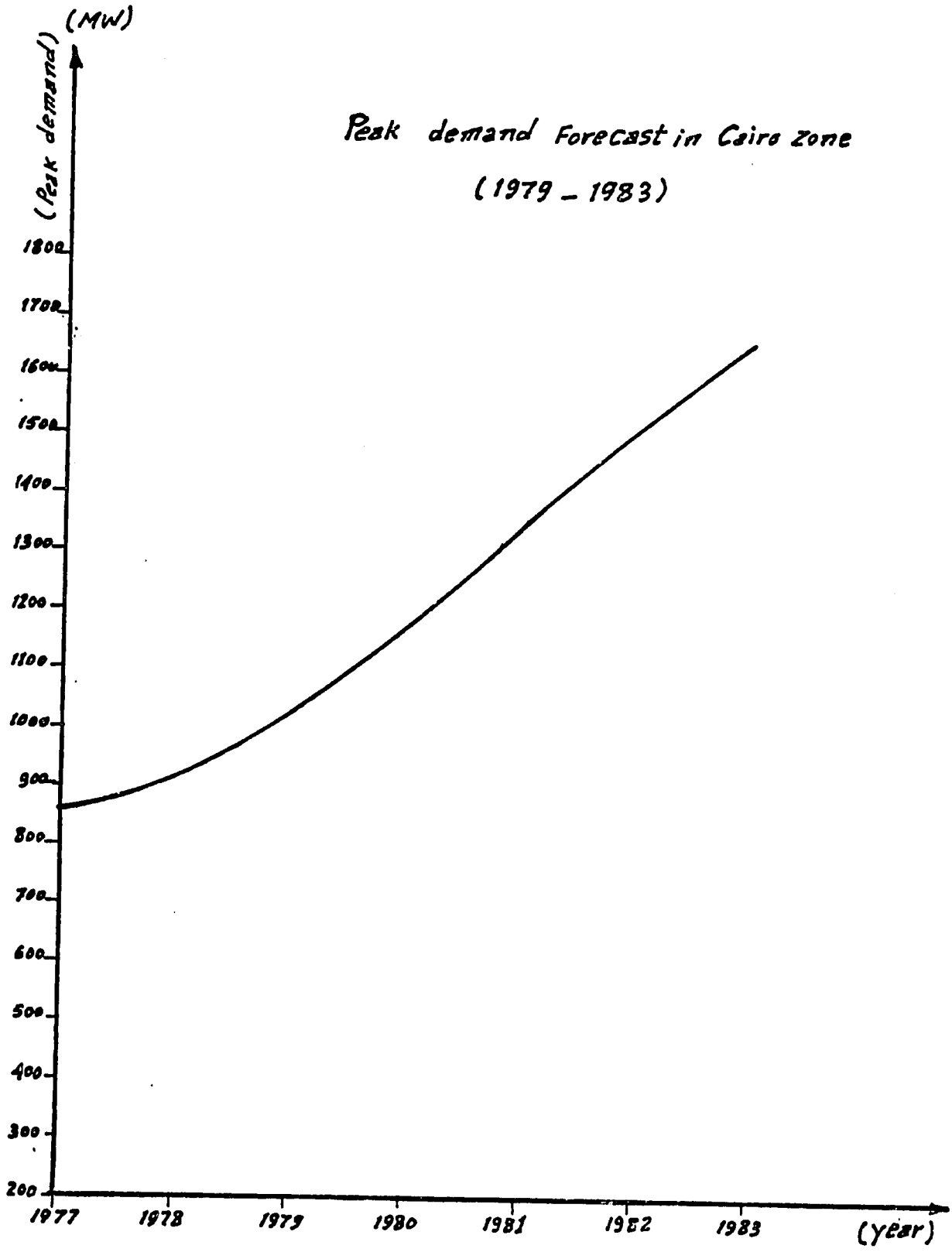
(MW)
(Peak demand)
Peak demand Forecast in Cairo zone
(1979 _ 1983)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
1977
1978
1979
1980
1981
1982
1983
(year)

Fig. (2).

6. Load Characteristics

Table (9) shows the load characteristics and annual load factor.

Year	Peak Demand (MW)	Energy Consumption TWH)	Annual load factor %
1978	920	4.857	60.3
1979	1020	5.684	63.61
1980	1176	6.529	63.38
1981	1343	7.467	63.47
1982	1521	8.462	63.51
1983	1659	9.228	63.50

Table (8) Peak Demand, Energy Consumption & Annual load factor.

7. References

1- Report on Review and Analysis of the Transmission and Subtransmission Networks in Great Cairo Zone up to the year 1985 (Egyptian Electricity Authority - EEA - Studies and Researches Sector, June 1979).

2- Report on Review and Analysis of the Unified Power Network and Expected Energy and Load Requirements up to the year 1990 (EEA, Studies and Researches Sector, Sept. 1978).

3- Electrical Distribution System Rehabilitation and Expansions - Volume IV, Cairo (by Harza Overseas Engineering Company and Sabbour Associate, Nov. 1978).

4- Joint Egypt/United States Report on Egypt/United States Cooperative Energy Assessment (Vol. I, Executive Summary, Main Report and Appendices, Dec. 1978).

5- Annual Reports of Electric Statistics for Years 1972, 1975, 1976 and 1977 (issued by EEA)

6- Power Sector Survey, Arab Republic of Egypt, System Planning Diagnostic Reports (by Sanderson & Porter , INC., Power Sector Survey Team, April 1977).

7- Report on Review and Analysis of the Unified Power System Network and Expected Energy and Load Requirements up to 1985 (EEA, Studies and Researches Sector, Dec. 1976).

URBAN SYSTEM PLANNING

Report 4

PLANNING OF SUBTRANSMISSION NETWORK OF CAIRO ZONE UP TO 1983

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PLANNING OF SUBTRANSMISSION NETWORK OF CAIRO ZONE UP TO 1983

1. INTRODUCTION

Due to the continuous increase in electrical loads, a new electrical 66 kv network is proposed. The expected electrical loads in year 1983 is about 1600 MWs, while the total generated power in Cairo zone will be about 1000 MWs. The new proposed network will contain 22 new S.S. (66/11 kv), in addition , 3 new S.S. (220/66 kv) are proposed at Tebbin, Hadaba and Saptia to meet the requirements of the increased load and energy demands.

2. STUDY OBJECTIVES

The purpose of the study presented in this chapter is to set up a comparison between different operating connections for the planned 1983 sub-transmission network from the following aspects:

1. The rupturing capacity of circuit breakers.
2. The voltage level at each B.B.
3. Loading of O.H.T.L. and cables
4. Transformers loading.
5. Network losses
6. Service continuity.

The different operating connections are :

1. radial
2. semi-loop
3. loops
4. loops with all feeding sources having sectionalized B.B

5. loops connected.
6. loops connected with all feeding sources are having sectionalized B.B.
7. open loops which are fed from two sources.
8. open loops which are fed from two sources with feeding sources are having sectionalized B.B.
9. grid.
10. grid which all sources are having sectionalized B.B.

The S.C. and load flow studies have been performed for all different connections. In this project, the studies concerning the following operating conditions will be shown:

1. radial
2. semi-loop
3. loops, with all feeding sources are having sectionalized B.B.
4. grid with all feeding sources are having sectionalized B.B.
5. grid.

3. SUBTRANSMISSION NETWORK PARAMETERS:

The study is based upon the data listed in tables (1), (2), (3), (4), (5), (6), (7) and (8). These tables include respectively:

1. proposed 220 kv T. lines
2. proposed 66 kv O.H.T. lines
3. proposed 66 kv cables.
4. characteristics of new and added generators at power plants (Delta and Cairo zone) up to 1983
5. characteristics of new and added 220 kv S.S. at Cairo zone up to 1983.

Table (1)

Proposed 220 K.V. T.L.

Designation T.L.	No. of ct.	Length km	R/ct/km	x/ct/km	B/ct/km
Talka - Kasbia	2	40	0.0835	0.412	2.71×10^{-6}
Kasbia - Ismailia	2	64	0.0835	0.412	2.71×10^{-6}
Ismailia - Ismailia P.S.	2	20	0.0835	0.412	2.71×10^{-6}
Ismailia P.S. - Suez	2	68	0.0835	0.412	2.71×10^{-6}
Suez - Suez I	2	6	0.0835	0.412	2.71×10^{-6}
Suez I - Cement	2	43	0.0835	0.412	2.71×10^{-6}
Cement - Sokhna	2	23	0.0835	0.412	2.71×10^{-6}
Ismailia - Zagazig	2	73	0.0835	0.412	2.71×10^{-6}
Amiria- Kafr El Dawar	2	35	0.0835	0.412	2.71×10^{-6}
C.E. - Heliopolis	1 cable	2	0.0202	0.1344	$.281 \times 10^{-6}$
Tebin - W.H.	2	25	0.835	0.412	2.7×10^{-6}
C.E. - Saptia	1 cable	18	0.13	0.418	3.56×10^{-6}
C.N. - Saptia	2 cable	10	0.835	0.412	3.56×10^{-6}
Sadat - T. Matamir	2	50	0.835	0.412	3.56×10^{-6}
Summid - Dekhila	2	28	0.835	0.412	3.56×10^{-6}
Abu keir- Damanhour	2	28	0.835	0.412	3.56×10^{-6}
Dekhela - Amiria	2	6	0.835	0.412	3.56×10^{-6}
Abu Kier - Abis	2	20	0.835	0.412	3.56×10^{-6}
Damanhour - Kafr El Sheikh	2	52	0.835	0.412	3.56×10^{-6}
Kafr El Sheikh - Talkha	2	39	0.835	0.412	3.56×10^{-6}
Heliopolis - C.E.	1 cable	15	0.835	0.412	3.56×10^{-6}
Abu Kier - Dakhila	2	48	0.835	0.412	3.56×10^{-6}
Tebin - C. 500	2	53	0.835	0.412	3.56×10^{-6}

Table (2)

Proposed 66 kv O.H.T.L. Lines

Designation T.L.	Length km	R/ct/km	x/ct/km	B/ct/km x 10^{-6}
C.S. - Tora Asment	9	0.134	0.38	3
Fostat - Tora Asment	9	0.134	0.38	3
Heliopolis - Suez Petrol	9	0.134	0.38	3
C.W. - Warak	5	0.134	0.38	3
Hadaba - Chemicals	11	0.134	0.38	3
Mostorod - Bahteem	6	0.134	0.38	3
Tebin II - Tebin V	2	0.134	0.38	3
New Teb. - Tebin II	4	0.134	0.38	3
New Teb. - Tebin V	2	0.134	0.38	3
New Teb. - Tebin IV	2	0.134	0.38	3
Asment Helwan - Kafr El Elw	1	0.134	0.38	3
Asment Helwan - Teb. P.S.	7	0.134	0.38	3

Table (3)

Proposed 66 kv Cables

Designation Cables	Lengths km	R/ct/km	x/ct/km	B/ct/kmx10^{-6}
Haram - Hadaba	7.8	0.075	0.09	84.78
Giza - Haram	6.6	0.075	0.09	84.78
Giza - Almin	10.8	0.075	0.09	84.78
Almin - Warak	8.3	0.075	0.09	84.78
Almin - Gezera	3	0.075	0.09	84.78
Nasser Inst. Ghamra	6	0.075	0.09	84.78
Saptia - Gezera	4	0.075	0.09	84.78
Gezera - Omar El-Khiam	2	0.075	0.09	84.78
Saptia - Azbakia	1.75	0.075	0.09	84.78
Abassia - C.E.	5	0.075	0.09	84.78
Azbakia - Abdin	1.5	0.075	0.09	84.78
Tebin I - New Teb.	1	0.075	0.09	84.78
Matar - Misr El-Gedida	6	0.075	0.09	84.78
Matar - Heliopolis	3	0.075	0.09	84.78
C.E. - Misr El-Gedida	15	0.075	0.09	84.78
Shagara - C.N.	2	0.075	0.09	84.78
Shagara - Shoubra	3	0.075	0.09	84.78
Hadaba - Giza	11.1	0.075	0.09	84.78
C.E. - Abdin	7	0.075	0.09	84.78
Heliopolis - M.G.	15	0.075	0.09	84.78
C.E. - Matar	15	0.075	0.09	84.78
Abbassia - Nasr	4.63	0.075	0.09	84.78
Basateen - Fostat	2	0.075	0.09	84.78
Saptia - Sayeda	4.78	0.075	0.09	84.78

Table (4)

Characteristics of New and Added Generators at Power Plants (Delta and Cairo Zone) up to 1983

No.	Description of power plant	No. & capacity MVA	available power KW	Rated voltage KV	Direct Subtransient Reactances %
1	C.W.	1 X 105	1 X 87.5	13.8	11
2	Old Tebin	2 X 25	2 X 25	10.5	16.5
3	New Tebin	5 X 23	5 X 23	10.5	16.5
4	Heliopolis	3 X 12.5	3 X 12.5	10.5	0.23
5	C.E.	2 X 25	2 X 25	10.5	16.5
6	Kafr El Dawar	3 X 10	3 X 10	10.5	15
7	Talkha	8 X 23	8 X 23	10.5	16.5
8	Abu Keir	4 X 150	4 X 150	15	15
9	Ismailia	2 X 150	2 X 150	15	15
10	New Suez	2 X 150	2 X 150	15	15

Table (5)

Characteristics of New Added 220 KV S.S. at

Cairo Zone up to 1983

No.	Description of S.S.	Capacity and No. of transformers MVA	Voltage ratio allowed for Regulation	X %
1	New Tebin	2 X 125	$\frac{220 \pm 12\ \%}{66}$	17.1
2	Hadaba	2 X 125	$\frac{220 \pm 8\ \%}{66}$	17
3	Saptia	2 X 125	$\frac{220 \pm 8\ \%}{66}$	17

Table (6)

Characteristics of New Step up Transformers at power station in Cairo Zone up to 1983

No.	Description of transformers	Capacity and No. of transformers (MVA)	Voltage ratio allowed for regulation	X %
1	C.W.	1 X 100	$\frac{220}{13.8 \pm 2.5\%}$	13.67
2	El Tebin	2 X 25	$\frac{10.5}{66 \pm 2.5\%}$	10
3	New Tebin	5 X 23	$\frac{10.5}{66 \pm 5\%}$	10

Table (7)

Generated Power, Loads and C.B's Capacities

B.B. Name	C.B. Capacity MVA	Load MW	Generation MW	No. of generating units & rating
a- Existing B.B.				
Shoubra	1,500	24		
Bahteem	2,500	30		
Mostorod	2,500	30		
Heliopolis	3,000	42	36	3 X 12
C.N.	1,500	45	100	2 X 30 + 1 + 20 + 2 X 10
Helmia	1,500	24		
Nasr	1,500	36		
Saptia	1,500	59		
Abassia	1,500	36		
Marouf	2,000	21		
Sayeda	1,500	42		
Basateen	1,500	34		
Tora	1,500	23		
C.S.	1,500		240	4 X 60
W.H.	3,000	60		
Kafr El Elew	1,500	10		
Tebin P.S.	1,500		75	3 X 15 + 2 X 25
Tebin 2	1,500	69		
Tebin 1	1,500	56		
Tebin 4	3,000	50		
Tebin 3	2,000	30		
C.W.	2,500	Generation on 220 KV B.B. 4 X 87,5		
Chemical	3,000	10		
Embaba	1,500	50		
Haram	1,500	52		
Hawamdia	1,500	14		

Table (7) Continued

B.B. Name	C.B. Capacity MVA	Load MW	Generation MW	No. of generating units & rating
Esko	2,500	24		
Ghamra	2,500	24		
New Tebin	3,500		115	3 X 23 + 2 X 23
Abo Zaabal	1,500	35		
Helwan	1,500	30		
Asment Tora		89		
Misr El Gedida	The C.B. Rating for these New B.B. are 3,500 MVA's	64		
Matar		34		
Asment Helwan		86		
Suez Petrol		59		
Nasr Institute		26		
Gezera		31		
Azbakia		45		
Abdin		25		
Ein El Sira		20		
Fostat		55		
Tebin 5		76		
Warak		24		
Almin		33		
Giza		46		
Hadaba				
Omar El Khiam		7		
15th May		22		
Shagra		46		
Masna 100		20		
C.E.	2500	61	50	2 X 25
Tebin 6	3500	75		

Table (8)

Division of Loads for Sectionized B.B.

B.B. name	Load Division (MW) 1	2	No. of transformers and their rating
a- B.B. Connected to 220 kv network			
C.N.	27	18	1 X 75 + 1 X 75
Heliopolis	-	42	1 X 125 + 2 X 125
C.E.	33	28	2 X 75 + 1 X 75
W.H.	33	27	2 X 125 + 1 X 125
Saptia	29	30	1 X 125 + 1 X 125
C.S.	-	-	1 X 75 + 1 X 75
C.W.	-	-	1 X 75 + 1 X 75
New Tebin	-	-	1 X 125 + 1 X 125
Hadaba	-	-	1 X 125 + 1 X 125
b- Other B.B. that are expected to be Sectionalized			
Sayeda	21	21	
Abassia	18	18	
Basateen	17	17	
Almin	16	17	
Giza	23	23	
Gezira	16	15	
Azbakia	23	22	

6. Characteristics of new step-up transformers at power station in Cairo Zone up tp 1983.
7. C.B. rupturing capacities, the expected loads and expected generation at the existing and the planned bus-bars.
8. The loads and transformers division for the bus-bars which are expected to be sectionalized in some proposed configurations.

4. LOAD FLOW STUDY OF 220 KV NETWORK

The load flow for 220 kv transmission network is illustrated in fig. (1), showing the buses loading, generating stations, voltage levels and the loading of transmission lines.

In order to study the load flow for 66 kv network of Cairo zone, the power fed from all lines which are connected to Cairo zone is determined. These lines are cut and replaced by their line flow equivalents. The power flows which are transmitted to Cairo zone through these lines are:

1- 62 MVA from Zagazig to C.N.

2- 152.5 MVA from 10th Ramadan to C.E.

3- 88 MVA from Sokhna to W.H.

The load flow study for the 66 kv subtransmission network is based on the above injected flows from Delta network and Cairo 500 S.S.

In doing the load flow studies, the voltage levels are kept within the range ± 5% by using transformers tappings of + 7% for 220/66 kv transformers except the transformers at:

1- C.N., for which the tapping is + 5%

2- Heliopolis, for which the tapping is + 10%

A tapping of + 5% is used for transformers 500/220 kv at Cairo 500 S.S.

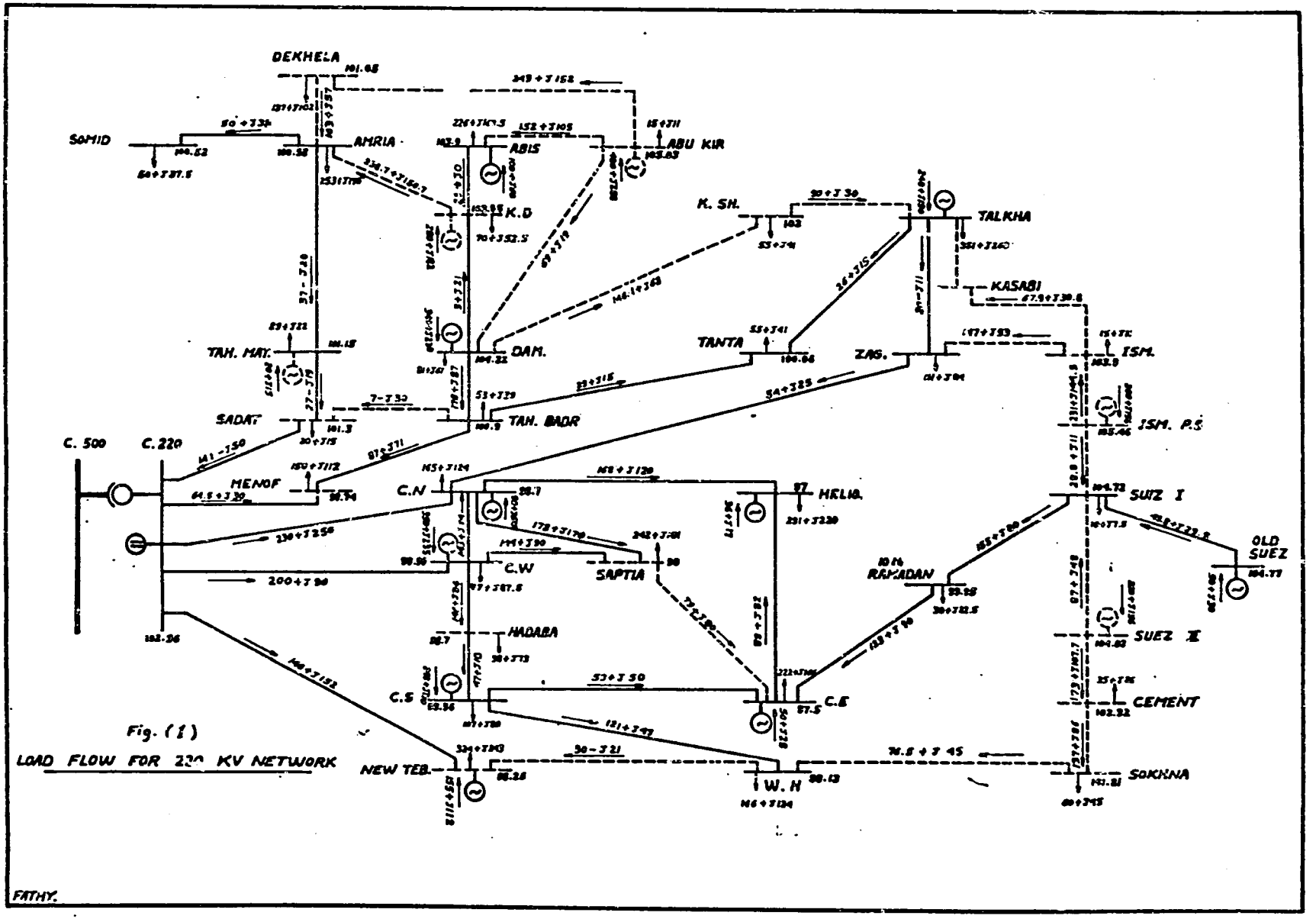

Fig. (1)

LOAD FLOW FOR 220 KV NETWORK

5. SHORT CIRCUIT AND LOAD FLOW STUDIES OF 66 KV CAIRO NETWORK

a. Radial

The S.C. at all buses is illustrated by Fig. (2). The S.C. levels are within the rupturing capacities of the existing circuit breakers.

The load flow for this case is shown in Fig. (3). The voltage level ranges between 103% and 85%. The transmission losses is about 15.4 MW and hence the efficiency of transmission becomes 99%. The losses can be seen from table (9). As shown in table (10) the following lines are slightly overloaded: Matar - Misr El-Gedida, Saptia - Marouf, and W.H. - 15th May. It can be noted that one extra transformers are required at Saptia Substation as shown by Table (11).

b. Semi loops

The S.C. at all buses is illustrated in Fig. (4). The S.C. levels are within the rupturing capacities of the existing circuit breakers.

The load for this operating connection is shown in Fig. (5). The voltage level ranges between 102% and 96% except at Abu Zabel and Masna 100 where it goes down to 94%. The transmission losses is shown in table (5). Its amount is about 10 MW and hence efficiency of transmission is 99.4%. As shown in table (10), the following lines are slightly overloaded: Heliopolis - Misr El Gedida and Saptia- Marouf. Two extra transformers are required at C.E. and Saptia substations as shown by table (11).

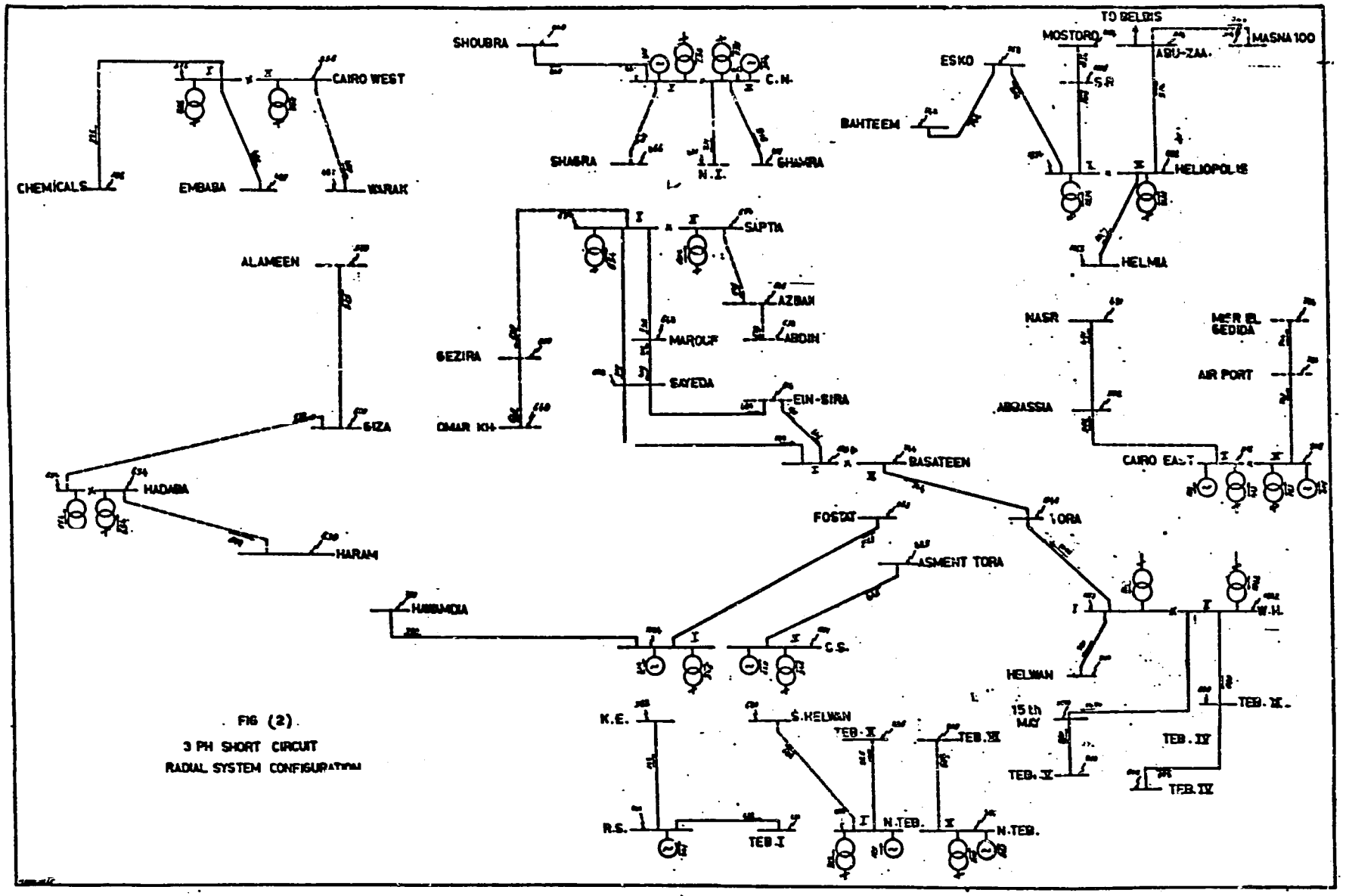

FIG (2)

3 PH SHORT CIRCUIT

RADIAL SYSTEM CONFIGURATION

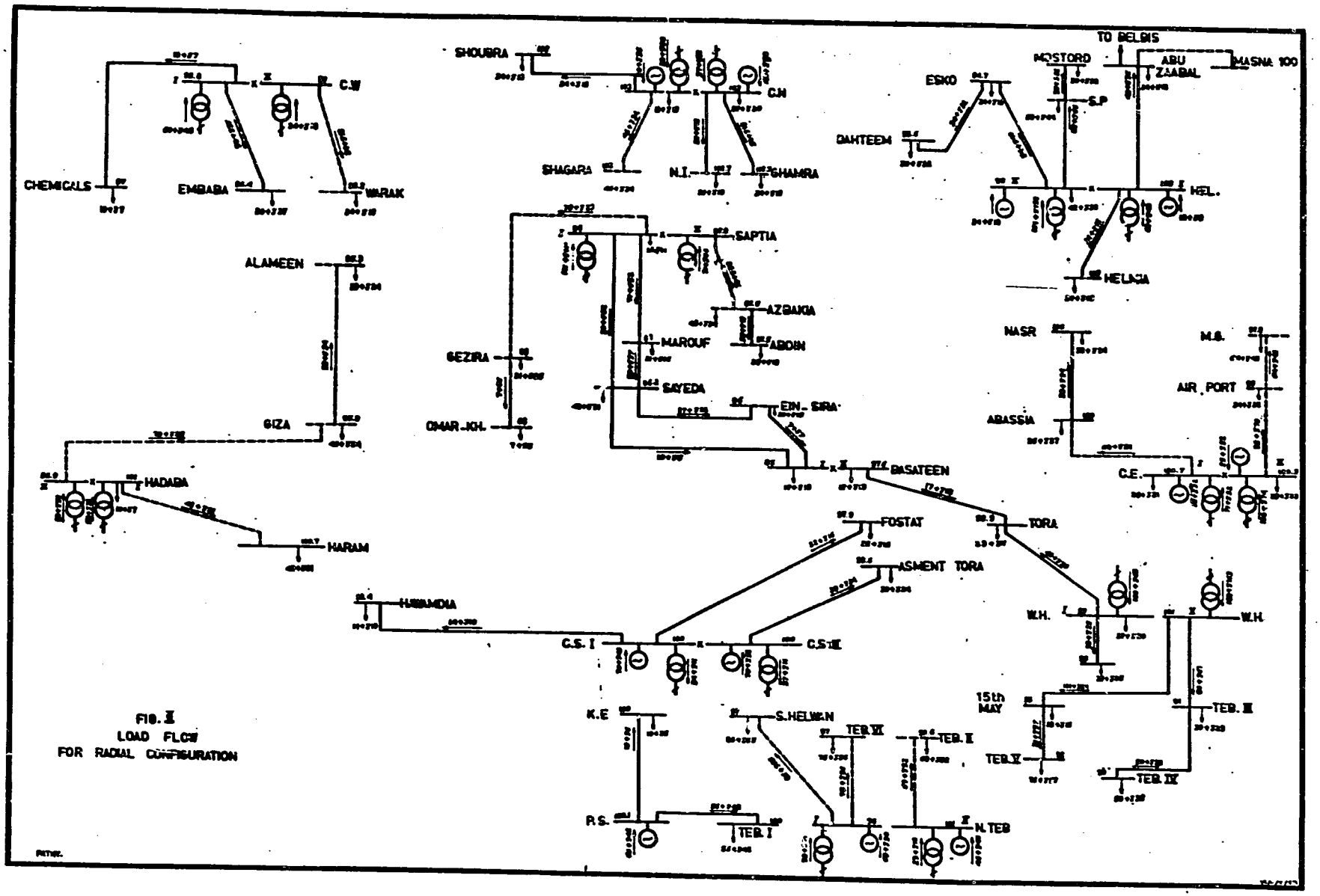

FIG. II
LOAD FLOW
FOR RADIAL CONFIGURATION

Table (9)

Transmission Losses (MW)

Junctions from	Junctions to	No. of ct.	Radial	Semi-Loops	Loops	Grid with sec. BB.	Grid
C.W.	Embaba	2 oh	0.32	0.16	0.25	0.22	0.2
C.W.	Warak	2 oh	0.07	0.33	0.06	0.2	0.2
C.W.	Chemical	2 oh	0.04	0.04	0.03	0	0
Hadaba	Haram	2 c	0.18	0.13	0.86	0.24	0.15
Hadaba	Giza	3 c	0.66	0.25	0.92	0.22	0.55
Haram	Giza	2 c	-	0.03	0.08	0.04	0
Hawamdia	Haram	2 oh	-	-	-	0.16	0.1
Giza - 1	Almin -1	2 c	0.17	-	0.02	0.025	0.05
Giza - 2	Almin - 2		-	-	0.94	0.025	0.05
Warak	Shobra	2 c	-	-	-	0.03	0.01
Almin - 1	Gezira-1	2 c	-	0.01	0	0.15	0.005
Almin - 2	Gezira-2		-	0.01	0.13	0.015	0.005
Gezira-1	Omar El Khayam	2 c	0	0	0.04	0	0
Gezira-2	Omar El Khayam		0	0	0.02	0	0
C.N.	Shoubra	2 c	0.03	0.03	0.04	0.02	0.02
C.N.	Naser Inst.	3 c	0.04	0.04	0.02	0.09	0.04
Nasr Inst.	Ghamra	2 c	-	0	0	0	0
C.N.	Ghamra	2 c	0.05	0.04	0.02	0.03	0.02
Shoubra	Shagara	2 c	-	0.06	0.07	0.19	0.06
Saptia	Sayeda	1 c	0.14	0.1	0.14	0.07	0.02
Saptia	Marouf	2 c	0.19	0.04	0.19	0.08	0.03
Saptia-1	Azbakia-1	2 c	0.15	0.005	0.19	0.005	0
Saptia-2	Azbakia-2			0.005	0.19	0.005	0
Marouf	Sayeda	2 c	0.1	0.07	0.11	0.04	0.01
Basateen	Sayed	2 c	0.02	0.02	0.04	0	0
Basateen	Ein El Sira	2 c	0	0	0.01	0	0.01
Ein El Sira	Sayeda	2 c	0.05	0.04	0.05	0.01	0
Azbakia-1	Abdin-1	2 c	0.02	0.01	0.02	0.005	0
Azbakia-2	Abdin-2			0.01	0.07	0.005	0
C.E.-1	Abassia-1	2 c	0.28	0.45	0.11	0.1	0.12
C.E.-2	Abassia-2			0.45	0.25	0.1	0.12
Abassia-1	Nasr	2 c	0.05	0.41	0.01	0.025	0.03
Abassia-2	Nasr			-	0.06	0.025	0.03
Helmia	Nasr	2 c	-	-	-	0	0.02
Heliopolis	Helmia	3 c	0.04	0.01	0.02	0.11	0.04
Suez Petrol	Mostorod	2 oh	0.06	0.03	0.03	0.08	0.03
Heliopolis	Suez Petrol	2 oh	1.95	0.35	1.59	0.41	1.42
Heliopolis	Esko	2 oh	0.94	0.33	0.76	0.24	0.68
Esko	Bahteem	2 oh	0.17	0.01	0.14	0.01	0
Mostorod	Bahteem	2 oh	-	0.08	0	0.12	0
Heliopolis	Matar	2 c	-	0.45	0.03	0.14	0.07

Table (9) Continued

Transmission Losses (MW)

Junctions		No. of ct.	Radial	Semi-Loops	Loops	Grid with Sec. BB.	Grid
From	to						
W.H.	Tora	2 oh	0.4	0.09	0.11	0.27	0.25
C.S.	Fostat	2 oh	0.66	0.1	0.45	1.1	0.66
C.S.	Hawamdia	2 oh	0.10	0.17	0.03	0.24	0.18
C.S.	Tora Asment	2 oh	0.24	0.05	0.69	0.49	1.27
Tora Asment	Fostat	2 oh	-	0.03	-	0.02	0.1
C.S.	Kafr el Elw	2 oh	-	-	0.19	0.27	0.32
Fostat	Basateen	2 oh	-	-	-	0.01	0.03
Kafr el Elw	Asment Helwan	2 oh	-	0.04	0.01	0.04	0.04
C.S.	Asment Helwan	2 oh	-	-	0.45	-	-
Tebin P.S.	Tebin-1	2 oh	0.07	0.02	1.34	0.15	0.21
Tebin-1	Tebin-2	2 oh	-	-	0.06	0	0.35
Tebin-2	Tebin-5	2 oh	-	0.14	0.04	0.15	0.14
New Tebin	Tebin-5	2 oh	-	0.13	0.54	0.3	1.27
New Tebin	Tebin-1	2 oh	-	0.03	0.03	0.05	0.54
Tebin-3	Tebin-4	2 oh	0.027	0.02	0.05	0.05	0
W.H.	Tebin-3	2 oh	5.4	0.12	1.66	1.59	0.7
W.H.	Tebin-4	2 oh	-	0.05	0.31	0.03	0.81
W.H.	15th May	2 oh	0.95	0.05	0.07	0.4	0.6
Tebin-5	15th May	2 oh	3.4	-	-	0.12	0.35
Misr El Gedida	Matar	2 c	0.27	0.13	-	0.07	0.02
Basateen	Abassia	2 c	-	-	-	0	0.14
Basateen	Tora	2 oh	0.08	0.05	-	0.05	0
Tebin P.S.	Asment Helwan	2 oh	-	0.03	-	0.17	0.09
Kafr el Elw	Tebin P.S.	2 oh	-	0.01	-	0.13	0.06
Warak	Almin	2 c	-	0.09	-	0.16	0.02
Hadaba	Chemical	2 oh	-	0.0	-	0.01	0.01
Embaba	Haram	2 oh	-	0.04	-	0	0.01
Nasr Inst.	Saptia	3 c	-	-	-	0.03	0.01
C.N.	Helmia	2 c	-	-	-	0.03	0.03
C.E.	Abdin	2 c	-	0.21	-	0.23	0.04
Saptia	Gezira	2 c	0.05	0.01	-	0.0	0.02
New Tebin	Tebin-2	2 oh	0.32	0.09	-	0.96	-
Heliopolis	Mostorod	2 oh	-	0.17	-	-	-
New Tebin	Tebin-4	2 oh	-	0.1	-	-	-
New Tebin	Asment Helwan	2 oh	0.89	0.05	-	-	-

Table (10)

Percentage loading for O.H.T. Lines and Cables

Junctions from	Junctions to	radial	Semi loops	Loops	Grid with sec.B.B.	Grid
C.W.	Embaba	52	38	49	47	45
C.W.	Warak	25	52	23	44	44.5
C.W.	Chemical	10	20	9.7	3.5	73.3
Hadaba	Haram	65	56	81	66	53
Hadaba	Giza	82	65	80	40	65
Hadaba	Giza	82	33	80	40	65
Haram	Giza	-	6.8	43.9	31	4.2
Hawamdia	Haram	-	-	-	26	21
Giza 1	Almin 1	51	-	14	29	42
Giza 2	Almin 2	51	-	81	29	42
Warak	Shobra	-	-	-	25	12
Almin 1	Gezira	-	26	17.6	44.7	22
Almin 2	Gezira	-	26	64	44.7	22
Gezira 1	Omr El-Khiam	14	10.7	82	9	9
Gezira 2	Omr El-Khiam	14	10.7	62.8	9	9
C.N.	Shobra	37.5	33	48	26	32.6
C.N.	Naser Inst.	27	26	34.5	65	42
Naser I.	Ghamra	-	2.5	13.5	3	6.5
C.N.	Ghamra	37	34	23	32	35
Shobra	Shagra	-	4.5	14.5	29.4	13
C.N.	Shagra	70	76	54	94	50
Saptia	Sayeda	92	93	60	74	38.7
Saptia	Marouf	107	109	109	78	47.5
Saptia	Azbakia 1	73	37.8	98	49	80
Saptia	Azbakia 2	73	37.8	98	49	80
Marouf	Sayeda	78	76.7	80	48	18.7
Bassateen	Sayeda	30	27	60	14.5	23
Bassateen	Ein-El-Sira	44	12	50	3.5	35

Table (10) cont'd

Junctions from	Junctions to	radial	Semi loop	Loops	Grid with sec.B.B.	Grid
Azbakia 1	Abdin 1	40	37	36	11.5	21
Azbakia 2	Abdin 2		37	36	11.5	21
C.E.1	Abbassia 1	100	108	79.8	89	83
C.E.2	Abbassia 2		108	62	89	83
Abbas. 1	Nasr	50	76	29	40	50
Abbas. 2	Nasr		76	70	40	50
Helmia	Nasr	-	70	-	12	43.5
Heliop.	Helmia	25	41	21	49	35.4
Suez Pet.	Mostorod	30	24	29	50	29
Heliop.	Suez Pet.	92	39	88	53	88
Heliop.	Esko	57	33	54	30	53
Esko	Bahteem	31	9	29.8	7	29
Mostorod	Bahteem	-	23	1.6	22	0.2
Heliop.	Misr El-Gedida	-	104	-	97	68
Wadi H.	Tura	42	41	24	39	37.9
C.S.	Fosta	23	20	51	80	62
C.S.	Hawamdia	14	14	13.8	40	35.4
C.S.	Asment Tura	34	36	90	73	81
Asment Tura	Fosta	-	2.3	7.5	15.8	34.5
C.S.	Kafr el-Elw	-	-	41	47	52
Fostat	Bassateen	-	-	-	13	41.5
Kafr el Elw	Asm. Helwan	-	2	30	61	63
C.S.	Asm. Helwan	-	-	60	-	
Teb. P.S.	Teb. 1	58	51	78	25.8	30.8
Teb. 1	Teb. 2	-	-	48	8.5	77
Teb. 2	Teb. 5	-	12.5	23	43	43

Table (10) cont'd

Junctions from	Junctions to	radial	semi loops	Loops	Grid with sec. B.B.	Grid
New Teb.	Teb. 5	-	61	80	24	35
New Teb.	Teb. 1	-	20.6	45	60	107
Teb. 3	Teb. 4	52	17	27	33.7	7.8
W.H.	Teb. 3	84	41	60	58.5	40
W.H.	Teb. 4	-	1.7	26.6	26.6	44.6
W.H.	15th May	109	26	32	57	71
Teb. 5	15th May	79	-	-	33	47.2
C.E.	Misr El Gedida	-	-	89	42	67.5
Misr el Gedida	Airport	100	63	-	50	25
Bassat.	Abbassia	-	-	-	9	65
Bassat.	Tura	18	17.8	-	16	47
Teb. P.S.	Asment H.	-	22.5	-	28	26
Kafr el Elw	Teb. P.S.	10	21.3	-	25	22
Warak	Almin	-	43.7	-	59	21.6
Hadaba	Chemical	-	-	-	14	10.5
Embaba	Haram	-	-	-	2.5	4
Naser Inst.	Saptia	-	-	-	40	17.5
C.N.	Helmia	-	-	-	33.7	35.7
C.E.	Abdin	-	76	-	47	19.6
Saptia	Gezira	59	81.5	-	9	35.6
New Teb.	Teb. 2	72	45.8	-	55	-
Heliop.	Mostorod	-	77	-	-	-
New Teb.	Teb. 4	-	26.8	-	-	-
New Teb.	Asment H.	90	47.6	-	-	-
N. Teb.	Teb. 6	78	43.5	101	81	35

Table (11)

Transformers % Loading

No.	Designation	No. of Trans. and rating	Radial	Semi loop	Loops	Grid with sec.B.B.	Grid
1	C.N.	1 X 75	66	60	44	48	75
		1 X 75	64	60	78	65	
2	Heliopolis	2 X 125	83	100	82.5	74	78
		1 X 125	62	90	76	94	
3	C.E.	2 X 75	87	77	75	52	63
		1 X 75	75	77	72	78	
4	W.H.	2 X 125	99.5	43	52.6	46	59
		1 X 125	95	76	81	60	
5	C.S.	1 X 75	47	49	12	40	53
		1 X 75	51	50	14	51	
6	New Tebin	1 X 125	94	59	41	50	46
		1 X 125	20	48	48	53	
7	Hadaba	1 X 125	52	60	78	50	56
		1 X 125	79	60	87	41.5	
8	C.W.	1 X 75	100	84	77	81	76
		1 X 75	40	88	54	80	
9	Saptia	1 X 125	100*	76.5*	69*	56	75
		1 X 125	86	85	97	71	

* Additional transformer is used.

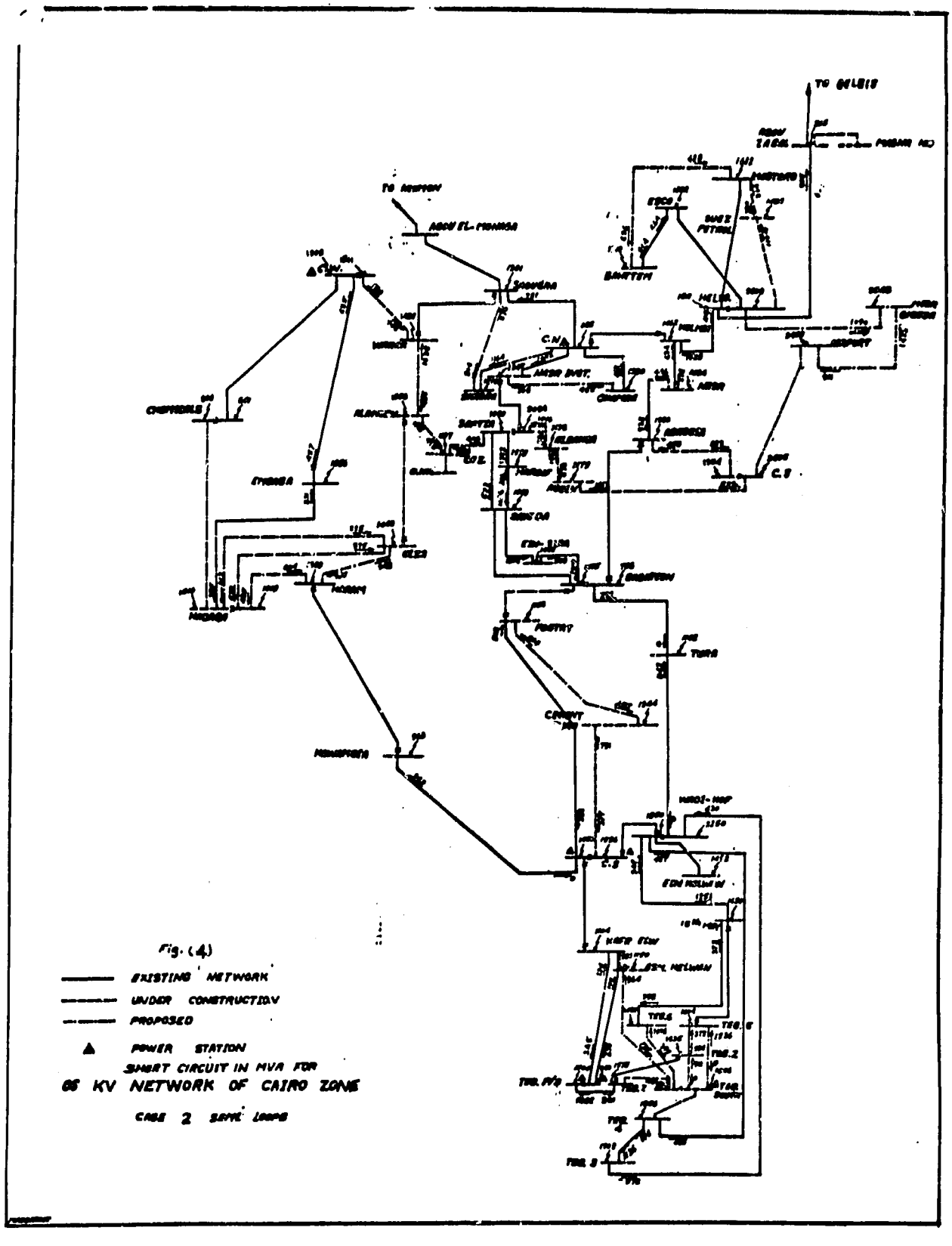
Fig. (4)
EXISTING NETWORK
UNDER CONSTRUCTION
PROPOSED
POWER STATION
SHORT CIRCUIT IN MVA FOR
66 KV NETWORK OF CAIRO ZONE
CASE 2 SAME LOADS

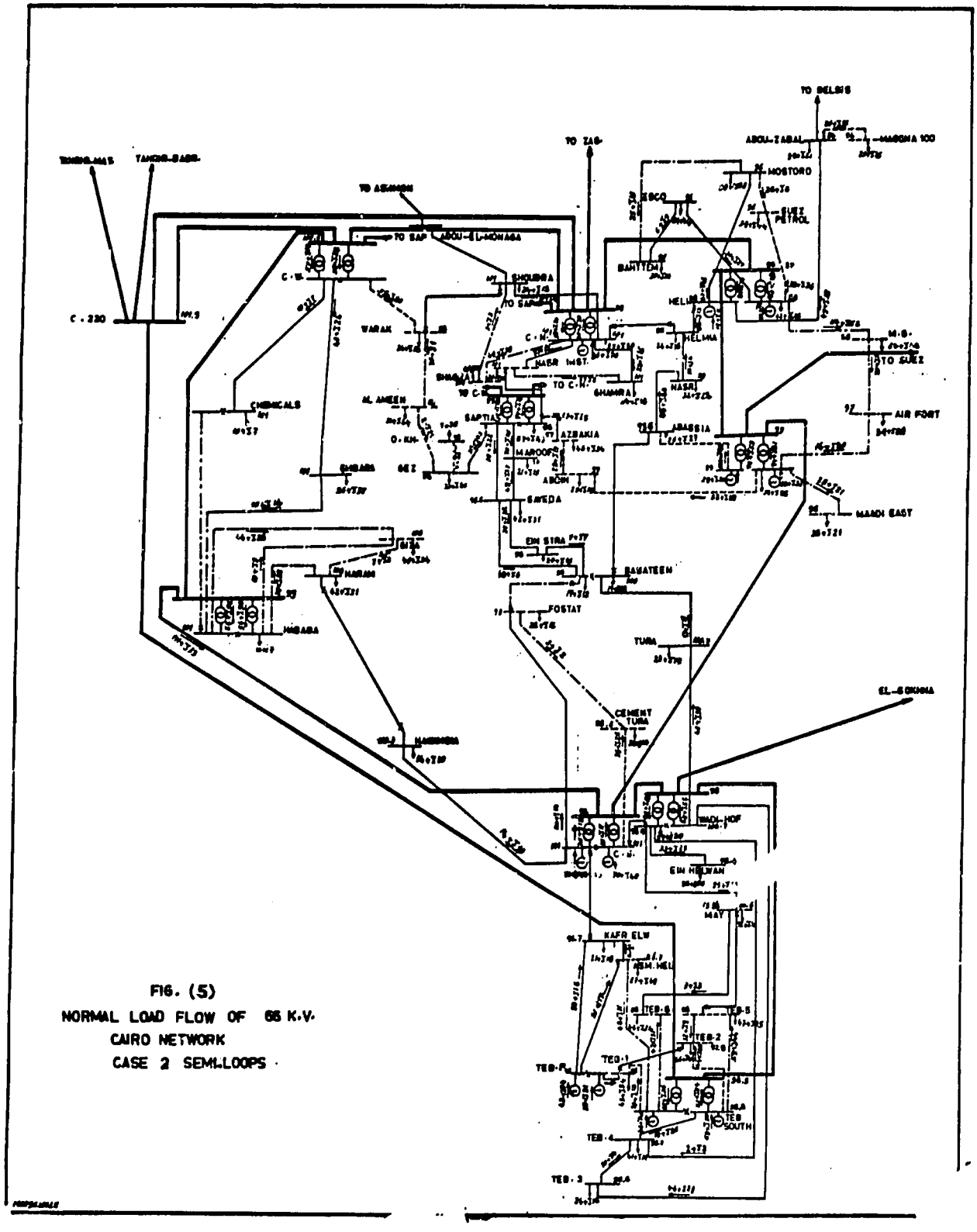

FIG. (5)
NORMAL LOAD FLOW OF 66 K.V.
CAIRO NETWORK
CASE 2 SEMI-LOOPS

c- Loops (with feeding sources having sectionalized B.B.)

The S.C. at each bus is illustrated in Fig. (6). Some B.C.'s at few buses must be replaced as the S.C. MVA at these buses exceeds the installed rupturing capacity. These buses are: Helmia, Cairo S., Kafr El-Elw, Tebin 2, Tebin 1, Abou Zaabal & Helwan. The S.C. level for this configuration reaches 2100 MVA.

The load flow is illustrated in Fig. (7). The transmission losses are given in Table (9). The total losses amounts to 14 MW and hence the efficiency of transmission is about 99%. The voltage level at buses ranges between 106% and 96%. The lines loading is given in Table (10). It can be seen that the following lines are slightly overloaded : Saptia - Marouf and New Tebin.-Teb. 6. The transformers loading is given in table (11). It is shown that one extra transformer at Saptia is required.

d- Grid (with all feeding B.B. sources setionalized)

The S.C. at each bus is illustrated in Fig. (8). The S.C. level reaches 4519 MVA at C.S. S.S. The C.B. of most of the buses must be replaced as the level of S.C. at all buses is greater than their rupturing capacity except for C.B.S. at Bahteem. Mostorod, C.W., chemical, and New Tebin.

The load flow for this configuration is shown in Fig. (9). The voltage level ranges between 105% and 100%. The transmission eff. is about 99.4%. The losses are given in table (9). The slightly overloaded lines encountered in this configuration are: New-Teb. - Teb. 2 and Heliopolis - S.P. The lines loading is given in Table (10) where Table (11) shows the transformers percentage loading.

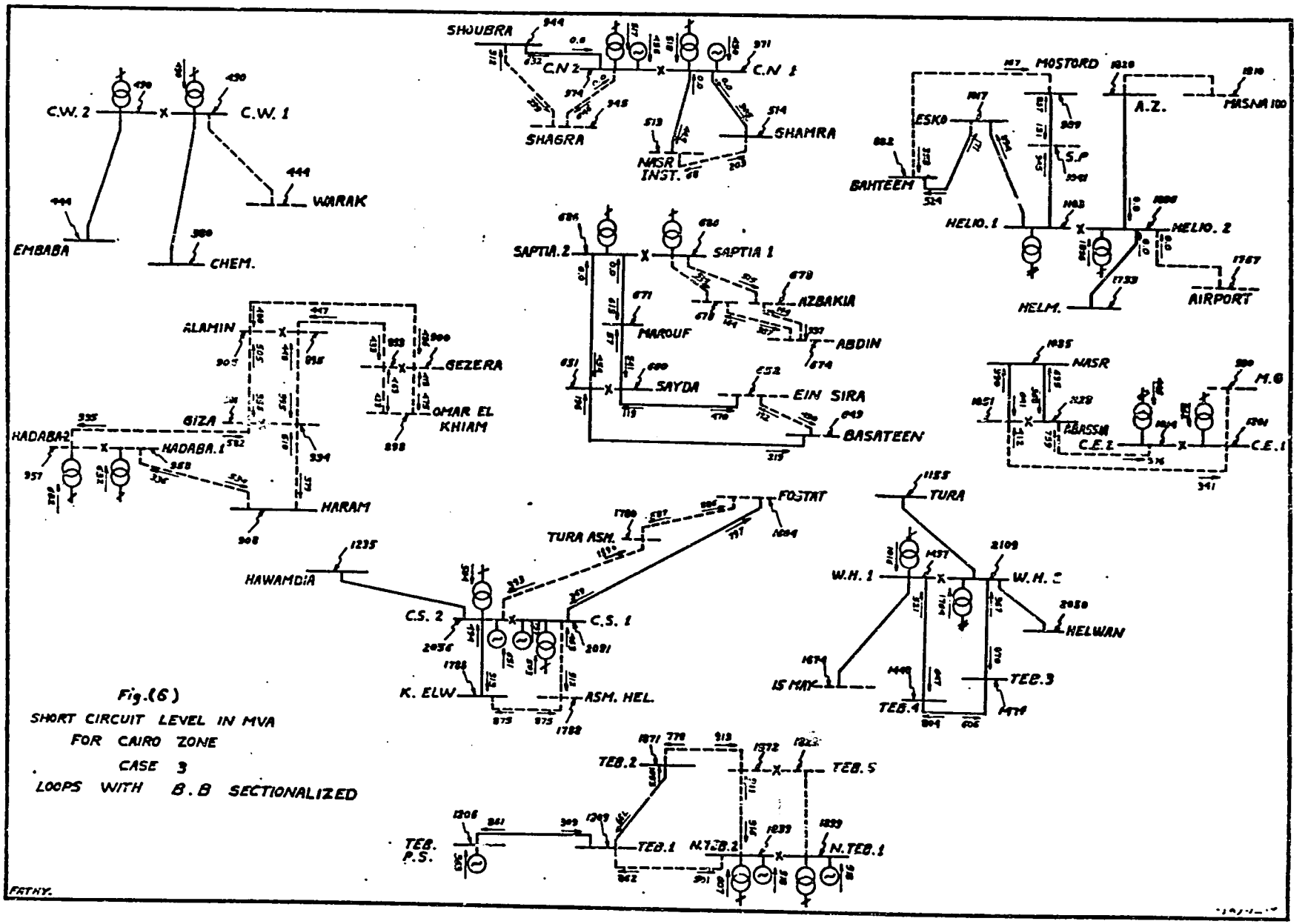

Fig.(6)
SHORT CIRCUIT LEVEL IN MVA
FOR CAIRO ZONE
CASE 3
LOOPS WITH B.B SECTIONALIZED

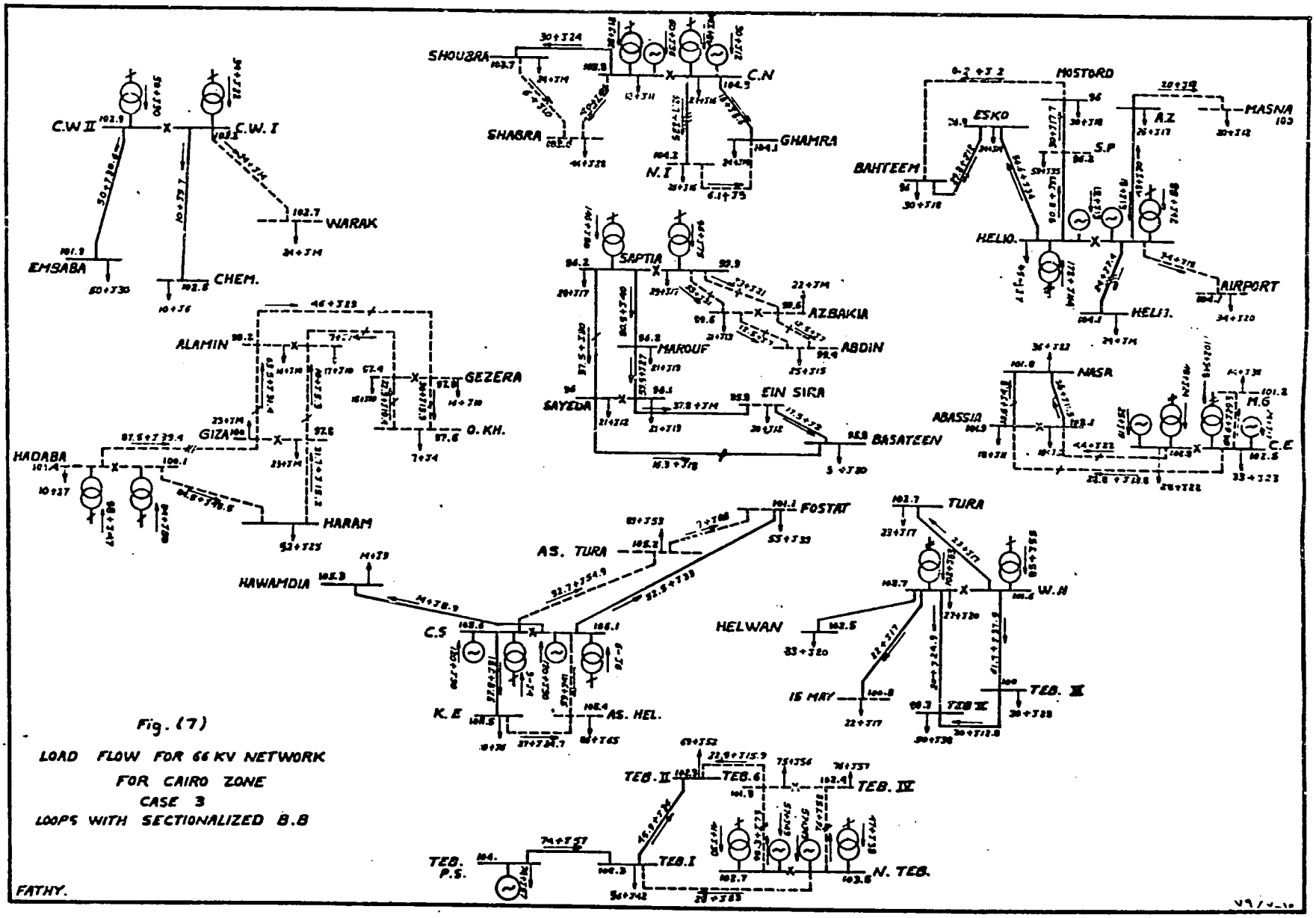

Fig. (7)

LOAD FLOW FOR 66 KV NETWORK
FOR CAIRO ZONE
CASE 3
LOOPS WITH SECTIONALIZED B.B

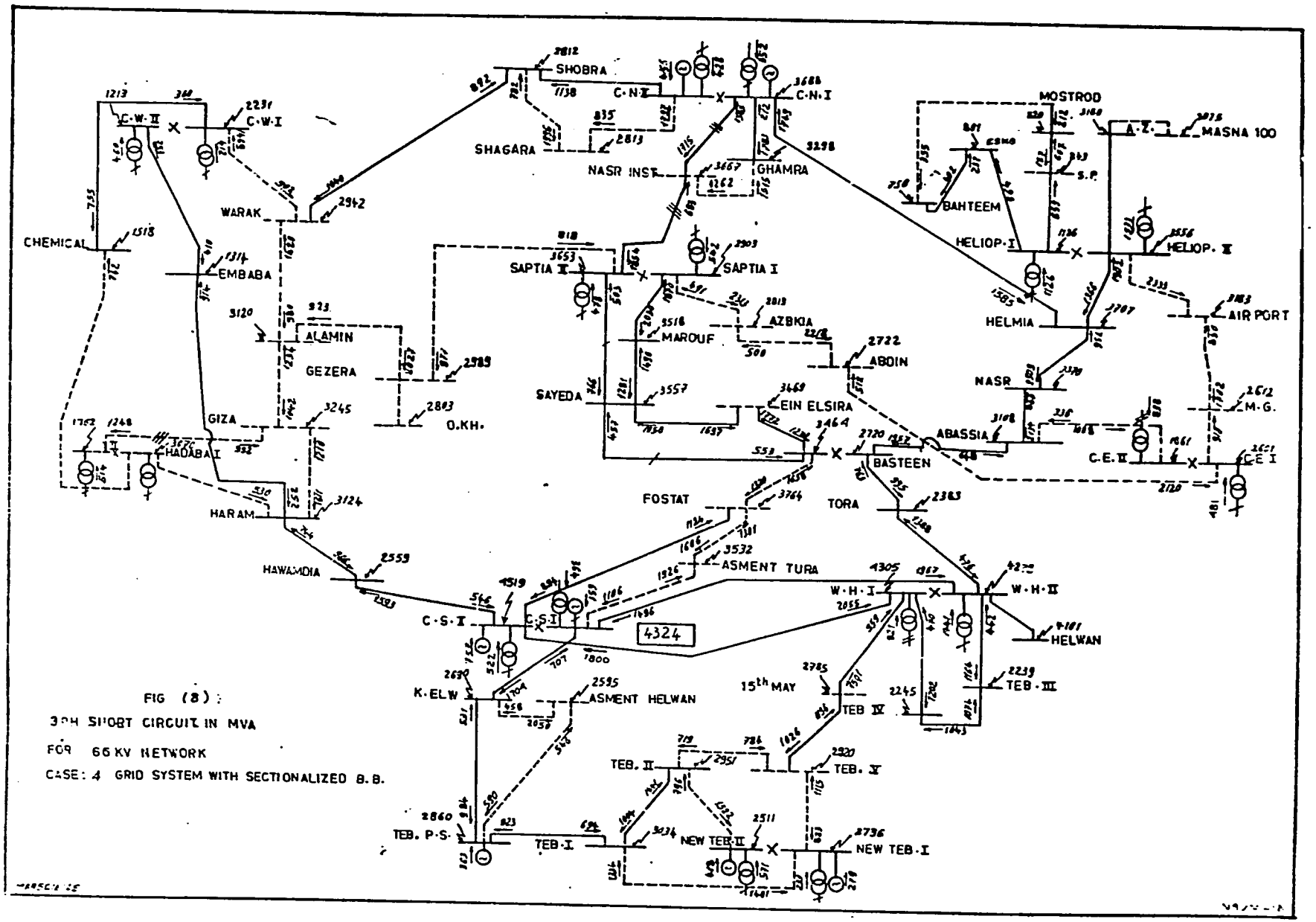

FIG (8):

3PH SHORT CIRCUIT IN MVA

FOR 66 KV NETWORK

CASE: 4 GRID SYSTEM WITH SECTIONALIZED B.B.

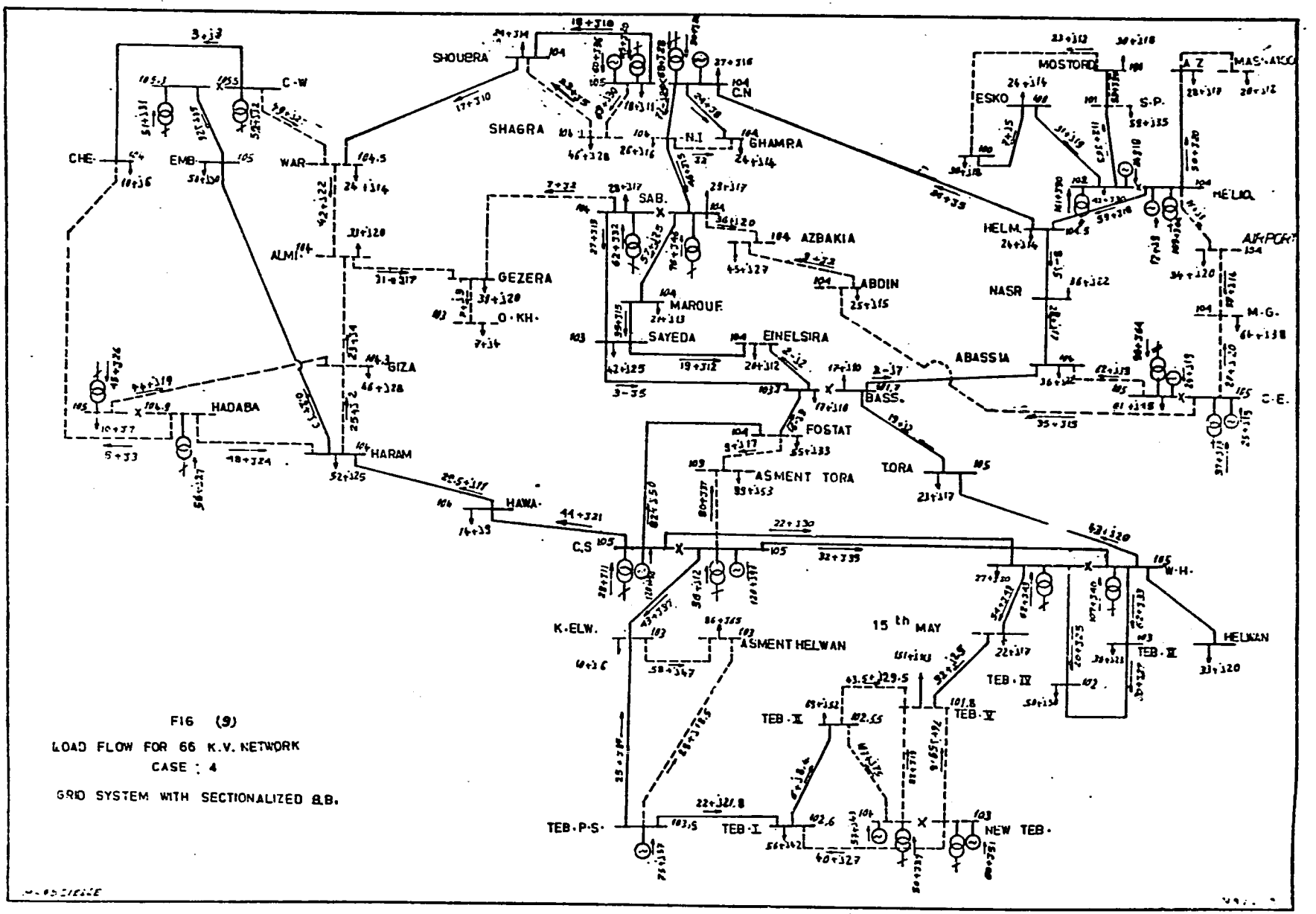

FIG (9)

LOAD FLOW FOR 66 K.V. NETWORK

CASE : 4

GRID SYSTEM WITH SECTIONALIZED B.B.

e- Grid

This operating connection is the worst from S.C point of view. The S.C. level reaches 6500 MVA as shown in Fig. (10). Technically, the C.B.'s of such high rupturing capacity are unvailable today for replacement.

The load flow for this case is shown in Fig. (11). The voltage level ranges between 106% and 101%. The transmission losses given in table (9) is about 12.6 MW and hence efficiency is 99.3%. Table (10) shows the percentage loading of the transmission lines.

Table (11) shows that none of the transformers is overloaded

6. Conclusions

The above study can be summarized by the following table

No.	Operating Coonection	Radial	Semi loop	Loops (Seperate)	Grid with sec. B.B.	Grid
1	No. of C.B.'s to be replaced	-	-	70	204	all C.B.'s
2	Voltage Level %	103-85	102-94	106-96	105-100	106-101
3	No. of slightly overloaded lines	3	2	2	2	-
4	Transmission Efficiency	99%	99.14%	99%	99.4%	99.3%

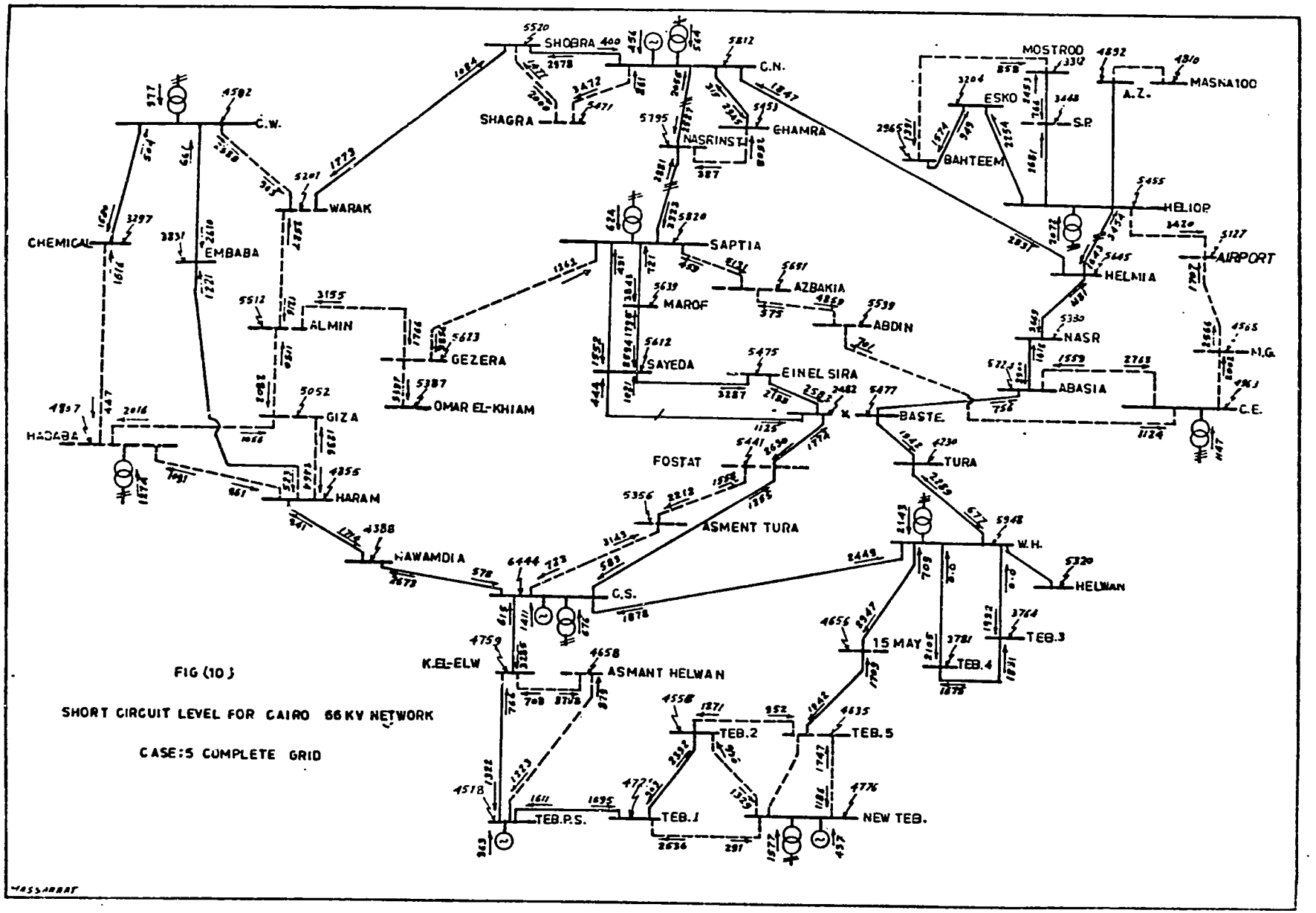

FIG (10)

SHORT CIRCUIT LEVEL FOR CAIRO 66 KV NETWORK

CASE:5 COMPLETE GRID

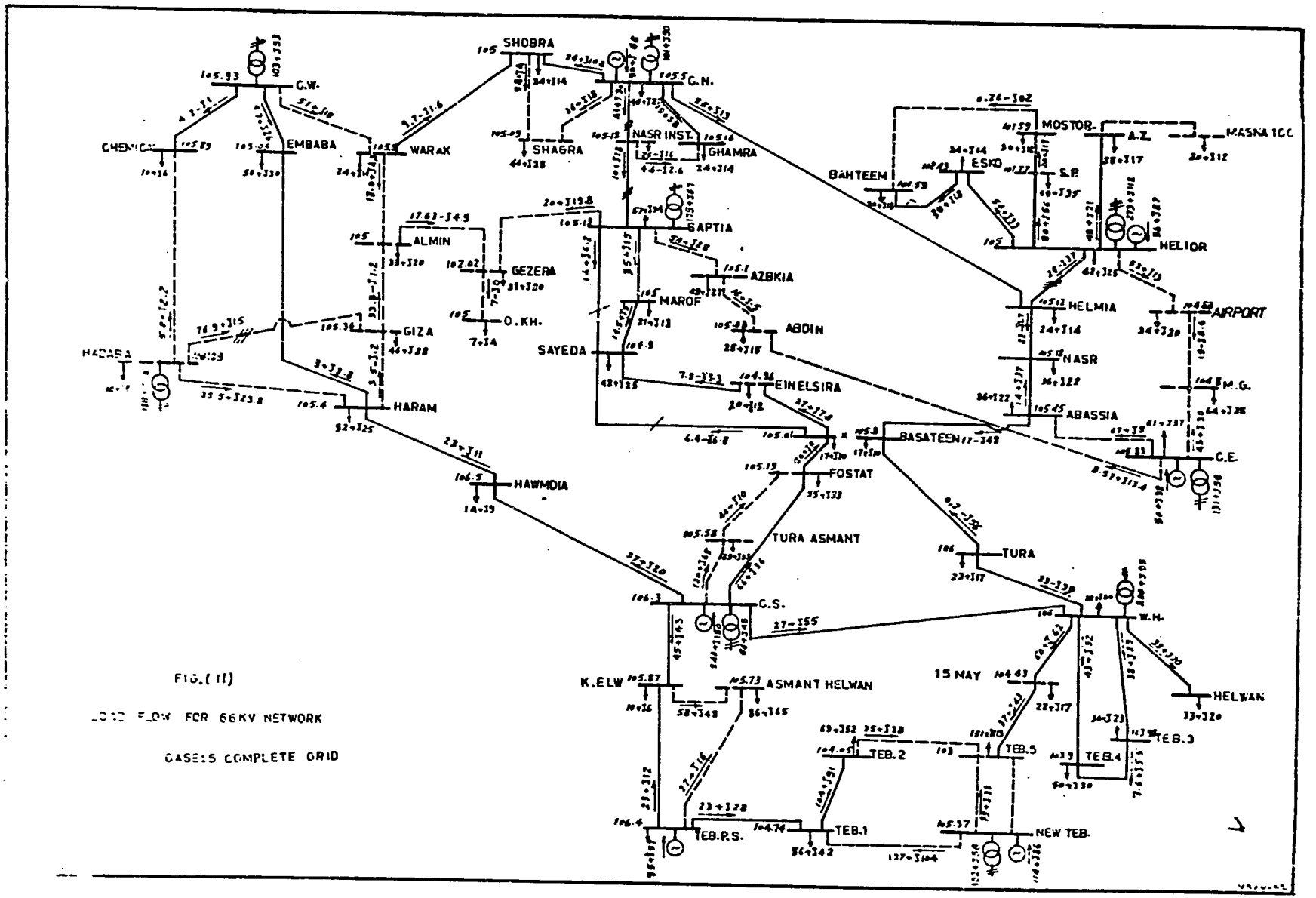

FIG.(11)

LOAD FLOW FOR 66KV NETWORK

CASE:5 COMPLETE GRID

The short circuit study shows that:

1. There is no C.B. replacement in the radial and the semi-loops operating cases.
2. 70 C.B.s are to be replaced in the separate-loops case.
3. 204 C.B.s must be replaced in case of grid with sectionalized B.B. sources.
4. All C.B.s must be replaced for the complete grid case.

The load flow study shows that:

1. In radial configuration, 3 lines are slightly overloaded. The voltage level is below the acceptable range at some bus bars.
2. In the semi loops configuration, the transmission lines from Heliopolis to Misr-El-Gedida and from Saptia to Marouf are slightly overloaded.
3. In the case of seperate loops, the transmission lines from Saptia to Marouf and from New Tebbin to Tebbin 6 are slightly overloaded.
4. In the grid with sectionalized B.B. the slightly overloaded lines are New Teb. , Teb.2 and Heliopolis - S.P.
5. In the complete grid case, no overloaded lines are encountered.

7. References

1- Report on Review and Analysis of the Transmission and Subtransmission Networks in Great Cairo Zone up to the year 1985 (Egyptian Electricity Authority - EEA - Studies and Researches Sector, June 1979).

2- Report on Review and Analysis of the Unified Power System Network and Expected Energy and Load Requirements up to year 1990 (EEA, Studies and Researches Sector, Sept.1978.

3- Electrical Distribution System Rehabilitation and Expansions. Volume IV, Cairo (by Harza Overseas Engineering Company and Sabbour Associate, Nov. 1978).

4- Report on the Activities of the Task Group Studying the Development of Cairo Zone Network (EEA, Feb. 1977).

5- Power Sector Survey, Arab Republic of Egypt, System Planning Diagnostic Reports (by Sanderson & Porter, INC., Power Sector Survey Team, April 1977).

6- Report on Review and Analysis of the Unified Power System Network and Expected Energy and Load Requirements up to 1985 (EEA, Studies and Researches Sector, Dec. 1976).

7- Power System Planning (by Robert L. Sullivan Assoiate Professor of Electrical Engineering, University of Florida).

8- Electrical Transmission and Distribution Reference Book, by Central Station Engineers of the Westinghouse Electric Corporation.

URBAN SYSTEM PLANNING

Report 5

INVESTMENT COST OF VARIOUS SUBTRANSMISSION SCHEMES OF CAIRO ZONE UP TO 1983

M. A. Swidan
M. M. El-Metwally
I. Abou El-Fadl

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Investment costs of Various Subtransmission schemes of Cairo Zone up to 1983

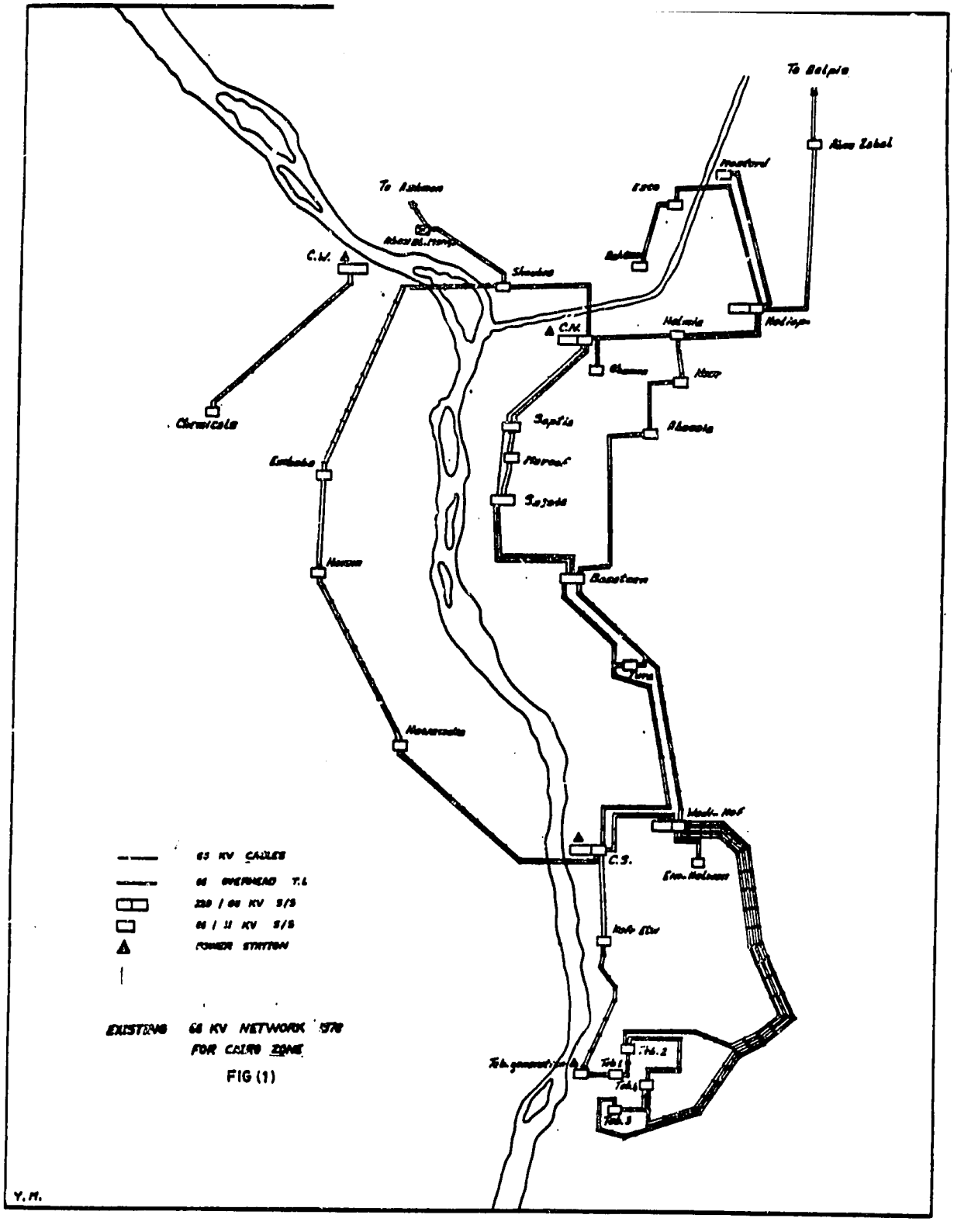
1- Introduction

The existing 66 kv subtransmission network of Cairo Zone is composed of 28 substations of 66/11 kv and seven substations of 66/6.6 kv. These substations are connected to each other through overhead transmission lines and underground cables of 890 km and 130 km lengths respectively. This subtransmission network is fed from three thermal Power Plants, namely Cairo North, Cairo South and Tebbin P.S. In addition to that, power is also supplied from the national unified system through five 220/66 kv substations namely at Cairo North, Cairo South, Cairo West, Heliopolis and Wadi Hoff. Most of the 66 kv network in Cairo Zone is over twenty years old and the rupturing capacity of the circuit breakers is of the order 1500 MVA which is not capable to meet the requirements of the short circuit level of the present subtransmission system. Fig.(1) shows the existing 66 kv network.

2- Study objectives and Methodologies:

To meet the increased requirements of load demand up to 1983 in Cairo Zone, it is planned to construct twenty three 66/11 kv substations in addition to two extensions of two existing 66/11 kv substations to feed the new load centres.

In this chapter, it is aimed to calculate the investment costs required for the different operational schemes proposed in Report 4. As shown in Report 4, four cases which result in short circuit levels less than or about 4000 MVA are selected for the cost comparison.


To Belpio
Rizu Zebal
To Ashmun
C.W.
C.M.
C.S.
Chemicals
Embaba
Sapatia
Sajada
Basatine
Madi. Nof
Tab.1
Tab.2
Tab.3
Tab.4
65 KV CABLES
66 OVERHEAD T.L
220 / 66 KV S/S
66 / 11 KV S/S
POWER STATION
EXISTING 66 KV NETWORK 1978
FOR CAIRO ZONE
FIG (1)
Y.M.

These acceptable cases are enumerated as follows:

1- Radial scheme
2- Semi loop scheme
3- Separate loops scheme
4- Grid with sectionalized busbars.

The cost of the equipments required in each case is taken from the actual tenders in the project sector of EEA for 1978 as shown in Table (1).

3- Radial Configuration

Fig. (2) shows the suggested radial connection which is based on feeding each substation from one main source and opening the 66 kv bus bars in the 220/66 kv substation. The short circuit level in this case is below the rupturing capacity of the existing circuit breakers, as shown in table (2).

The new equipments required for this proposed configuration are:

1- Twenty three 66/11 kv new substations in addition to two extensions whose characteristics and investments are shown in Table (3).
2- Double circuit overhead transmission lines of 25 km length (as shown in Table (4)).
3- Single circuit underground cables of 161.75 km length (as shown in Table (4)).

The total investment of these equipments is 72,176,250 L.E. of which the foreign currency is 59,837,500 L.E.

Details for investment cost calculations are shown in table (5) where one transformer of 220/66 kv is added at Saptia.

Table (1)

The cost of 66 kv Equipments
(1978 prices)

Equipment	Total L.E.	Foreign L.E.	Local L.E.
Substation 66/11 kv 4 x 25 MVA	3,200	2600	600
Substation 66/11 kv 4 x 10 MVA	1,850	1,500	350
Single circuit underground cable	55,000	50,000	5,000
Double circuit over head T.L.	32,000	22,000	10,000
Circuit breaker:- convential type	18,340	18,340	-
Circuit breaker SF_6 Type	25,740	25,740	-

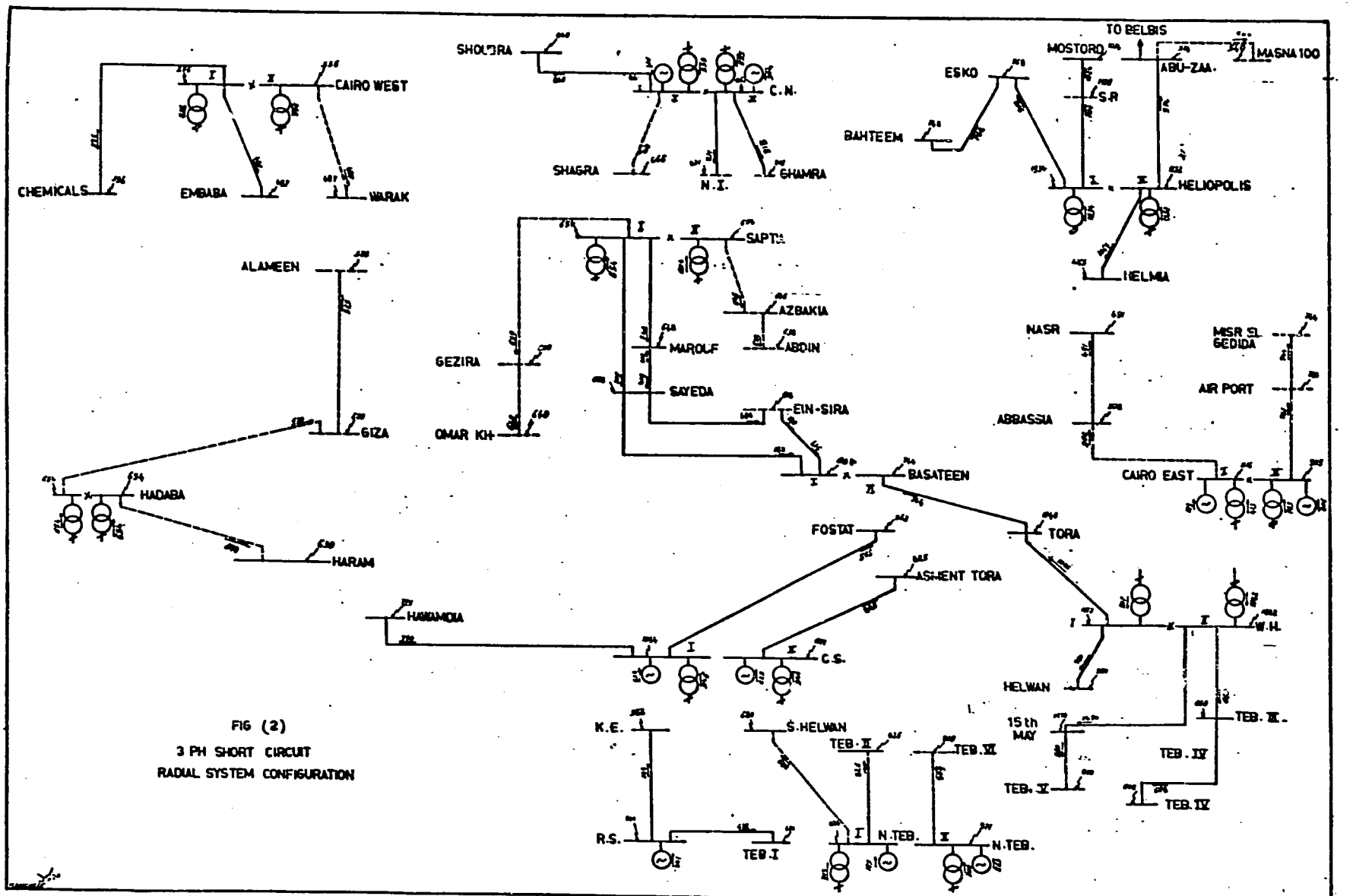


FIG (2)

3 PH SHORT CIRCUIT

RADIAL SYSTEM CONFIGURATION

Table (2)

Short Circuit Results of the Radial Configuration

B.B. Name	Year of operation	Rating M.V.A.	S.C. MVA
Shoubra	Existing	1,500	840
Bahteem	Existing	2,500	748
Mostorod	Existing	2,500	1,024
Heliopolis I	Existing	2,000	1,934
Heliopolis II	Existing	2,000	1,132
Cairo North I	Existing	1,500	881
Cairo North II	Existing	1,500	863
Helmia	Existing	1,500	1,065
Nasr	Existing	1,500	491
Saptia I	Existing	1,500	665
Saptia II	Existing	1,500	654
Abassia	Existing	1,500	502
Cairo East I	Existing	3,000	516
Cairo East II	Existing	3,000	909
Marouf	Existing	2,000	648
Sayeda	Existing	1,500	628

Table (2) Cont'd

B.B. Name	Year of Operation	Rating M.V.A.	S.C.MVA
Basateen I	Existing	1,500	551
Basateen II	Existing	1,500	744
Tura	Existing	1,500	1,046
Tura Asment	1983	3,500	805
C.S. I	Existing	1,500	1,084
C.S. II	Existing	1,500	1,171
W.H. I	Existing	3,000	1,117
W.H. II	Existing	3,000	1,882
Kafr El-Elw	Existing	1,500	388
Teb P.S.	Existing	1,500	441
Teb 1	Existing	1,500	432
Teb 2	Existing	1,500	826
Teb 3	Existing	2,000	660
Teb 4	Existing	3,000	608
C.W. I	Existing	1,500	556
C.W. II	Existing	1,500	556
Chemical	Existing	3,000	396

Table (2) Cont'd

B.B. Name	Year of Operation	Rating M.V.A.	S.C. MVA
Embaba	Existing	2,000	497
Haram	Existing	2,000	630
Hawamdia	Existing	1,500	790
Misr El-Gedida	1983	3,500	744
Air-port	1983	3,500	783
Asment Helwan	1983	3,500	680
Esko	Existing	2,500	968
Suez Petrol	1983	3,500	1,100
Nasr INstitute	1983	3,500	831
Ghamra	Existing	2,500	816
Gezira	1983	3,500	650
Azbakia	1983	2,500	646
Abdin	1983	2,500	638
Ein El Sira	1983	2,500	614
Fostat	1983	3,500	563
Teb 5	1983	3,500	566
New Teb I	1980	3,500	884

Table (2) Cont'd

B.B. Name	Year of Operation	Rating M.V.A.	S.C. MVA
New Teb II	1980	3,500	971
Warak	1983	3,500	497
Almin	1983	3,500	575
Giza	1983	3,500	620
Hadaba	1983	3,500	654
Omar El-Khayam	1983	3,500	640
15th May	1983	3,500	980
Shagara	1983	3,500	866
Abu Zaabal	Existing	1,500	574
Masna 100	1983	3,500	540
Helwan	Existing	1,500	980
Teb. 6	1983	3,500	809

Table (3)

66/11 kv proposed and Under Construction
Substations capacity and Investment

	Name of sub-station	Cond-ition	Capacity	Investment cost in 1000 L.E.		
				Total	Foreign	Local
1	Esco	under-const.	4 x 25	1850	1500	350
2	Ein El Syra	"	4 x 10	1850	1500	350
3	Omer El Khiam	"	2 x 25	2400	2000	400
4	Tebbin V	under-const.	3 x 25	2800	2300	500
5	Azbakia	"	4 x 25	3200	2600	600
6	Warak	"	4 x 10	1850	1500	350
7	Cement Tura	"	3 x 25	2800	2300	500
8	Abdin	under-const.	4 x 10	1850	1500	350
9	Massna 100	"	2 x 20	1900		300
10	Suez-Petrol	"	4 x 25	3200	2600	600
11	Cairo East	"	2 x 25	2400	2000	400
12	Cement Helwan	"	3 x 25	2800	2000	400
13	Almin	"	4 x 25	3200	2300	500
14	Kawmia (Teb.6)	"	3 x 25	2800	2600	600
15	NaserInstitute	"	4 x 25	3200	2300	500
16	Giza	"	4 x 25	3200	2600	600
17	Gizera	"	4 x 25	3200	2600	600
18	Airport	"	3 x 25	2800	2300	500
19	15thMay city	"	2 x 25	2400	2400	600
20	East Maadi cement	"	2 x 25	2400	2400	600
21	Shagara	"	4 x 25	3200	2600	600
22	Misr El Gedida	"	4 x 25	3200	2600	600
23	Fostat	"	4 x 25	3200	2600	600
24	Ext. Teb. V	"	1 x 25	240	200	40
25	Ext. Teb. VI	"	1 x 25	240	200	40
	Total			61,980	50,700	11,280

Table (4)

The proposed Underground Cables and O.H.L. for Radial Schemes

Name of Line	Type	No. of circuit	Lengt km	Total length
Hadaba - Giza	cable	3	11.1	33.3
Giza - Almin	"	2	10.8	21.6
Hadaba - Haram	"	2	7.8	15.6
C.N. - Shagara	"	2	2	4
Septiah - Gezera	"	2	4	8
Gezera - O. Kh.	"	2	2	4
Saptia - Azbakia	"	3	1.75	5.25
Azbakia - Abdin	"	2	1.5	3
C.E. - Airport	"	3	15	45
Airport - M.G.	"	2	6	12
C.E. - Abbassia	"	2	5	10
Asment H. - New Teb.	T.L.	2	5	10
C.W. - Warak	"	2	5	10
C.S. - Tora	"	2	9	18
N. Teb. - Teb.VI	"	2	2	4
New Teb. - Teb II	"	2	4	8

Cables (single circuit) 161.75 km

O.H.T.L. (double circuit) 25 km

Table (5)

The Required Investment for The Radial Configuration

Equipments	No.of units or km	Investment in L.E. Total	Foreign	Local
Substations	25	61,980,000	50,700,000	11,280,000
Double circuit overhead trans-mission lines	25	800,000	550,000	250,000
Single circuit underground cables	161.75	8,896,250	8,087,500	808,750
Transformer 220/66	1	500,000	500,000	-
Total		72,176,250	59,837,500	12,338,750

4. Semi Loop Configuration

Fig. (3) shows the proposed configuration of the 66 kv Cairo Network. In this schemes each substation is fed from two main sources and at the same time each loop is connected to the adjacent one by a line which is always open in normal operation and will be closed in emergency conditions. In this case short circuit levels are within the capacity of the existing circuit breakers in the existing substations. The equipments required for the network in this case in addition to the twenty three substations and the extensions are:

1- 225.46 km single circuit under ground cables shown by Table (6).
2- 55.5 km double circuit overhead transmission lines and 11 km single circuit overhead transmission lines as shown by Table (6).

The total investment for this configuration is estimated to be 77,332,300 L.E. of which the foreign currency is 64,315,000 L.E.

Details of investment cost calculations are shown by Table (7).

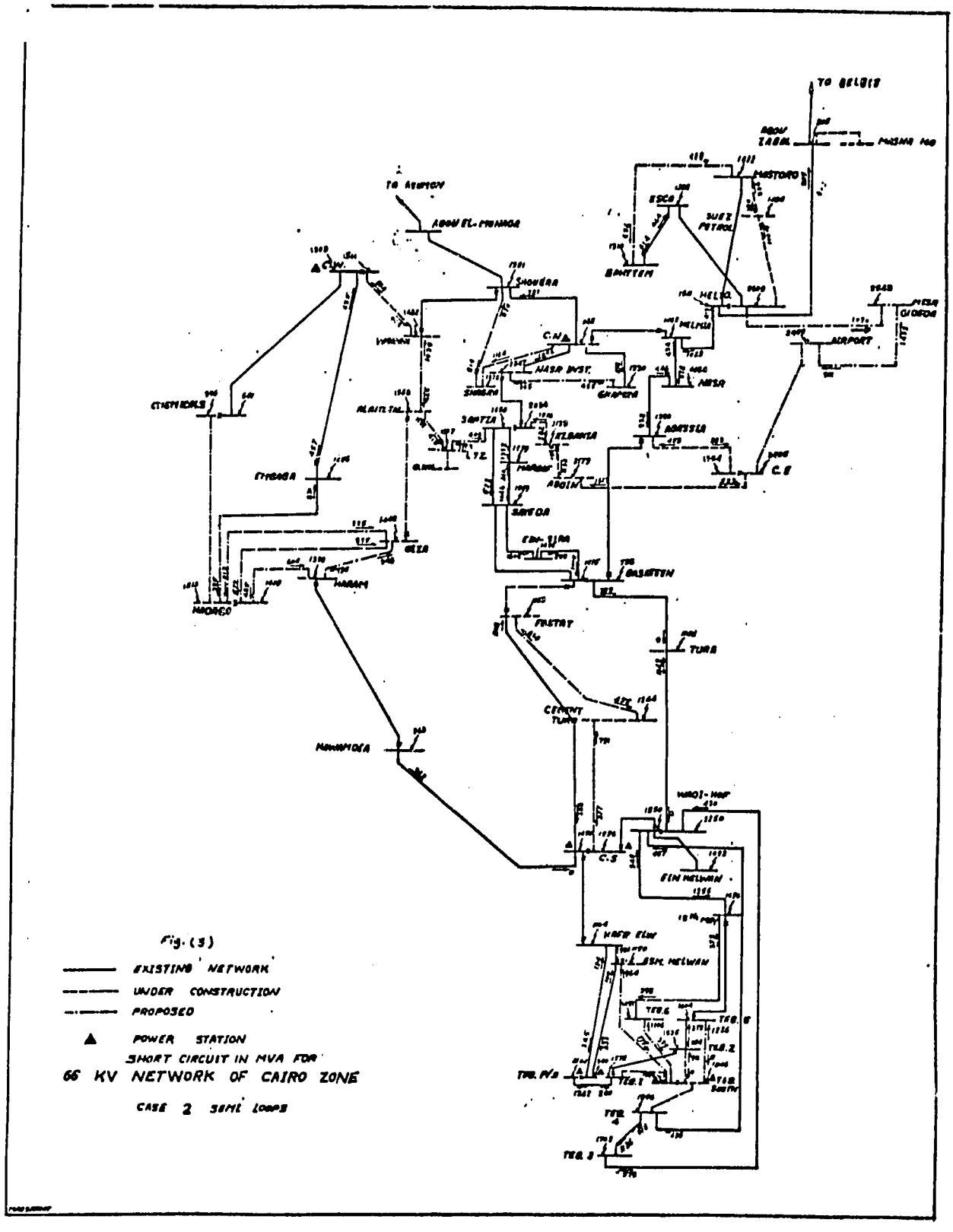

TO BELBIS
TO MINIA
ABOU EL-MANAGA
SHOUBRA
C.N.
HELIO.
MELIOA
MASR
ABBASIA
C.E
AIRPORT
GIZEZA
SUEZ PETROL
ESCO
BAHTEEM
CHEMICALS
ELMAHALLA
ABOUIN
SAWDA
BASATEEN
FESTAT
TURA
CEMENT TURA
MAHMODIA
C.S
EIN HELWAN
HARAM
MADECO
GEZA
ELMANSA
SAMTTA
SHUBRA
GAMEIA
MASR INST.
Fig. (3)
EXISTING NETWORK
UNDER CONSTRUCTION
PROPOSED
POWER STATION
SHORT CIRCUIT IN MVA FOR
66 KV NETWORK OF CAIRO ZONE
CASE 2 SEMI LOOPS

Table (6)

The proposed transmission lines and cables for the semi-loop configuration

Name of line	Type	No.of circuit	Lenght km	Total length km
Haram - Giza	cable	2	6.6	13.2
Warak - Alamin	"	2	8.3	16.6
Hadaba - Chemicals	T.L.	1	11	11
Hadaba - Giza	cable	2	11.1	22.2
Hadaba - Giza	"	1	11.1	11.1
Hadaba - Haram	"	2	7.8	15.6
C.N. - Shagara	"	2	2	4
Shagara - Shobra	"	2	3	6
Naser Inst.- Ghamra	"	2	6	12
Helio. Suez Petrol	T.L.	2	9	18
Bahteem - Mostord	"	2	6	12
Helio. - M.G.	cable	3	6	12
Matar- C.East	"	2	15	30
Abbassia-Cairo East	"	3	5	15
Matar - M,G.	"	2	6	12
Cairo East-Abdin	"	2	7	14
Abdin - Azbakia	"	2	1.5	3
Azbakia - Saptieh	"	2	1.75	3.5
Saptieh - Gezira	"	2	4	8
Gezira - Almin	"	2	3	6
Gezira - Omar Khiam	"	2	2	4
C.South - Asment Tora	T.L.	2	9	18
Fostat - Asment Tora	"	2	9	18
Mostord - S.P.	"	2	1.5	3
Teb.(5) - New Teb.	"	2	2	4
Teb. p.s. - Asmant H.	"	2	7	14
Teb. (5) - Teb. (2)	"	2	2	4
K.El-Elw- Asmant H.	"	2	1	2
Teb. (4) - New Teb.	"	2	2	4
New Teb. - Teb. (6)	"	2	2	4
New Teb. - Asment H.	"	2	5	10
Teb. I- New Teb.	cable	2	1	2
Abbasia - Nasr	"	2	4.63	9.26

Total length of single circuit underground cables = 225.46 km
length of double circuit O.H.T.L. 55.5 km
length of single circuit O.H.T.L. 11 km

Table (7)

The investment cost for the semi-loop configuration

Equipment	No.of unit or length	Investment in L.E.		
		Total	Foreign	Local
Substations	25	61,980,000	50,700,000	11,280,000
Double circuit overhead transmission lines	55.5 km + 11 km single circuit	1,952,000	1,342,000	610,000
Single circuit underground cables	225.46 km	12,400,300	11,273,000	1,127,300
Transformer 220/66	2	1,000,000	1,000,000	-
Total		77,332,300	64,315,000	13,017,300

5 Separate loops configuration

Fig. (4) shows the suggested separate loops connection. This operational method is based on the idea of dividing the 66 kv network of Great Cairo Zone into separate loops, each loop is fed from one main source while the 66 kv bus bars in the 220/66 kv substations are sectionalized. The draw back of this configuration is that each loop is operated indepently. If the main source is out of service the continuity of supply is not good as in the case of the following loops:

1- Saptia - Azbzkia - Abdin.
2- Heliopolis - Suez Petrol - Mostord - Esco - Bahteem.

The short circuit levels in this case are within the rupturing capacity of the existing circuit breakers except at Cairo South, Helmia, Kafr Elw, Teb I, Teb II, Abu Zaabal and Helwan substations. The equipments required for this configuration in addition to the substations which have been listed in Table (3) are:

1- 201.58 km of single circuit underground cables (Table 8).
2- 36 km of double circuit over head transmission lines (Table 8).
3- 70 circuit breakers to be replaced by higher capacity in Cairo South and Helmia substations as follows:

Cairo South : (15 circuit breakers)

4 for the generators
2 for the transformers 2 x 75 MVA
2 for the feeders to Fostat
2 for feeders to Cement Tora
2 for the feeders to Hawamdia
1 for the feeders to Asment Helwan
1 for the feeders to Kafr El-Elw
1 for the bus coupler

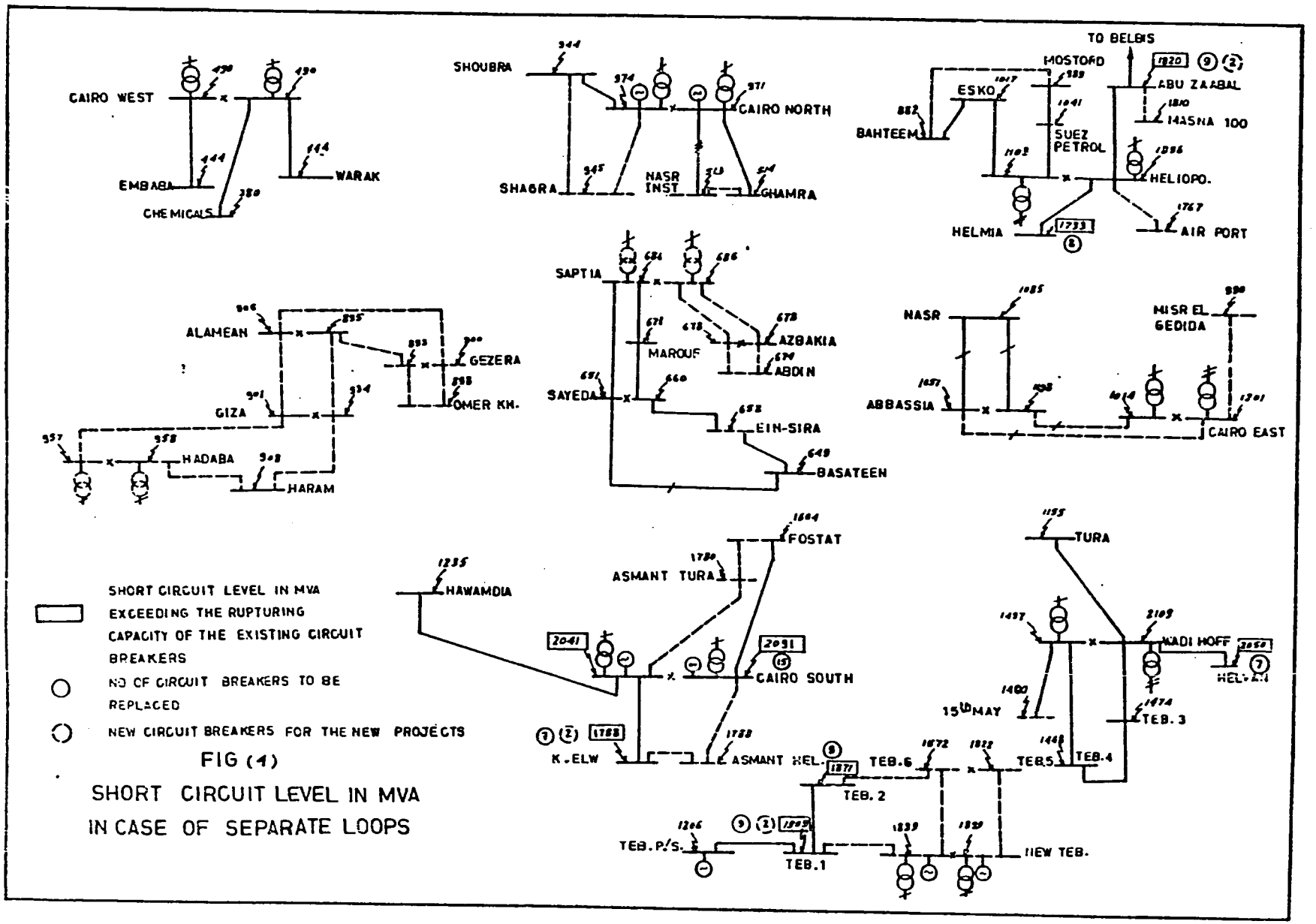


FIG (4)

SHORT CIRCUIT LEVEL IN MVA IN CASE OF SEPARATE LOOPS

Table (8)

The proposed underground cables and O.H.T.L.
for the separate loops configuration

Name of line	Type	No. of circuit	length km	Total length
Hadaba-Giza	cable	3	3 x 11.1	33.3
Hadaba-Haram	"	3	3 x 7.8	23.4
Haram-Giza	"	2	2 x 6.6	13.2
Giza-Almean	"	2	2 x 10.8	21.6
Almean-Gizera	"	1	3	3
Gizera-O.Khiam	"	1	2	2
O.Khiam-Gizera	"	1	2	2
Gizera-Almean	"	2	3	6
Almean-Giza	"	1	10.8	10.8
C.W.- Warak	T.L.	2	5	10
Ghamra-N.I.	cable	2	6	12
C.N.-Shagara	"	2	2	4
Shobra-Shagara	"	2	3	6
Saptieh-Azbakia	"	1	1.75	1.75
Azbakia-Abdin	"	1	1.5	1.5
Abdin-Azbakia	"	1	1.5	1.5
Azbakia-Saptia	"	1	1.75	1.75
K-El-Elw-Asment H.	T.L.	2	1	2
Tora - C.S.	"	2	9	18
Tura - Fostat	T.L.	2	9	18
Mostorod - Bahteem	"	2	6	12
Helio.- Airport	cable	2	3	6
Teb.VI-Teb.II	T.L.	2	2	4
C.E.-Abbassia	cable	2	5	10
Abbassia-C.E.	"	1	5	5
C.E. - M.G.	"	2	15	30
Teb. 220- Teb. VI	T.L.	2	2	4
Teb. 220- Teb V	T.L.	2	2	4
Teb.1 - Teb. 220	cable	2	1	2
Saptia - Saveda	"	1	4.78	4.78

underground cables single circuit 201.58 km
double circuit O.H.T.L. 36 km

K. ELW (9 circuit Breakers)

4 for the transformers

2 for feeders to Cairo South

2 for feeders to Asment Helwan*

1 for bus coupler

Tebbin I (circuit Breakers)

4 for the transformers

2 for the feeders to Tebbin power station

2 for feeders to Tebbin II

2 for feeders to New Tebbin

1 for bus coupler

Tebbin II (9 circuit Breakers)

4 for the transformers

2 for feeders to Tebbin I

2 for feeders to Tebbin VI*

1 for bus coupler

Helwan (7 circuit Breakers)

4 for the transformers

2 for feeders to Wadi Hoff

1 for bus coupler

Abu-Zaabal (11 circuit Breakers)

4 for the transformers

2 for feeders to Heliopolis

2 for feeders to Masna 100*

2 for feeders to Belbees

1 for bus coupler

Helmia (8 circuit Breakers)

4 for the transformers
3 for the feeders to Heliopolis
1 for the bus coupler

The total investment required in this case is estimated to be 76,261,700 L.E. of which the foreign currency is 63,613,800 L.E.

Details of investment calculation are shown in Table (9).

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* Additional circuit breakers cells for proposed T.L. and cables in the existing substations.

Table (9)

The investment required for the separate loop configuration

Equipment	No. of units	Investment in L.E.		
		Total	Foreign	Local
Substation	25	61,980,000	50,700,000	11,380,000
Double circuit overhead transmission lines	36	1,152,000	792,000	360,000
Single circuit underground cable	201.58 km	11,086,900	10,079,000	1,007,900
Circuit breakers to be replaced	70			-
Sf_6 Type (35)		900,900	900,900	-
Convential (35) Type		641,900	641,900	-
Transfprmer 220/66	1	500,000	500,000	-
		76,261,700	63,613,800	12,647,900

6. Grid with Sectionalized bus bars:

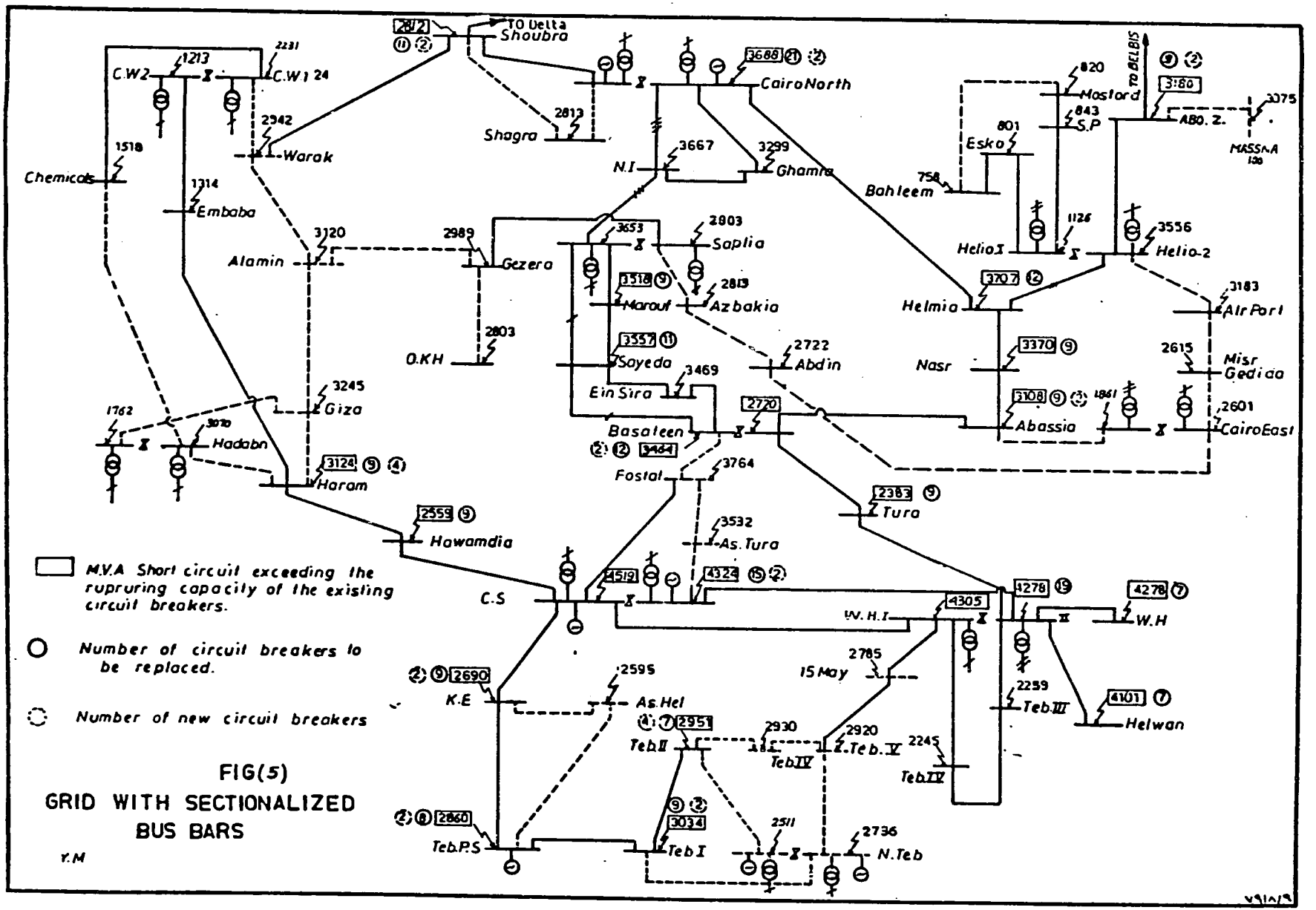
The most reliable scheme of operation is the completely closed grid configuration. In this configuration it is suggested to connect the whole 66 kv network of Great Cairo Zone into one complete closed grid. Each 66/11 kv substation is fed from two main sources at least. Applying the three phase short circuit study to this scheme the short circuit level reaches about 6000 MVA at most of the 66 kv bus bars of the network. To reduce this level to about 4000 MVA which is the permissible value of short circuit in the 66 kv networks; it is recommended to open the grid at few points such as:-

1- Sectionalizing the 66 kv bus bars of the 220/66 kv substations.
2- Sectionalizing the 66 kv B.B. in Bassatin 66/11 kv substations.
3- Open the 66 kv over head transmission line from Cairo South to Wadi Hoff220/66 kv substations.

Fig.(5) shows the scheme of Grid with sectionalized Bus bars. This configuration is considered to be the most reliable scheme of operation which fulfil the short circuit level constraints. From the load flow study in report No (4), the loading of the lines and cables is within the permissible limits. But the investment required in this configuration is much more than the other schemes.

In addition to the proposed substation which is listed in table (3) it is required to:

1- Construct 224.8 km single circuit underground cables which are listed in Table (10) with a total cost of 12,364,000 L.E.



M.V.A Short circuit exceeding the rupruring capacity of the existing circuit breakers.

Number of circuit breakers to be replaced.

Number of new circuit breakers

FIG(5)

GRID WITH SECTIONALIZED BUS BARS

Y.M

Table (10)
The proposed O.H.T.L. and cables in Grid with sectionalized buses configuration

Name of line	Type	No. of circuits	length km	Total km
Warak-Almin	cable	2	8.3	16.6
Almin-Gizera	"	2	3	6
Gizera - Omer Khiam	"	2	2	4
Almin - Giza	"	2	10.8	21.6
Giza - Haram	"	2	6.6	13.2
Haram - Hadaba	"	2	7.8	15.6
Hadaba - Giza	"	3	11.1	33.3
Hadaba - Chemicals	T.L.	1	11	11
Cairo N. - Shagara	cable	2	2	4
Shagara - Shobra	"	2	3	6
Ghamra - Nasr Inst.	"	2	6	12
Saptieh - Gizera	"	2	4	8
Bassatin - Fostat	"	2	2	4
Fostat - Asment Tora	T.L.	2	9	18
Asment Tora - C.South	"	2	9	18
Saptieh - Azbakia	cable	2	1.75	3.5
Azbakia - Abdin	"	2	1.5	3
Abdin - Cairo East	"	2	7	14
C.East - Misr Gedida	"	2	15	30
Misr Gedida - Airport	"	2	6	12
Airport - Heliopolis	"	2	3	6
Abbassia - Cairo East	"	2	5	10
Mostord - Bahteem	T.L.	2	6	12
Teb.V - New Teb	"	2	2	4
Teb.V - Teb. II	"	2	2	4
Teb. II - New Teb.	"	3	4.25	12.75
New Teb. - Teb. I	cable	2	1	2
Teb. P.S. - Asment H.	T.L.	2	7	14
Kafr El Elw- Asment H.	"	2	1	2
C.W. - Warak	"	2	5	10

Total length of single circuit underground cables are 224.8 km
Total length of double circuit O.H.T.L. is 45.25 km
Total length of single circuit O.H.T.L. is 15.25 km

2- Construct 45.25 km of double circuit O.H.T.L. and 15.25 km of single circuit O.H.T.L. which are listed also in Table (10) with a total cost of 1,692,000 L.E.

3- Changing 204 circuit breakers of nineteen existing substations.

4- Add 22 new circuit breakers in the existing substations.

Fig. (5) shows the circuit breakers to be changed as follows:

1- <u>Shoubra: (13 circuit breakers)</u>

2 feeders to Shagara*
2 feeders to Cairo North
2 feeders to Delta Network
4 Transformers
1 Bus coupler
2 feeders to Warak

2- <u>Cairo North: (23 circuit breakers)</u>

2 Transformers 220/66 kv
1 Bus coupler
4 Transformers 66/11 kv
1 Bus coupler
6 Generating units
3 feeders to Nasr Institute
2 feeders to Shagara*
2 feeders to Helmia
2 feeders to Shoubra

3- <u>Maaroof : (9 circuit breakers)</u>

4 Transformers
2 feeders to Saptia
2 feeders to Sayeda
1 Bus coupler

4- Sayeda : (11 circuit breakers)

4 Transformers
1 Bus coupler
2 feeders to Maaroof.
1 feeder to Saptia
2 feeders to Bassatin
1 feeder to Ain El Syra

5- Bassatin: (14 circuit breakers):

4 Transformers
1 Bus coupler
2 feeder to Ain El Syra
1 feeder to Sayeda
2 feeders to Fostat
2 feeders to Abassia
2 feeders to Wadi Hoff

6- Helmia: (12 circuit breakers):

4 Transformers
1 Bus coupler
3 feeders to Heliopolis
2 feeders to Nasr
2 feeders to Cairo North

7- Nasr: (9 circuit breakers):

4 Transformers
1 Bus coupler
2 feeders to Helmia
2 feeders to Abbassia

8- Abbassia : (11 circuit breakers):

4 Transformers
1 Bus coupler
2 feeders to Nasr
2 feeders to Bassateen
2 feeders to Cairo East *

9- Cairo South : (17 circuit breakers) :

2 Transformers 220/66 kv
1 Bus coupler
4 Generating units
2 feeders to Fostat
2 feeders to Hawamdia
2 feeders to Asment Tora*
2 feeders to Kafr el Elw
2 feeders to Wadi Hoff

10- Kafr el Elw : (11 circuit breakers):

4 Transformers
1 Bus coupler
2 feeders to Cairo South
2 feeders to Tebbin Power Station
2 feeders to Asment Helwan *

11- Tebbin Power Station : (10circuit breakers):

3 Generating units
1 Bus coupler
2 feeders to Tebbin I
2 feeder to Kafr El Elw
2 feeder to Asment Helwan*.

12- Tebbin I: (11 circuit breakers):

4 Transformers
1 Bus coupler
2 feeders to Tebbin II
2 feeders to Tebbin Power Station
2 feeders to New Tebbin *

13- Tebbin II: (11 circuit breakers):

4 Transformers
1 Bus coupler
2 feeders to Tebbin I
2 feeders to Tebbin IV *
2 feeders to New Tebbin*

14- Hawamdia : (9 circuit breakers):

4 Transformers
1 Bus coupler
2 feeders to Cairo South
2 feeders to Haram

15- Haram : (13 circuit breakers):

4 Transformers
1 Bus coupler
2 feeders to Giza *
2 feeders to Embaba
2 feeders to Hawamdia
2 feeders to Hadaba*

16- Tora: (9 circuit breakers):

4 Transformers
1 Bus coupler
2 feeders to Bassatin
2 feeders to Wadi Hoff

17- Wadi Hoff 220/66 kv: (19 circuit breakers):

3 Transformers 220/66 kv
2 Bus coupler
2 feeders to Tura
2 feeders to Tebbin III
2 feeders to Tebbin IV
2 feeders to Tebbin V
2 feeders to Cairo South
2 feeders to Ain Helwan
2 feeders to Wadi Hoff.

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* Additonal circuit breakers cells for the proposed transmission lines and cables in the existing sub-stations.

18- Ain Helwan : (7 circuit breakers)

4 Transormers

1 Bus coupler

2 feeders to Wadi Hoff

19- Wadi Hoff 66/11 kv : (7 circuit breakers):

4 Transformers

1 Bus coupler

2 feeders to Wadi Hoff 220/66 kv

The total number of circuit breakers is 226 circuit breakers. Assuming that 113 unit of SF_6 Type with cost = 2,908,620 L.E.
and the other 113 unit of convential type wity
cost = 2,072,420 L.E.

The total cost required for the circuit breakers is 4,981,040 L.E.

Tables (11) shows the equipments cost required for the grid configuration with sectionalized bus bars.
The total cost is 81,017,040 L.E.
of which 68,084,290 L.E. in foreign currency

Table (11)

The cost of the equipment for the grid with sectionalized Bus Bars configuration

Equipment	No. of units	Investments (L.E.)		
		Total	Foreign	Local
Substations	25	61,980,000	50,700,000	11,280,000
Double O.H.T.L.	45.25 km	1,692,000	1,163,250	528,750
Single O.H.T.L.	15.25 km			
Single circuit underground cable	224.8 km	12,364,000	11,240,000	1,124,000
circuit breakers (226)				
SF6 Type	113	2,908,620	2,908,620	-
convential Type	113	2,072,420	2,072,420	-
		81,017,040	68,084,290	12,932,750

7. Conclusions:

To feed the required 1983 loads from the unified power system, it is planned to construct twenty three 66/11 kv substations in the suggested load centres and extent 2 substation.

In this report different configuration alternatives have been proposed and investigated from the cost point of view. By comparing the four chosen cases the following conclusions are down.

1- The great share of investment is for constructing the new substations and extending some of the existing ones. This investments are estimated to be 61,980,000 L.E. of which 50,700,000 L.E. of foreign currancy.

2- Radial system is the cheapest methodology but it is unfeavourable in operation for less availability of service to consumers. The cost of investment in this case is 72,176,250 L.E.

3- The most expensive methodology is the grid with sectionalized B.B. system. On the other hand it offers maximum service continuity.

4- The cost differences between the grid with sectionalized B.B. system and the other methodologies is due to:

   a- The cost of 204 circuit breakers which are required to be replaced by others with higher capacity (3500 MVA), and adding new 22 circuit breakers in the existing substations for the proposed lines. The total investment cost of the circuit breakers are 4,981,040 L.E.

   b- The investment cost of cables and overhead transmission lines which is estimated to be 14,056,000 L.E.

5- The separate loop method is faced with the drawback of interrupting service to the customers upon loosing the supply.

6- The semi loop configuration results in short circuit. levels within the rupturing capacity of the existing substations. The security of supply is maintained by feeding each substation from two main sources. The cost of investment in this case is estimated to be 77,332,300 L.E.

Table (12) shows the cost comparison between the different methodologies.

Table (12)

Comparison between the Total Cost of Investment of the Different Methodologies (000) L.E.

Equipment	Radial			Semi Loop			Seperate Loops			Closed Grid		
	Total	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local
Substation	61,980	50,700	11,280	61,980	50,700	11,280	61,980	50,700	11,280	61,980	50,700	11,280
Overhead Transmission Lines	800	500	250	1,952	1,342	610	1,152	792	360	1,692	1,163,25	528.75
Underground Cables	8,896,25	8,087,5	808,75	12,400,3	11,273	1,127,3	11,086,9	10,079	1,007,9	12,364	11,240	1,124
CIRCUIT B.	-	-	-	-	-	-	1,542.8	1,542.8	-	4,981.04	4,981.04	-
Transformer	500.0	500.0	-	1.000	1.000	-	500	500	-	-	-	-
Total	72,176.25	59,837.5	12,338.75	77,332.3	64,315	130,017.3	76,261.7	63,613.8	12,647.9	81,017.04	68,084.29	12,932.75

8. References

1- Report on Review and Analysis of the Transmission and Subtransmission Networks in Great Cairo Zone up to the year 1985 (Egyptian Electricity Authority - EEA - Studies and Researches Sector, June 1979).

2- Report on Review and Analysis of the Unified Power System Network and Expected Energy and Load Requirements up to the year 1990 (EEA, Studies and Researches Sector, Sept.1978).

3- Electrical Distribution System Rehabilitation and Expansions, Volume IV, Cairo (by HARZA Overseas Engineering Company and Sabbour Associate Nov. 1978).

4- Report on the Activity of the Task Group for Studying the Development of Cairo Zone Network (EEA, Feb. 1977).

5- Planning Investments with Economics of Scales (by Larry e. Westphal).

6- Principles of Engineering Economy (by Eugene L. Grant and W. Grant IRESON).