REPUBLIC OF MALAWI

# FEASIBILITY STUDY
# OF
# NKULA B-LILONGWE B
# TRANSMISSION LINE CONSTRUCTION
# PROJECT

## SUMMARY

AUGUST 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

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# PREFACE

In response to a request from the Government of the Republic of Malawi, the Japanese Government decided to conduct a survey on Nkula B - Lilongwe B Transmission Line Construction Project and entrusted the survey to Japan International Cooperation Agency (JICA).

JICA sent to the Republic of Malawi a survey team headed by Mr. Masao Koike, the Electric Power Development Co., Ltd., from March 1989 to July 1989.

The team exchanged views with the officials concerned of the Government of the Republic of Malawi and conducted a field survey. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the development of the Project and to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Malawi for their close cooperation extended to the team.

August, 1989

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

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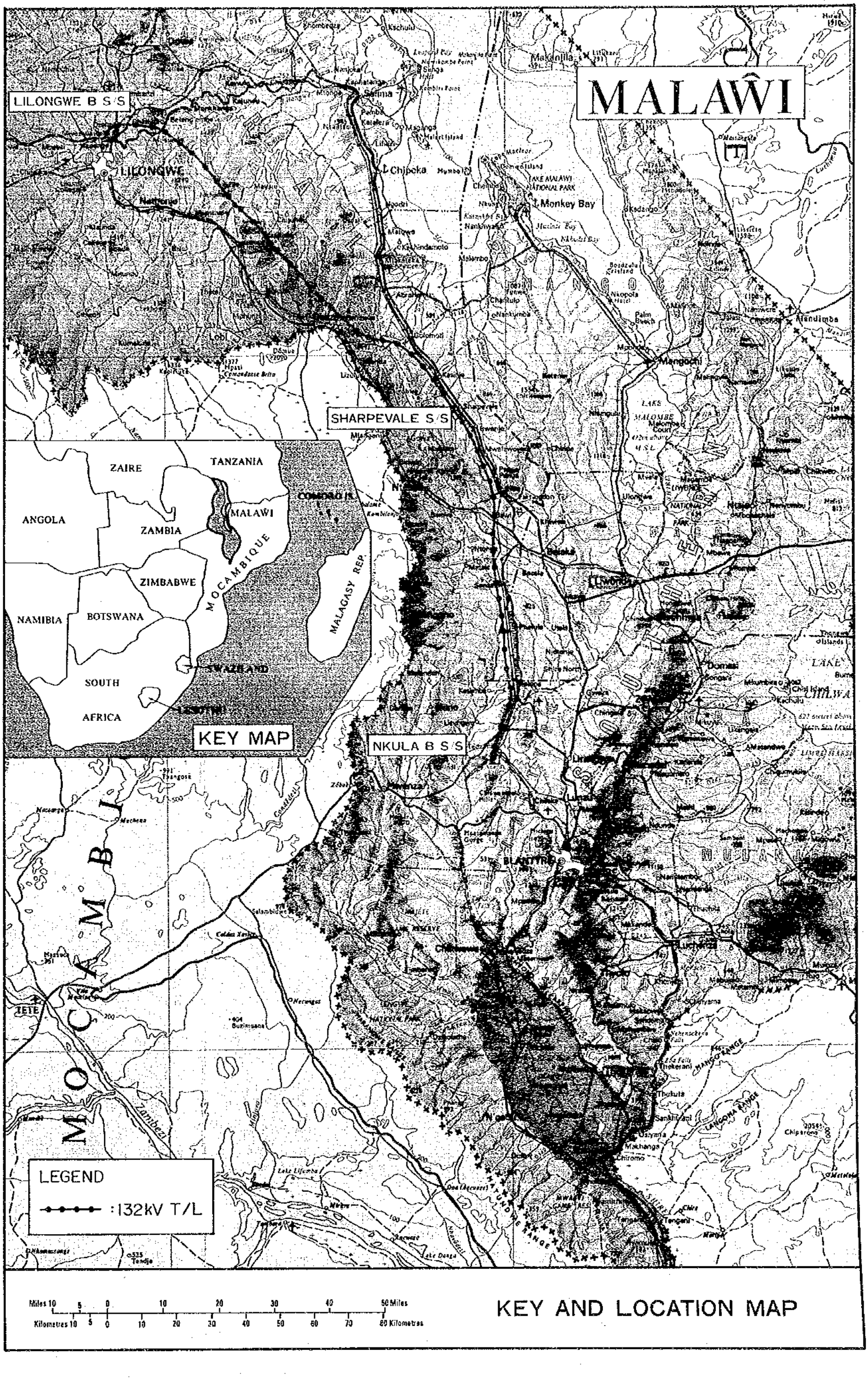
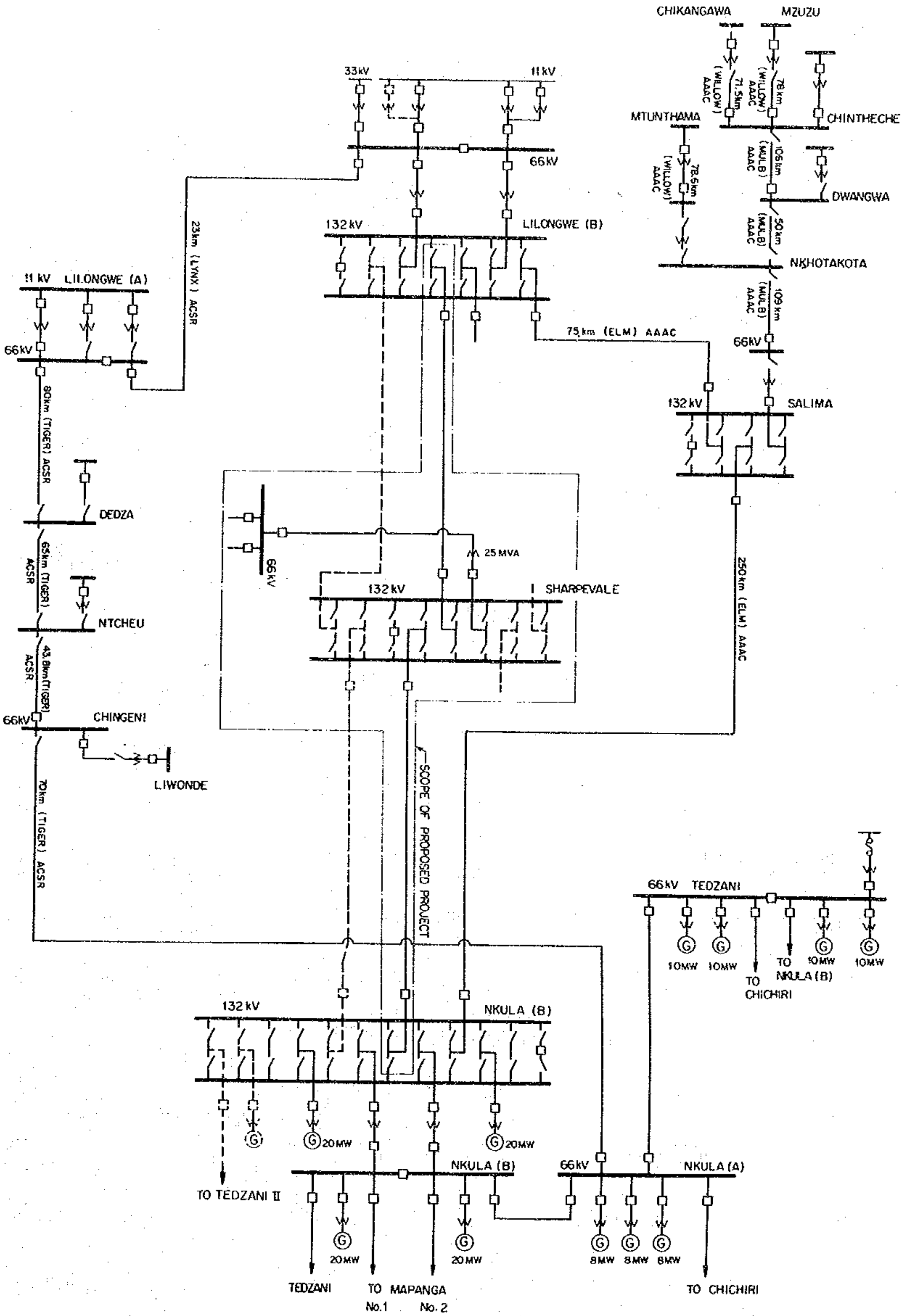



KEY AND LOCATION MAP

TRANSMISSION SYSTEM



# CHAPTER 1 PROJECT PLAN

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## 1-1 Historical Development

In the Republic of Malawi, generation capacity of 144.6 MW which shares 85% of its total generation equipment capacity (current total installed capacity is 169.8 MW including 25.4 MW of stand by thermal plant) is produced by hydraulic power. Hydro-electric power stations are concentrated in a basin of the Shire River flowing through the southern part of the country, and the power generated there is being supplied to the whole country of Malawi.

In particular, the central (capital city, Lilongwe) and northern areas receive electricity through single line of the 66 kV transmission line from the Nkula A Power Station (electric transmission capacity: 5 MW) and single line of the 132 kV wooden pole-supported transmission line from Nkula B Power Station (electric transmission capacity 20 MW). If one line of these power transmission lines is in fault, therefore, extreme load restriction and operation of uneconomical diesel power plants are compelled.

In order to attain safety supply of electricity to the central and northern region of the country and deal with a future increase in power demand in these areas, therefore, the Malawi Government is proceeding with electric power source development along the Shire River and enforcing a plan for reinforcement of power transmission and substation facilities there on a priority basis as the national energy policy.

As part of such steps, the Malawi Government asked the Japanese Government in July, 1988 to conduct a feasibility study (hereinafter referred to as F/S) in preparation for new establishment of a 250 km 132 kV overhead transmission line connecting the Nkula B Power Station along the Shire River and Lilongwe B Substation, in the capital city, as well as execution of a plan for new establishment and expansion of substations.

To consult on the scope of work (hereinafter referred to as S/W) for the F/S regarding the request about this case, the Japanese Government sent an S/W mission to the Republic of Malawi from December 2 to December 18, 1988 and carried out a summarizing investigation.

Furthermore to study the possibility of the installation of a 132 kV overhead transmission line between Nkula B Power Station and Lilongwe B Substation, the Japanese Government sent an F/S mission comprising six (6) engineers of Electric Power Development Co., Ltd. (EPDC) through Japan International Cooperation Agency (JICA) to the Republic of Malawi in March, 1989. After conducting site investigation and consultations with various local agencies and organizations concerned, the mission compiled an F/S report.

The F/S mission requested by the JICA was composed of six (6) engineers of EPDC entrusted with the task. Their names are as follows:

| | | | |
|---|---|---|---|
| 1. | Mission leader | Masao Koike | General control |
| 2. | Mission member (Virtual sub-mission leader) | Isao Saeki | Transmission line engineer |
| 3. | Mission member | Hajime Mimizuka | Substation engineer |
| 4. | Mission member | Katsutoshi Ono | System analysis engineer |
| 5. | Mission member | Shusaku Watanabe | Civil engineer |
| 6. | Mission member | Shigeru Nakano | Economic analysis engineer |

# CHAPTER 2 PURPOSES AND SCOPE OF INVESTIGATION

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## 2-1 Purposes of Investigation

Purposes of the current F/S study were to implement (1) site survey, (2) collection of existing data concerning the matter, (3) consultations with the Repbulic of Malawi organizations concerned and completion and submission of an F/S report. The scope of work covers establishment of a 132 kV transmission line between the Nkula B Power Station and the Lilongwe B Substation and new construction and expansion of related substations.

## 2-2 Scope of Investigation

The works required for Feasibility Study (F/S Investigation).

## 2-3 Scope of Works of Investigation

The works required for the Feasibility Study shall include the following:

(1) Load Forecast

(a) Analysis on the past data of electric energy consumption and economic growth

(b) Forecast of total and regional energy consumption

(c) Study of daily, seasonal and yearly load curve

(d) Forecast of total and regional peak demand

(e) Establishment of the computer-aided load forecast methodology compatible with variation of forecasting factors

(2) Persue and review the present, on-going and formulated systems programs and previous studies for power generation, transmission, substation, distribution, load dispatching and communication systems.

(3) Study of the Implementation Program

(a) Transmission line

(b) System analysis (Power system analysis)

(c) Telecommunication and dispatching system

(d) Substation/Switchyard

(4) Identification of the Bill of Quantities

(5) Preparation of Schedule of Budgetary Expenditure for the Implementation Program

(6) Preparation of Construction Schedule, Implementation Schedule, and Overall Reports for the Implementation Program

(7) Economic and Financial Analysis of the Project

(a) Economic Analysis

(b) Financial Analysis

# CHAPTER 3 CONCLUSION AND RECOMMENATION

## CHAPTER 3 CONCLUSION AND RECOMMENDATION

The result of the current F/S study are as follows:

### 3-1 Conclusion

The conclusion obtained as a result of the current F/S study was as follows:

(1) Efficiency of Transmission Line Establishment Plan

The plan for the establishment of a 132 kV transmission line between Nkula B Power Station and Lilongwe B substation signifies the construction of the facilities necessary and effective for electric power supply to Lilongwe (capital city), and the northern area.

(2) Early Start of Construction Work

The transmission lines supplying electricity to Lilongwe, the capital city, are double (2) circuits -- one single circuit of the 132 kV wooden pole-supported transmission line and another circuit of the 66 kV steel pole supported overhead transmission line. If some fault occurs in one (1) of the two (2) transmission line, extreme load restriction is compelled. In order to rectify such a state of affairs, it is necessary to promptly undertake construction of this 132 kV transmission line which will allow stabilized power supply.

(3) Necessity for Double Circuit Designed Overhead Transmission Line

Under This Project calling for connecting Nkula B Power Station and Lilongwe B substation, it is required to construct one (1) circuit transmission line on a priority basis.

In consideration of an anticipated power demand increase in Lilongwe, the capital, as well as around Lake Malawi, where resort development is planned, and also the need for stabilized power supply and improvement of its reliability in the northern and central region, it will become necessary to establish another single circuit in the near future. If the base construction cost of single circuit steel tower system and that of double circuit steel tower system equipped with only one (1) circuit are compared, the latter will be higher. In overall judgment of investment effects, however, the double circuit design system actually with only one (1) single circuit wiring has been adopted as described in 9-3-2.

(4) Power Demand Forecast

As a result of power demand forecast, total peak time power demand in the central power system including Lilongwe and the northern power system in respective years are estimated as follows:

| Years | Peak Time Power Demand |
|---|---|
| 1992 | 50.9 MW |
| 1997 | 87.1 MW |
| 2002 | 144.8 MW |

The average of yearly growth rate will be about 11.3%. The time for start of the operation of the transmission line will be the 1992 on the premise that only single circuit will be constructed on the basis of the above shown demand forecast. The expansion of another circuit will become necessary at the end of 1999.

(5) The Termination of Transmission Line

The point of connection on the Nkula side will be the Nkula B Power Station while the corresponding point on the Lilongwe side will be the Lilongwe B Substation.

(6) Construction Cost

The construction cost required for this transmission line project including the interest during the construction period is amount of US$35,445 x $10^3$. (M.Kw 94,624 x $10^3$). Its breakdown into foreign and domestic currencies is as follows.

Foreign currency US$22,870 x $10^3$ (Including US$360 x $10^3$
(M.Kw61,055 x $10^3$) as the interest during the construction period)

Domestic currency US$12,575 x $10^3$ (Including US$198 x $10^3$
(M.Kw33,569 x $10^3$) as the interest during the construction period)

The rate of the interest is set at 1%/year.

(7) The Year on which the Estimation is based

The construction costs relating to this project have been estimated on the basis of unit cost as of the end of February, 1989 and Conversion Rate One (1) Japanese Yen is 0.0212 Malawi Kwacha or One (1) US Dollar is 2.6695 Malawi Kwacha and 125.92 Yen.

(8) Period of Construction

The construction period of this transmission line is presumed to require twenty-four (24) months in total. Hence, the period of construction shall be started in April, 1990, and completed in March, 1992.

(9) Economic Efficiency

Concerning the economic efficiency of this project, by interconnecting the power systems of Capital Lilongwe and the northern district and southern power system to this 132 kV transmission line, the substituting power generating facility in Lilongwe can be saved, and the savable amount is evaluated at US$28,020 x $10^3$/Year.

Furthermore, by the interconnection of this main line with Nkula B Power Station which will increase the capacity from 80 MW to 100 MW, the generated power of Nkula B Power Station will be effectively utilized.

(10) Others

Such effects that cannot be monetarily evaluated are the improved stability of power supply and the reduced fluctuation in voltage and frequency in Lilongwe District and the northern district, where power systems will be reinforced by this transmission line.

Furthermore, by the new installation of a substation in Sharpevale, the extent of utilization of this 132 kV overhead transmission line will be raised, and it is also inferred that this line will significantly contribute to the development and growth of agriculture and various industries in districts of Salima and near Lake Malawi. The line will also facilitate rehabilitation of the existing 132 kV wood pole line.

## 3-2 Recommendation

From above conclusion, the followings are recommended concerning this 132 kV transmission line construction project.

(1) Time of Completion

Since, at the end of 1991, power will become insufficient in Capital, Lilongwe with the transmission capacity of the single circuits of 132 kV and 66 kV line, this 132 kV transmission line construction project should be executed to be completed at latest by the end of March, in 1992.

(2) Switching Station for the Central and Northern Power Systems

In order to attain the effective operation of this 132 kV transmission line, a substation should be installed at Sharpevale for control of the 132 kV system.

(3) Accommodation of Finance for Construction Work

For the realization of the construction of this 132 kV transmission line, the Office of the President and Cabinet of Malawi is advised to promptly start the various preparations such as the establishment of the construction relating agencies and the accommodation of the required finance for the construction.

(4) Preparatory Work

As this 132 kV transmission line work is required to be completed in a rather short period, the wayleaves for line route, and acquisition of land for the substation should be obtained in advance.

(5) Recovery of Construction Cost

It is possible to cover the required finance of this 132 kV transmission line by the revenue obtainable from the electricity delivered through this line.

# CHAPTER 4 PRESENT STATE OF ELECTRIC ENTERPRISE IN MARAWI

# CHAPTER 4 PRESENT STATE OF ELECTRIC ENTERPRISE IN MALAWI

The outline of electric enterprise in Republic of Malawi, and ESCOM are as follows:

## 4-1 Politics and Economy

The Republic of Malawi became independent as a member of the British Commonwealth in July 1964 and adopted the system of a republic in 1966. Its president has been Ngwazi Dr. H. Kamuzu Banda since its independence and he was given the title of life president in 1971.

Although Malawi adopts the policy of non-alignment politically, its foreign policy is realistic and based on moderate good neighbor policy line. Its relations with the U.K. and other Western Bloc Countries are good, while it is the only African country that maintains normal diplomatic relations with the Republic of South Africa.

The total population has been about 7.5 million since 1987, while the population density is 64 persons/$km^2$. The average population growth rate in the recent 10 years period from 1977 to 1987 was 3.1%, which was almost at the same level as the average figure of 3% for African countries south of the Sahara Desert.

The basic industry of Malawi is agriculture, and 85% of its total population are engaged in farming. The government has been pursuing the policy of putting priority on agricultural development, and by positively absorbing economic and technical assistance from Free Nations in the Western Bloc, it has been maintaining the food self-sufficiency rate at a high level. Because of the damage due to drought and other natural disasters and also entry of about 500,000 refugees from Mocambique (equivalent to about 7% of the total population of that country) due to political unrest there, however, the self-sufficiency rate of foods declined in 1987. Primary agricultural produce includes maize, which is the staple food, as well as tobacco, tea, sugar, cotton and beans, while fish caught in Lake Malawi provides valuable protein to the people in the country.

Its industry has been developing smoothly since its independence. However, competitive power of its products has declined since the scale of its domestic market is small and also since the cost of raw materials and equipment rose as the railway transportation routes from Ports Beira and Nacala through Mocambique were cut off. Its main industrial goods are textiles, fishing nets and processed foods, while cement and brick manufacture, iron processing and flour milling are seen with much expectations in regard to their future.

## 4-2 Energy

In the Republic of Malawi, 92% of its primary energy is provided by such non-commercial energy sources as fuelwood including charcoal and leftovers of agricultural produce, with the remaining 8% supplied by such commercial energy sources as hydro-electricity, petroleum and coal.

The annual consumption of fuelwood including charcoal totalled about 9,200,000 cubic meters (actual figure for 1985). Of these, 72% were applied to household use, 23% to drying tobacco and the remaining 5% to such business purposes as brick and tea production.

As a consequence, forests of 50,000 hectares are being lost every year. Being apprehensive of desolation of forests, the government is appealing for effective utilization of fuelwood and charcoal and at the same time calling for forestation and shift to alternative energy sources.

Consumption of commercial energy increased sharply between 1970 and 1975. Business stagnated due to hikes of international crude oil prices in 1975-1980 and owing to higher commodity prices resulting from the severance of both Beira and Nacala routes after 1980, however, and the growth rate for the consumption of so-called imported energy slowed down. In recent years, the consumption rather turned downward.

### (1) Electric Power

Hydro-electricity is one of the representative domestic energy sources in the country, and the electric power produced by four hydro power plants being along the River Shire located in southern part of the country -- Nkula Fall A and B, Tedzani Fall and Zomba -- (a total of 144.6 MW) account for as much as 99.8% (actual figure in 1988) of the total power generated. Malawi's total hydro-electric power potential is said to be 1,000 MW, and expansion of Nkula Fall B (20 MW) in the southern reaches of River Shire and the new establishment at Kapichira Fall (125 MW) are now in the stage of development preparation as next projects, while in the northern part of the country, mini-hydro power projects at Karonga (2,000 kW), Chilumba (200 kW), etc. are considered to be fairly promising.

(2) Oil and Coal

In Republic of Malawi, where no oil resources are existent, total volume of oil and refined oil products are imported with the exception of quite small volume of ethanol, which is used after being mingled with diesel oil at the ratio of 20:80. Most of such oil products are utilized as automobile fuel. The effect of the change in the transportation routes is also serious, and because of the higher transportation cost including insurance premiums and also because of the devaluation of Kwacha, Malawi's currency, oil product prices increased as much as 33% between 1983 and 1985, despite decline of crude oil prices.

In 1981, a U.S. survey mission confirmed existence of oil reserve beneath the bottom of Lake Malawi, but the stage of commercial drilling has not yet been reached.

Malawi depends on imports for 90% (actual figure for 1986) of its coal requirement. Most of coal is consumed in industrial boilers, while coal imports, which rose to 70,000 tons in 1982, declined to 29,000 tons in 1985, owing to instability of coal imports as well as sharp price increases. Coal price, which was 70 Kwacha/ton when imports were made from Mozambique, jumped to 117 Kwacha/ton after import sources were shifted to Zambia and Zimbabwe. (actual figure for 1986) The estimated coal reserve within Malawi is said to surpass 800 million tons, but its development is only at its initial stage, as the Mining and

Development Corporation (MIDCOR), established entirely with governmental contributions in 1985, is engaged in coal mining on a trial basis in the northern part of Kaziwiziwi area. Although there is some problem with regard to profitability because of high transport cost, the coal is expected to take the place of fuelwood and charcoal as the fuel for drying tobacco, if the mining operation progresses smoothly.

## 4-3 History of Electric Enterprise Development

The Electricity Supply Commission of Malawi (ESCOM), the national electric enterprise in the country, was established through reorganization of the then, existing body simultaneously with the national independence in 1964. The power generation capacity of ESCOM at the time of its establishment consisted of coal thermal (7,000 kW) at Blantyre, hydro (600 kW) at Zomba and diesel (Total: 6,595 kW) at Blantyre, Zomba, Lilongwe, Mzuzu, Fort Jonston (Mangochi) with a total of 14.2 MW.

Since its inception, ESCOM has been grappling with hydro-power development in River Shire flowing through the southern part of the country. Beginning with the start of operation of the first power station (24 MW) in Nkula Fall A in 1966, it commenced operation of the Tedzani Fall (40 MW) in 1973 and that of the Nkula Fall B (80 MW) in 1980, thereby expanding power generation facilities greatly. Meanwhile in 1968, it started electric power exports to Mocambique. In order to deal with the rapid increase of power demand in Lilongwe, the new capital, it completed the Nkula-Dedza-Lilongwe 66 kV transmission line in 1972 and the Nkula-Salima-Lilongwe 132 kV transmission line in 1977, thereby realizing the north-south interconnection of power supply systems. Subsequently, it has been improving its power distribution network and promoting rural electrification until now.

Due to the development of new hydro power sources and realization of the interconnected power system, old, inefficient small-scale diesel power generators installed at demand centers in various locations as well as the coal thermal power station at Blantyre were abolished one after another. As power sources linked to the entire power system to provide reserve power in emergency, a series of small-scale diesels at Karonga, Mzuzu, etc. and the gas turbine at Blantyre (15 MW) were newly introduced subsequently, but it is only the hydro power plant at Zomba (600 kW) that is still working now among all the power generation facilities existent at the time of the ESCOM's establishment.

## 4-4 Present Power Supply Systems

Power supply systems of ESCOM can be broadly divided into the southern power supply system centered around Blantyre in the south, the central power supply system in and around Lilongwe, the new capital, and the northern power supply system, which covers the area north of Chintheche. These power supply systems are connected each other with national power line network. Now, the system for Karonga and Chitipa, the northernmost parts of the country, remain the only independent power supply systems, but these are also planned to be incorporated in the northern power supply system sooner or later (See Fig. 4-1).

As for the scale of the system, the southern power supply system, which consumes 74.5% of the total energy consumption, is the biggest, and the central and northern systems aggregately consume no more than 25.5% of the total. Although no data is available regarding the peak demand for each area, if such peak demand for each system is estimated on the basis of the peak demand for the interconnected systems and energy sold for respective areas, the peak demand supposedly reached 71 MW in the case of the southern power supply system and a total of 24 MW for the central/northern systems at the end of 1988 (See Table 4-1).

### (1) Power Generation Facilities

The installed capacity, including stand-by thermal plants, of the entire power generation facilities of ESCOM as of December 1988 was 169.8 MW. A characteristic of ESCOM's electric power supply systems is that power sources are concentrated on the southern part of the country. The hydro-electric power plants located in the reaches of River Shire in the south accounted for 85.2% of the total power generation capacity in the nation and provided as much as 99.8% of the total power supply (See Table 4-2).

(2) Power Transmission, Distribution and Substation Facilities

The total length of transmission and distribution facilities in the ESCOM's power supply systems as of December 1988 was 6,182 km of overhead cables and wires and 209 km of underground cables, while the capacity of substations totaled 787 MVA (See Table 4-3).

ESCOM, which has been positively promoting the national transmission network connection program for more than 10 years until now, completed the incorporation of the system for Lilongwe, the capital, in the national network in 1972 and subsequently linked independent systems of Mzuzu, Mangochi Salima, Mtuthama and Kasungu to the trunk system one after another. Since the per-capita power consumption barely reached 57 kWh per year in 1986, it is the real state of affairs that more than 95% of the total population have not yet been benefited by electricity. Such being the case, promotion of rural electrification programs and improvement and/or reinforcement of power transmission and/or distribution networks for that purpose are major tasks to be achieved hereafter.

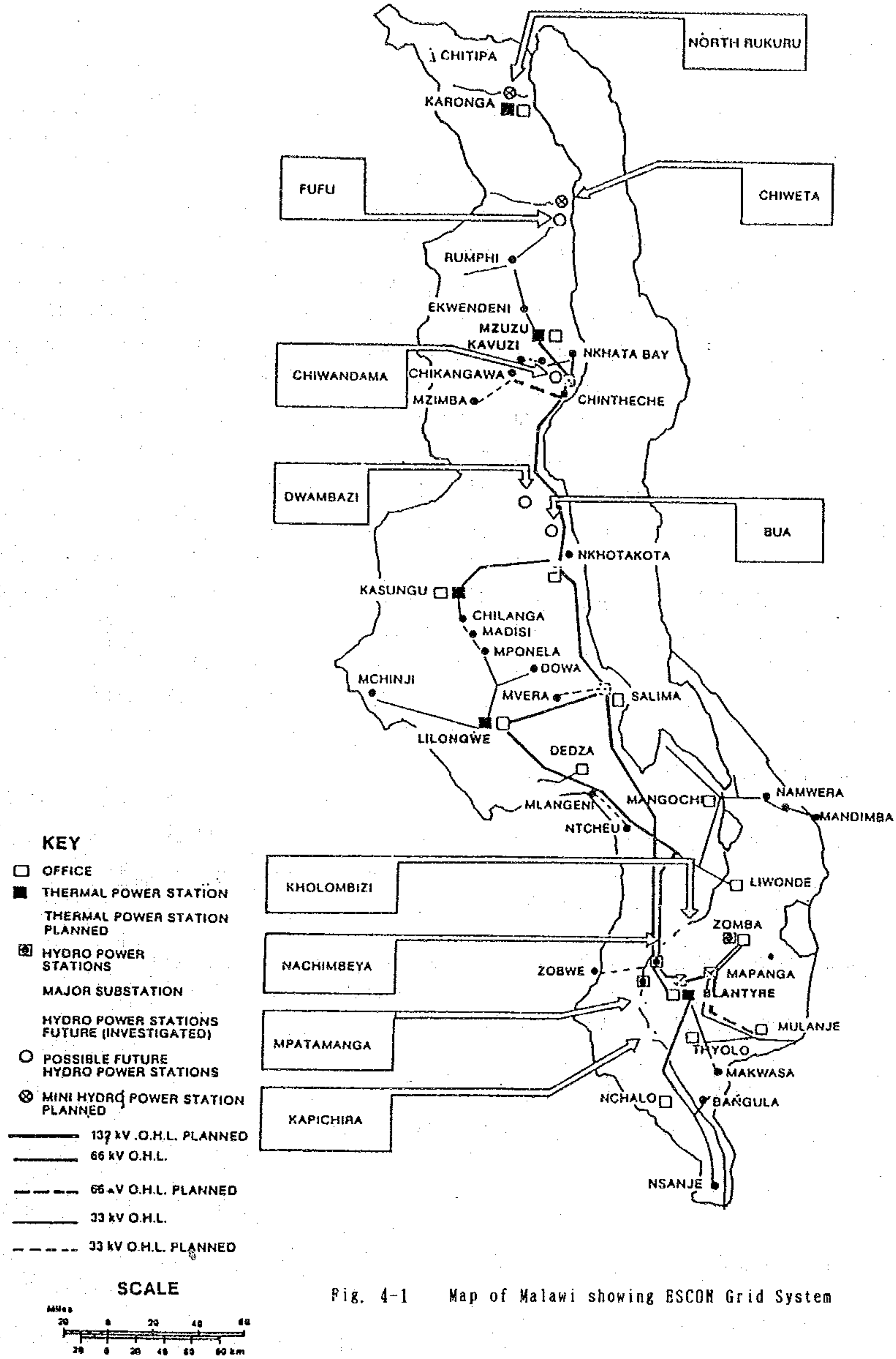



Fig. 4-1 Map of Malawi showing ESCOM Grid System

Table 4-1 Demand Trend in each Region

| Year | Energy Sold (MWh) | | | | Peak load (MW) | | | |
|---|---|---|---|---|---|---|---|---|
| | S.R. | C.R. | N.R. | Total | S.R. | C.R. | N.R. | Total |
| 1973 | 163,999(92.13) | 12,953 | 1,052 | 178,004(100) | 32.065 | 2.532 | 0.206 | 34.803 |
| 1974 | 174,115(90.55) | 16,943 | 1,219 | 192,277(100) | 35.815 | 3.485 | 0.251 | 39.551 |
| 1975 | 212,339(89.91) | 22,428 | 1,408 | 236,175(100) | 43.651 | 4.611 | 0.289 | 48.551 |
| 1976 | 223,430(88.31) | 28,024 | 1.547 | 253,001(100) | 44.721 | 5.609 | 0.310 | 50.640 |
| 1977 | 229,473(86.49) | 34,199 | 1,648 | 265,320(100) | 44.733 | 6.667 | 0.321 | 51.721 |
| 1978 | 245,462(85.19) | 40,412 | 2,250 | 288,124(100) | 46.547 | 7.663 | 0.427 | 54.637 |
| 1979 | 279,011(84.45) | 48,123 | 3,250 | 330,384(100) | 51.515 | 8.885 | 0.600 | 61.000 |
| 1980 | 291,034(82.20) | 59,202 | 3,805 | 334,041(100) | 55.023 | 11.193 | 0.719 | 66.935 |
| 1981 | 274,541(79.95) | 65,029 | 3,815 | 343,386(100) | 53.991 | 12.789 | 0.750 | 67.530 |
| 1982 | 275,609(77.02) | 77,506 | 4,712 | 357,827(100) | 54.859 | 15.427 | 0.938 | 71.224 |
| 1983 | 304,057(77.20) | 84,521 | 5,297 | 393,875(100) | 56.718 | 15.766 | 0.988 | 73.472 |
| 1984 | 303,835(74.85) | 95,577 | 6,518 | 405,930(100) | 63.409 | 19.947 | 1.360 | 84.716 |
| 1985 | 299,572(75.12) | 91,821 | 7,422 | 398,815(100) | 61.550 | 18.865 | 1.525 | 81.940 |
| 1986 | 318,209(74.45) | 100,538 | 8,659 | 427,406(100) | 70.728 | 22.346 | 1.925 | 94.990 |
| Annual Growth Rate (%) | | | | | | | | |
| 73-86 | 5.2% | 17.1% | 17.6% | 7.8% | 6.3% | 18.2% | 18.8% | 8.0% |
| 76-86 | 3.6% | 13.6% | 18.8% | 6.4% | 4.7% | 14.8% | 20.0% | 6.5% |

Source : ESCOM Annual Reports

Notes : (a) Figures in bracket show the percentage share of the total.
(b) Peak loads were calculated by the JICA mission under the condition described in item 4-3.
(c) S.R. …Southern Region
C.R. …Central Region
N.R. …Nothern Region including Karonga

Table 4-2 Plant Capacity as at 31st December, 1988

| Type | Location | Installed Capacity(kW) | Date Installed | No. and Unit Capacity(kW) | Annual Energy Generation(MWh) |
|---|---|---|---|---|---|
| Gas Turbine | Blantyre | 15,000( 8.9%) | 1975 | 1×15,000 | 25( 0.0%) |
| Diesel | | 10,200( 5.6%) | | | 1,389( 0.3%) |
| | Karonga | 990 | 1980 | 2× 120 | |
| | | | 1988 | 3× 250 | |
| | Mzuzu | 2,250 | 1974 | 1× 250 | |
| | | | 1975 | 1× 150 | |
| | | | 1980 | 1× 1,100 | |
| | | | 1983 | 1× 750 | |
| | Kasungu | 360 | 1972 | 2× 85 | |
| | | | 1974 | 1× 85 | |
| | | | 1979 | 1× 105 | |
| | Lilongwe | 5,400 | 1972 | 1× 3,000 | |
| | | | 1978 | 1× 1,100 | |
| | Chitipa | 300 | 1988 | 2× 150 | |
| | | | 1980 | 1× 1,300 | |
| | Mtunthama | 900 | 1980 | 1× 240 | |
| | | | 1981 | 1× 65 | |
| | | | 1981 | 1× 120 | |
| | | | 1981 | 1× 235 | |
| | | | 1984 | 1× 240 | |
| Hydro | | 144,600( 85.6%) | | | 511,137( 99.7%) |
| | Nkula Fall-A | 24,000 | 1966 | 2× 8,000 | |
| | | | 1967 | 1× 8,000 | |
| | Nkula Fall-B | 80,000 | 1980 | 2×20,000 | |
| | | | 1981 | 1×20,000 | |
| | | | 1986 | 1×20,000 | |
| | Tedzani Fall | 40,000 | 1973 | 2×10,000 | |
| | | | 1976 | 1×10,000 | |
| | | | 1977 | 1×10,000 | |
| | Zomba | 600 | 1953 | 1× 300 | |
| | | | 1954 | 1× 300 | |
| Total | | 169,800(100.0%) | | | 512,551(100.0%) |

Source : ESCOM Annual Report 1986 and data presented by ESCOM

Table 4-3 Details of Transmission, Distribution and Substation
As at 31st December, 1988

| Gacilitis | Southern Region | Central Region | Northern Region | Isolated station Karonga | Chitipa | Total |
|---|---|---|---|---|---|---|
| Overhead Lines (km) | 3,078.504 | 2,209.106 | 590.847 | 63.029 | 4.50 | 5,972.99 |
| 132KV Lines | 165.02 | 175.57 | | | | 340.59 |
| 66KV Lines | 347.01 | 525.73 | 193.30 | | | 1,093.04 |
| 33KV Lines | 950.368 | 362.907 | 131.173 | | | 1,444.448 |
| 11KV Lines | 833.79 | 670.47 | 114.25 | 32.96 | 4.50 | 1,655.974 |
| 400/230 Volts Lines | 782.316 | 474.429 | 152.124 | 30.069 | - | 1,428.938 |
| Underground Cable(km) | 106.281 | 88.631 | 11.793 | 1.58 | | 208.585 |
| 33KV Cable | 2.616 | 0.035 | 0.034 | | | 2,685 |
| 11KV Cable | 51.713 | 22.292 | 2.635 | 0.03 | | 76,970 |
| 400/230 Volts Cable | 51.952 | 66.304 | 9.124 | 1.55 | | 128.93 |
| Substations (kVA) | 595,285 | 159,442 | 29,090 | 2,421.00 | 600 | 786,838 |
| Interbus Transformers 132/66KV | 50,000 | | | | | 50,000 |
| Step-down 132/ 66/11kV | | 25,000 | | | | 25,000 |
| Step-down 66/ 33kV | 90,000 | 10,000 | 10,000 | | | 110,000 |
| Step-down 66/ 11kV | 64,000 | 43,000 | | | | 107,000 |
| Step-down 33/ 11kV | 68,000 | 3,500 | 5,550 | | | 77,050 |
| Step-down 33/0.4/0.23kV | 29,310 | 7,880 | 3,025 | | | 40,215 |
| Step-down 11/0.4/0.23kV | 117,975 | 66,962 | 7,515 | 1,421 | | 193,873 |
| Step-down 3.3/0.4kV | | | | | 200 | 200 |
| Step-up 0.4/3.3/11kV | | 3,100 | 3,000 | 1,000 | 400 | 7,500 |
| Step-up 11/ 66kV | 126,000 | | | | | 126,000 |
| Step-up 11/132kV | 50,000 | | | | | 50,000 |

Source : ESCOM Annual Report 1986 and data presented by ESCOM

# CHAPTER 5 DEMAND FORECAST

# CHAPTER 5 DEMAND FORECAST

## 5-1 Present State of Electric Power

Regarding energy resources of the Republic of Malawi, oil is not produced now, while coal production is of small scale as its development has just been started. As for water resources, there are many untapped development points with rich water resources. As power supply source, water resources have been consistently developed in line with the national policy since the independence of the country in 1964.

The predecessor of ESCOM, founded in 1956, was reorganized as the Electricity Supply Commission of Malawi (ESCOM) on the occasion of the independence.

At that time, the new organization succeeded main assets of the former body as they were. Such assets consisted of a coal thermal power station in Blantyre, the hydro-electric power station in Zomba and diesel power stations in Lilongwe, Mangochi and Mzuzu.

The capacity of the power generation facilities at that time was 14.2 MW and 44 MWH per year, while overhead transmission line were 24 km of 33 kV voltage and 44 km for 66 kV voltage.

After the establishment of ESCOM, construction of the Nkula Fall A Power Station having the nation's first big dam was undertaken, and started operation of two (2) unit of 8 MW generators (total output 16 MW) in 1966 two years afterwards of establishment and that of another one (1) unit of 8 MW generator in 1967.

In Liwonde, 80 km up stream of the river, construction of a dam for adjusting flow of the Shire River was simultaneously undertaken. It was completed in August 1965.

Owing to the completion of this Nkula Fall A, facilities with the capacity of 24 MW (about 170% of the existing capacity) were added to those with the total capacity of 14.2 MW, and electric power was newly provided to the areas of Zomba, Blantyre, Mulanje and Thyolo in the southern part of the country. In 1968, power was exported to the Milanje area of Mocambique, and this export is still continuing now.

Upon the birth of the new capital city -- Lilongwe, maximum power demand increased rapidly, and it was feared that electric power will be in shortage thereafter. Accordingly, Tedzani Fall was newly projected as the second hydro-electric power facility in 1969, and construction of a 66 kV single circuit steel pole transmission line between Nkula and Lilongwe was planned at the same time.

The operation of the transmission line was started in 1972. Subsequently, the dam for water flow adjustment and a 10 MW generator in Tedzani were completed in 1973 and another generator was completed in 1974.

Meanwhile, operation of a 15 MW gas turbine generator in Blantyre was commenced in 1975.

At around that time, establishment of a wood pulp plant was planned in Chintheche in the northern region of the country. Then a third 10 MW generator in Tedzani was put to operation in 1976 and a fourth 10 MW one commenced its operation early in the end of 1977. The 132 kV wooden pole single circuit transmission line between Nkula B and Lilongwe B was opened at the end of 1977, with its operation started at the voltage of 66 kV at first. A transmission line was extended to Chintheche in 1980.

In line with the growth of power demand, the project for expansion of the facilities in Nkula B was undertaken in 1976.

The Nkula B Power Station was designed so as to allow installation of five (5) unit of 20 MW generators. As a result of the first phase of the work, two (2) generators were put the operation in 1980, while the establishment of a third generator was planned in 1978, with its operation begun in 1981. A fourth generator started working in 1986.

Due to start of operation of these generators, old, inefficient diesel generators were stopped one after another.

The coal thermal power generation in Blantyre was abandoned in 1977. Currently, the diesel generators connected to the power supply systems are only those in Mzuzu, Karonga and Kasungu.

The small-scale hydraulic power station in Zomba is still linked with the systems. Two hydro-electric power plants in Nkula and Tedzani produce more than 99% of electric power generated in the country.

Diesel generators are used as reserve facilities to supply power to the three towns mentioned above. Partly owing to local electrification, power demand is expected to grow continually in a stabilized manner hereafter.

Most of the power demand in the central and northern region is met with the power sent from hydro-electric power stations in the south through a 132 kV transmission line (partly 66 kV system). Because of the increase in power demand, however, keeping of the voltage is becoming increasingly difficult. Therefore, the establishment of a 132 kV transmission line (1 circuit of 2 circuits design line) between the Nkula B Power Station and the Lilongwe B Substation is urgently required.

## 5-2 Changes of Demand and Supply

### (1) Annual Energy Generation and Peak Load

In the 15 years period between 1973 and 1988, annual energy generation by ESCOM's supply systems increased from 192.3 GWh to 580.6 GWh at a annual growth rate of 7.6%, while the peak load grew from 34.3 MW to 101.0 MW at an annual increase rate of 7.5%. If the reviewed period is divided into 5 years segments, however, energy generation, which was rapidly augmented at an annual rate of 9.9% in the first five year period (between 1973 and 1978), posted an annual growth rate of no more than 5.3% in the 1983-1988 period, indicating a substantial demand slowdown in recent years (See Table 5-1).

A similar slowing-down trend of demand can be also observed in the peak load, which can be termed as strongly reflecting overall economic stagnation resulting from the cutting-off of the Beira and Nacala routes.

(2) Load Factor and System Loss Ratio

The Load factor (Lf) was seen varying considerably over the years as it ranged from 61.5% to 69.6%. As a result of economic stagnation, however, it has remained at a somewhat high level of 65% in recent years, and this trend is believed to continue for some time into future.

The overall system loss ratio, which includes in-house power consumption at power stations and transmission/distribution loss, averaged 12.0% in 1973-1988. In terms of time series, some temporary improvement was achieved in 1978, the year after the completion of the north-south linkage transmission line of Nkula-Salima-Lilongwe (132 kV) in 1977, as the ratio declined to 7.4% on the strength of the linkage. Subsequently, however, the situation deteriorated continually, and the actual ratio in last year (1988) reached 18.0%.

(3) Demand Forecast by ESCOM

A future demand forecast is the basis for formulating a power development program and a system reinforcement program. ESCOM also made a detailed forecast in its "Study to Update ESCOM's Least Cost Development Programme" (Apr. 1988: Prepared by Kennedy & Donkin Power Systems Ltd., England).

According to this report, if the economic development progresses as in the standard case, energy generation is expected to grow at a yearly rate of 8.6%, and the peak load at a rate of 8.7% in the 19 years between 1986 and 2005. These figures are somewhat higher than those in the past 15 years between 1973 and 1988, as the actual annual growth rate in the 15 years period was 7.6% for energy generation and 7.5% for peak load.

ESCOM has made several power demand forecast so far, including a predicted power sales annual increase of 8.3% during the 15 years period from 1985 to 2000 and the predicted power consumers is predicted to be 6.3%.

In addition to the power demand forecast by the power system, it is also predicted that the annual rate of increase during 12 years, period from 1985 to 1997 for the central power system, the northern power system, and total of central and north power system will be 5.6%, 11.5%, and 6.8%, respectively.

(4) Future Power Development Plan

According to "Proposed Energy I Project Cofinancing Brief," the future development plan is as follows:

| | | | | |
|---|---|---|---|---|
| 1992 | Transmission line | : | Nkula B-Lilongwe B 132 kV 250 km single circuit (This Power Transmission Project) | |
| 1992 | Nkula B No. 7 Unit to be added | : | 1 x 20 MW | |
| 1994 | Tedzani III to be added | : | 2 x 25 MW | Total 50 MW |
| 1997 | Kapichira to be established | : | 2 x 25 MW | Total 50 MW |
| 1999 | Kapichira to be expanded | : | 3 x 25 MW | Total 75 MW |

As rural electrification plans, there are also plans for electrifying Liwonde and Kasungu areas and small-scale rural electrification programs using hydro-electric power station.

As for financing for the projects, the establishment of the No. 7 unit with the capacity of 20 MW in Nkula B Power Station will be carried out through the financing by West Germany and World Bank is scheduled to enforce, in the spring of 1989, a feasibility study concerning the Tedzani III Power Station for additional installation of two 25 MW generators.

## 5-3 Results of Demand Forecast

### (1) Reliability of Forecast

As can be learned from the outcome of the multiple regression analysis, the power demand of Malawi greatly depends on an increase in the number of users, so far as the present state is concerned, and its correlation with GDP is insubstantial.

Such being the case, it is impossible to forecast the state of a remote future in which the spread of electricity may have caused a change in the demand structure. We are confident, however, that our forecast will be valid for about ten (10) years to come.

Therefore, it is necessary to revise demand forecast every five (5) years or ten (10) years. For this reason, ESCOM is recommended to carry out revision of the assumed demand values at such intervals.

### (2) Results of Demand Forecast

Outcome of the demand forecast for the power systems is somewhat lower than the value forecasted by ESCOM. However, there is not much difference between them. The future demand is expected to be somewhere between the values shown in the following table. (See table 5-2)

### (3) Demand Forecast for Central and Northern Power Systems

Although results of demand forecast for the Central and Northern Power Systems cannot be compared with ESCOM's forecast since forecasting conditions were different, the actual figures are expected to change almost as estimated by JICA. (See Table 5-3)

Table 5-1 Peak Load and Annual Energy Generation

(Interconnected System)

| Year | Energy Generated (MWh) | Peark Load (kW) | Load Factor (%) | Energy Sold (MWh) | System Losses (MWh) |
|---|---|---|---|---|---|
| 1973 | 192,296(195,296) | 34,300 | 64.0 | 175,431(178,004) | 8.8( 8.9) |
| 1974 | 211,949(213,336) | 39,300 | 61.6 | 191,057(192,277) | 9.9( 9.9) |
| 1975 | 262,684(264,681) | 48,200 | 62.2 | 234,469(236,175) | 10.7(10.8) |
| 1976 | 280,143(282,729) | 50,200 | 63.7 | 250,802(253,001) | 10.5(10.5) |
| 1977 | 293,936(296,942) | 51,400 | 65.3 | 263,672(265,320) | 10.3(10.6) |
| 1978 | 308,702(311,413) | 54,210 | 65.0 | 285,873(288,124) | 7.4( 7.5) |
| 1979 | 354,622(358,299) | 60,400 | 67.0 | 327,135(330,384) | 7.8( 7.8) |
| 1980 | 385,658(389,879) | 66,200 | 66.5 | 350,153(354,041) | 9.2( 9.2) |
| 1981 | 383,415(388,964) | 66,600 | 65.7 | 338,654(343,386) | 11.7(11.7) |
| 1982 | 406,187(409,388) | 70,600 | 65.7 | 354,692(357,827) | 12.7(12.6) |
| 1983 | 447,821(448,270) | 73,400 | 69.6 | 393,489(393,875) | 12.1(12.1) |
| 1984 | 469,577(470,192) | 84,600 | 63.4 | 405,378(405,930) | 13.7(13.7) |
| 1985 | 475,585(476,402) | 81,800 | 66.4 | 398,132(398,815) | 16.3(16.3) |
| 1986 | 511,546(512,551) | 94,800 | 61.6 | 426,513(427,406) | 16.6(16.6) |
| 1987 | 560,858( ) | 97,200 | 65.9 | 466,744( ) | 16.8( ) |
| 1988 | 580,572( ) | 101,000 | 65.6 | 476,268( ) | 18.0( ) |
| Annual Growth Rate (%) | | | | | |
| 73-78 | 9.9 ( 9.8) | 9.6 | | 10.3 ( 10.1) | |
| 78-83 | 7.7 ( 7.6) | 6.2 | | 6.6 ( 6.5) | |
| 83-88 | 5.3 ( 4.6) | 6.6 | | 3.9 ( 4.5) | |
| 73-88 | 7.6 ( 7.7) | 7.5 | | 6.9 ( 2.8) | |
| Average | | | | | |
| 73-78 | | | 63.6 | | 9.6( 9.7) |
| 78-83 | | | 66.6 | | 10.2(10.2) |
| 83-88 | | | 65.4 | | 15.6(14.7) |
| 73-88 | | | 65.0 | | 12.0(11.3) |

Source : ESCOM Annual Report

Notes : (a) Date for 1987 and 1988 are promptly reported value.
(b) Figures in bracket show the value for all Malawi including isolated system.

Table 5-2 Comparison with ESCOM's Demand Forecast for Whole Coutnry

-Base Case-

| Year n | Energy Generated (GWh) | | Peak Load (MW) | | Load Factor (%) | |
|---|---|---|---|---|---|---|
| | ESCOM | JICA | ESCOM | JICA | ESCOM | JICA |
| 1988 | 592.6 | 611.5 | 105.9 | 107.4 | 63.9 | 65.0 |
| 1989 | 636.6 | 655.3 | 114.1 | 115.1 | 63.7 | 65.0 |
| 1990 | 678.4 | 702.3 | 122.3 | 123.3 | 63.3 | 65.0 |
| 1991 | 736.1 | 752.7 | 133.4 | 132.2 | 63.0 | 65.0 |
| 1992 | 771.4 | 806.7 | 139.6 | 141.7 | 63.1 | 65.0 |
| 1993 | 808.5 | 864.6 | 146.3 | 151.8 | 63.1 | 65.0 |
| 1994 | 873.4 | 926.9 | 158.2 | 162.8 | 63.0 | 65.0 |
| 1995 | 949.3 | 993.7 | 172.3 | 174.5 | 62.9 | 65.0 |
| 1996 | 1045.5 | 1065.4 | 190.6 | 187.1 | 62.6 | 65.0 |
| 1997 | 1144.5 | 1142.4 | 209.6 | 200.6 | 62.3 | 65.0 |
| 1998 | 1254.0 | 1225.0 | 230.4 | 215.1 | 62.1 | 65.0 |
| 1999 | 1375.8 | 1313.7 | 253.6 | 230.7 | 61.9 | 65.0 |
| 2000 | 1511.7 | 1409.0 | 279.5 | 247.5 | 61.7 | 65.0 |
| 2001 | 1663.8 | 1511.3 | 308.4 | 265.4 | 61.6 | 65.0 |
| 2002 | 1832.9 | 1621.3 | 340.5 | 284.7 | 61.4 | 65.0 |
| 2003 | 2020.0 | 1739.4 | 376.4 | 305.5 | 61.3 | 65.0 |
| 2004 | 2228.2 | 1866.2 | 416.3 | 327.7 | 61.1 | 65.0 |
| 2005 | 2456.0 | 2002.4 | 460.9 | 351.7 | 60.9 | 65.0 |
| Growth Rate (%) | 8.73 | 7.23 | 9.03 | 7.23 | | |

Table 5-3 Comparison with ESCOM's Demand Forecast at Lilongwe with North area

| Year | Energy Generated (GWh) | | Peak Load (MW) | | Load Factor (%) | |
|---|---|---|---|---|---|---|
| | ESCOM | JICA | ESCOM | JICA | ESCOM | JICA |
| 1987 | 119.7 | 162.5 | 28.8 | 28.5 | 42.7 | 65.0 |
| 1988 | 133.2 | 183.3 | 29.0 | 32.2 | 47.2 | 65.0 |
| 1989 | 153.8 | 206.2 | 31.3 | 36.2 | 50.5 | 65.0 |
| 1990 | 171.2 | 231.5 | 33.3 | 40.7 | 53.4 | 65.0 |
| 1991 | 194.3 | 259.3 | 37.0 | 45.5 | 57.6 | 65.0 |
| 1992 | 209.5 | 289.9 | 42.0 | 50.9 | 59.1 | 65.0 |
| 1993 | 227.7 | 323.6 | 46.0 | 56.8 | 60.9 | 65.0 |
| 1994 | 255.1 | 360.7 | 50.0 | 63.3 | 64.7 | 65.0 |
| 1995 | 287.6 | 401.6 | 57.0 | 70.5 | 69.4 | 65.0 |
| 1996 | 324.6 | 446.4 | 64.0 | 78.4 | 74.9 | 65.0 |
| 1997 | 363.2 | 495.7 | 72.0 | 87.1 | 79.1 | 65.0 |
| 1998 | 406.7 | 549.7 | 80.0 | 96.6 | | 65.0 |
| 1999 | 455.6 | 609.3 | 90.0 | 107.0 | | 65.0 |
| 2000 | 510.7 | 674.5 | 106.0 | 118.5 | | 65.0 |
| 2001 | | 746.0 | | 131.0 | | 65.0 |
| 2002 | | 824.4 | | 144.8 | | 65.0 |
| 2003 | | 910.4 | | 159.9 | | 65.0 |
| 2004 | | 1004.6 | | 176.4 | | 65.0 |
| 2005 | | 1107.7 | | 194.5 | | 65.0 |
| Growth Rate (%) | 11.8% | 11.3% | 10.5% | 11.3% | | |

Notes : (1) Energy forecasted by ESCOM on Consumption Base and forecasted by JICA on Generation Base.

(2) Peak Load Forecast by ESCOM is Base Case and Forecast by JICA is Base Case.

# CHAPTER 6 POWER SYSTEM ANALYSIS

# CHAPTER 6 POWER SYSTEM ANALYSIS

Based on the transmission line plan, examinations were made of the power flow, stability, short-circuit capacity as well as the countermeasures for the improvement of voltage stability which are detailed below. It can be concluded that linking the power source area in the south and the central power system with the transmission line for which this study is conducted will permit the intended transmission of the power (30 MW) by a single circuit transmission line (stringing for 1 circuit and designed for 2 circuits) and that there are no specific problems with either the stability or the short-circuit capacity.

Regarding the retaining of voltage, the result of a system analysis indicates the possibility of voltage drop at Chichiri Power Station.

## 6-1 Preconditions for Power System Analysis

Presented below is the fundamental data used for the power system analysis:

- Year analysed: 1992, 1994, 1997, 1999, 2005

- Commissioning year of generators and transmission lines in the system:

  1992: 132 kV single circuit transmission line will be completed between Nkula B - Sharpevale - Lilongwe B.

  No. 7 generator (20 MW) of Nkula B Power Station will be completed.

  1994: Generators, 2 x 25MW, will be completed at Tedzani III Power Station.
  Voltage up to 132 kV between Salima - Chintheche will be completed.

1997: Kapichira, 2 x 25MW, will be completed.
New 66 kV transmission line between Blantyre West and Mapanga will be completed.

1999: Additional three units of 25 MW generator will be completed at Kapichira.
New 66 kV transmission line between Blantyre West and Chichiri will be completed.

Additional stringing of 1 circuit to 132 kV transmission line will be completed between Nkula B - Sharpevale - Lilongwe B.

- Configuration of power system analysed

During the power system analysis, the power stations, transmission lines and substation facilities on the 132 kV, 66 kV and 33 kV lines were simulated as shown in Figs. 6-1, 6-2 and 6-3.

- Power demand at substation level

Peak load: Refer to Figs. 6-4 through 6-8.

- Load power factor: 0.9

- Equipment constant: Refer to Table 6-1 and Table 6-2.

- Line constant: Refer to Table 6-3.

- Standard voltage

The voltage at each power station was calculated by assuming the output voltage of the generator at Tedzani Power Station is 105% constant.

## 6-2 Power Flow Calculation

The peak power flow was calculated based on demand forecast for the years, 1992, 1994, 1997, 1999 and 2005. The obtained results are shown in Figs. 6-4 to 6-8.

(1) The Bottleneck in the Power Flow

(a) Transmission Line

i) There will be no overloaded transmission line as of 1992.

ii) From 1994, however, the 66 kV transmission line from the Nkula A Power Station to Dedza will be overloaded so that the linkage between Dedza and Lilongwe A will have to be separated.

iii) As of 1999, the expansion of Kapichira Power Station will be completed. The transmission lines for transferring the generated power of Kapichira Power Station, 132 kV line of between Kapichira - Blantyre West and 66 kV line of between Blantyre West - Chichiri will be overloaded.

(b) Transformer

An examination was made of the transformers for each substation to see whether they will be overloaded under the normal power flow conditions. It was found that none of transformers in any of the substations will experience any overload during the period from 1992 to 1999.

(2) Voltage Regulation

The purpose of voltage regulation is the regulation of the balance of reactive power. Voltage regulation is performed with generator, phase modifying equipment, and the tap of the transformer.

Since the Lilongwe B Substaion which will receive power through the project transmission line has no source of reactive power to maintain voltage and that the 66 kV transmission line to which the substation will be connected suffers a large voltage drop, the 66 kV bus bar voltage was found low.

However, in 1992 when the project transmission line will be commissioned and the transmission will carry a small amount of power, so that the voltage drop at the Lilongwe B will show carefree value, influenced by the capacitance of the transmission line. But the voltage drop will be occured following with load increase at Chichiri Power Station, so there will be a growing necessity to install power condensers with an adequate capacity and to reconsider the new transmission line to Chichiri Power Station.

In the northern power system, the voltage condition will be improved largely due to voltage up from the existing 66 kV line to 132 kV. It will be occuring some cases necessary to regulate the bus voltage by transformer tap at light load in the night on Nkhotakota and Chintheche substations.

To maintain the 66 kV bus bar voltage of the following substations at 95% level for each year, the installation of power modifying equipment shown below should be examined.

Power Modifying Equipment

(MVar)

| Substation \ Year | 1992 | 1994 | 1997 | 1999 |
|---|---|---|---|---|
| Lilongwe B (66 kV Bus) | * 11.5 | * 2.3 | 2.9 | 0.1 |
| Chichiri (66 kV Bus) | 10.6 | 18 | 24 | 14.2 |
| Nkhotakota (66 kV Bus) | * 5.5 | * 9 | * 11 | 9 |
| Mtunthawa (66 kV Bus) | 2.5 | 3.3 | 4.1 | 5 |
| Dwangwa (33 kV Bus) | 0.8 | 1.0 | 1.2 | 1.7 |
| Chintheche (66 kV Bus) | * 1.1 | * 9.6 | * 9.5 | * 10.5 |
| Chibaka (33 kV Bus) | 0.8 | 1.1 | 1.5 | 1.8 |
| Chikangawa (66 kV Bus) | 1.7 | 2.3 | 2.9 | 3.7 |
| Mzuzu (66 kV Bus) | 1.7 | 2.3 | 2.9 | 3.6 |
| Nkota Bay (33 kV Bus) | 2.8 | 3.6 | 4.4 | 5.4 |

Note: * means Shunt Reactor capacity

## 6-3 Stability Calculation

(1) The stability calculation was made for 1999 when the power flow through the project transmission line will culminate. The calculation was made on the assumption that faults will occur in sections of 132 kV transmission lines between Tedzani 3 and Nkula B

as well as between Sharpevale and Lilongwe B; the assumed faults are 3-phase short circuit faults in each transmission line.

The result of the stability calculation is shown in the swing curves in Figs. 6-9 and 6-10. The results show stability in either case of fault at both sections and that the generators at each power station will be able to perform stable operations.

## 6-4 Short Circuit Level

The calculation of short circuit level at 1999 basis in power system and results are shown in Fig. 6-11.

An examination of obtained results shows that the short circuit level on the 132 kV side bus of the 132 kV substation is 757 MVA (approximately 3.67 kA), while on the 66 kV side bus and the 66 kV substation bus it is below 665 MVA (6.4 kA).

It can be concluded from the above that there is an ample allowance if the breaking current of the circuit breaker adopted in the project were:

132 kV circuit breaker : 20 kA (IEC standard 145 kV), and
66 kV circuit breaker : 12.5 kA (IEC standard 72.5 kV).

## 6-5 Expansion Time of This Project

Since the project transmission line is the trunk line of Malawi, it is imperative that it should maintain high reliability for power transmission. It will be necessary to string the second circuit at the soonest possible date, considering overloading of the existing 66 kV transmission line between Nkula A and Lilongwe A and aging of first 132 kV transmission line between Nkula B and Lilongwe B.

Shown in Figs. 6-12 and 6-7 are the power flow through the first and second circuits of the project transmission line assuming that the Kapichira Power Station (3 units x 25 MW) listed in the power source development plan will be completed by 1999.

Under the condition of the first circuit shown in Fig. 6-12, 33.0 MW power flows through Lilongwe B and, the voltage drop between Nkula B and Lilongwe B is 8.0%. Under normal practice, the transmission line is operated by regulating the voltage drop at the receiving end within 10%. It can be said, therefore, that the transmission line is nearing its limit.

Based on the result of these calculations, it is wise to string the second circuit by 1999 at the latest.

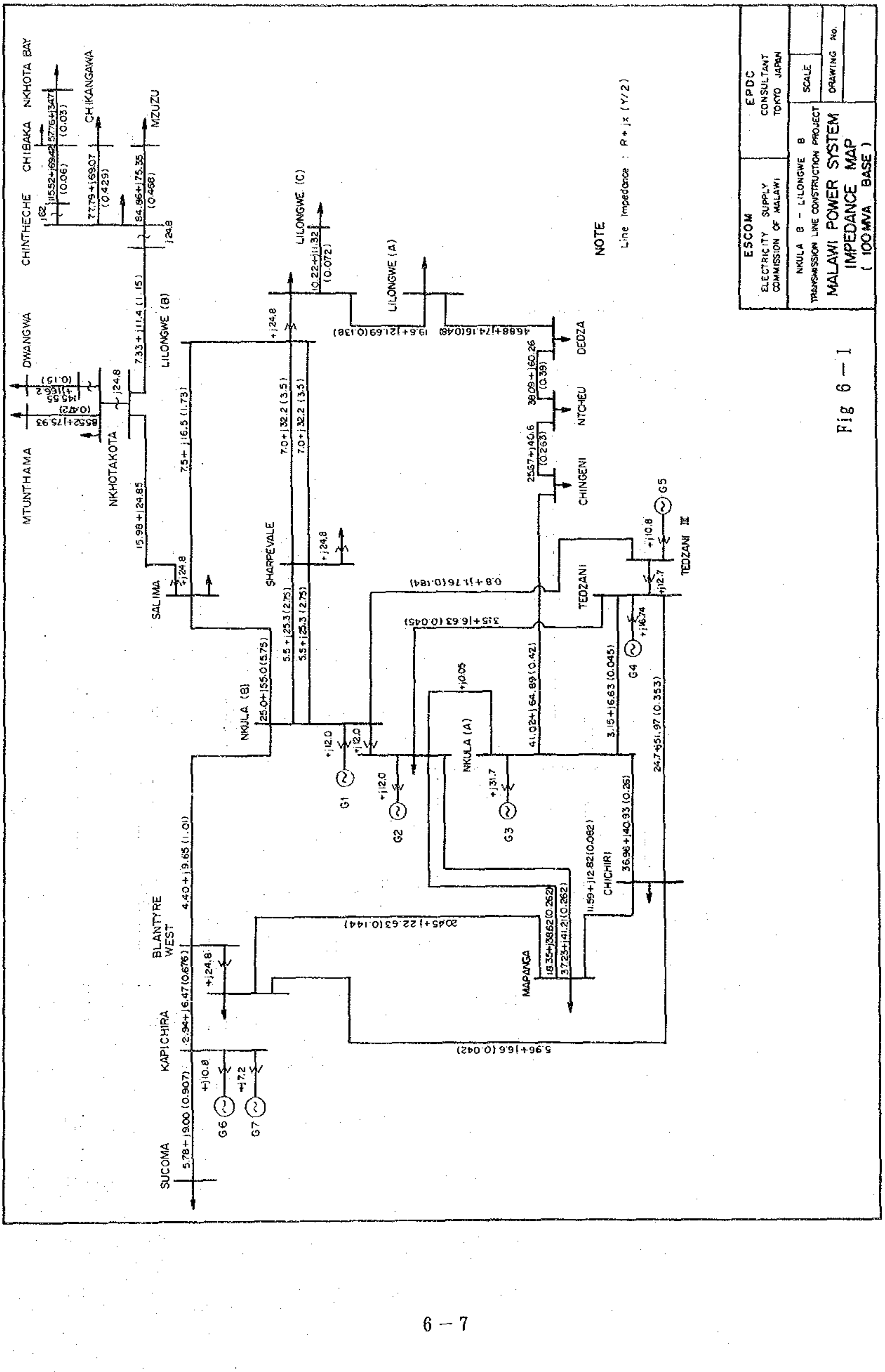

ESCOM
ELECTRICITY SUPPLY COMMISSION OF MALAWI
EPDC
CONSULTANT TOKYO JAPAN
NKULA B – LILONGWE B TRANSMISSION LINE CONSTRUCTION PROJECT
MALAWI POWER SYSTEM IMPEDANCE MAP (100 MVA BASE)
SCALE
DRAWING No.
NOTE
Line Impedance : R + jx (Y/2)
CHINTHECHE
CHIBAKA
NKHOTA BAY
CHIKANGAWA
MZUZU
MTUNTHAMA
DWANGWA
NKHOTAKOTA
LILONGWE (B)
LILONGWE (C)
LILONGWE (A)
DEDZA
NTCHEU
CHINGENI
SALIMA
SHARPEVALE
TEDZANI
TEDZANI III
NKULA (B)
NKULA (A)
CHICHIRI
MAPANGA
BLANTYRE WEST
KAPICHIRA
SUCOMA
G1
G2
G3
G4
G5
G6
G7

Fig 6 — 1

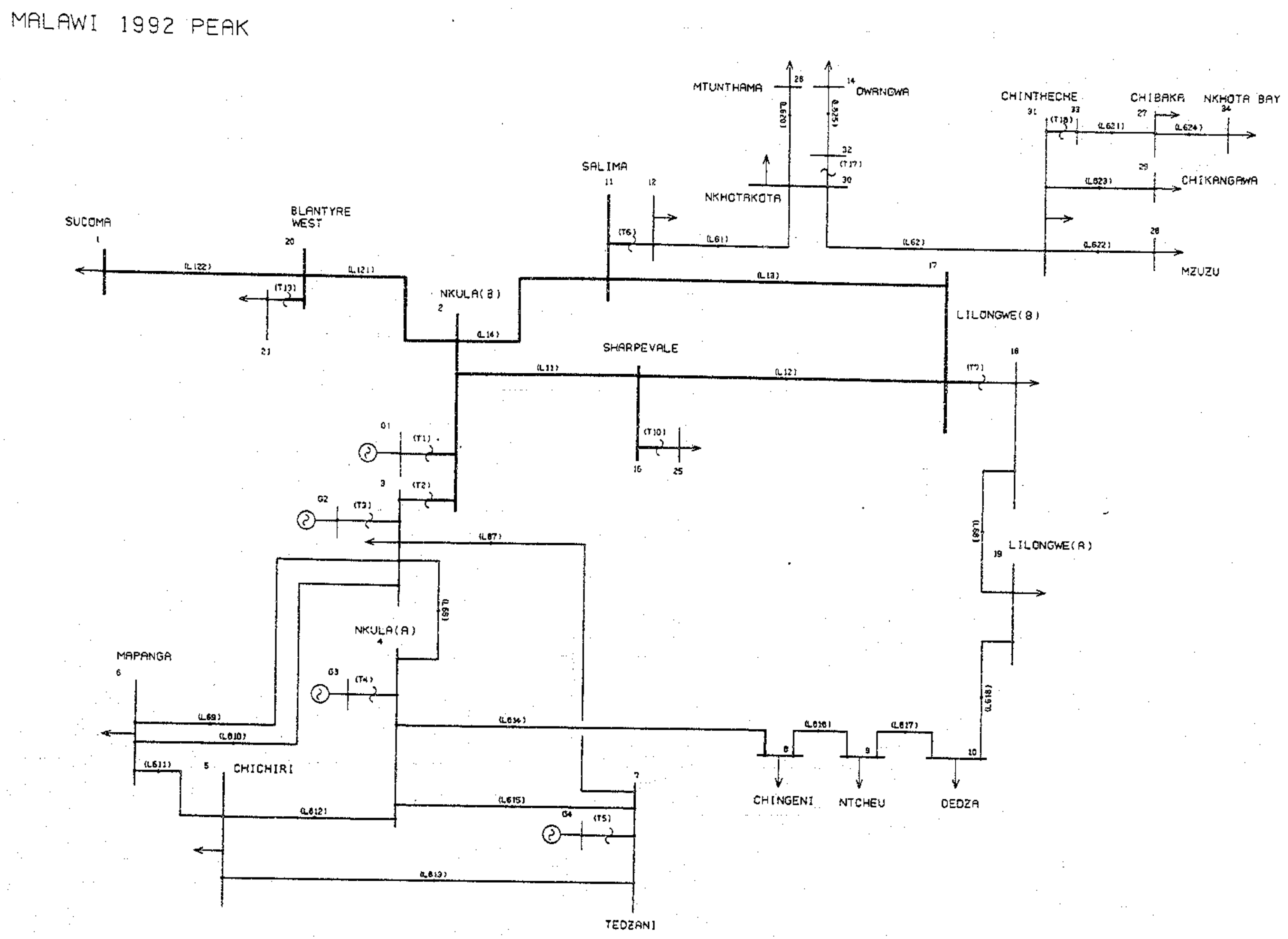



Fig 6 — 2 Node Blanch in 1992 Peak

MALAWI 1999 PEAK CASE-1

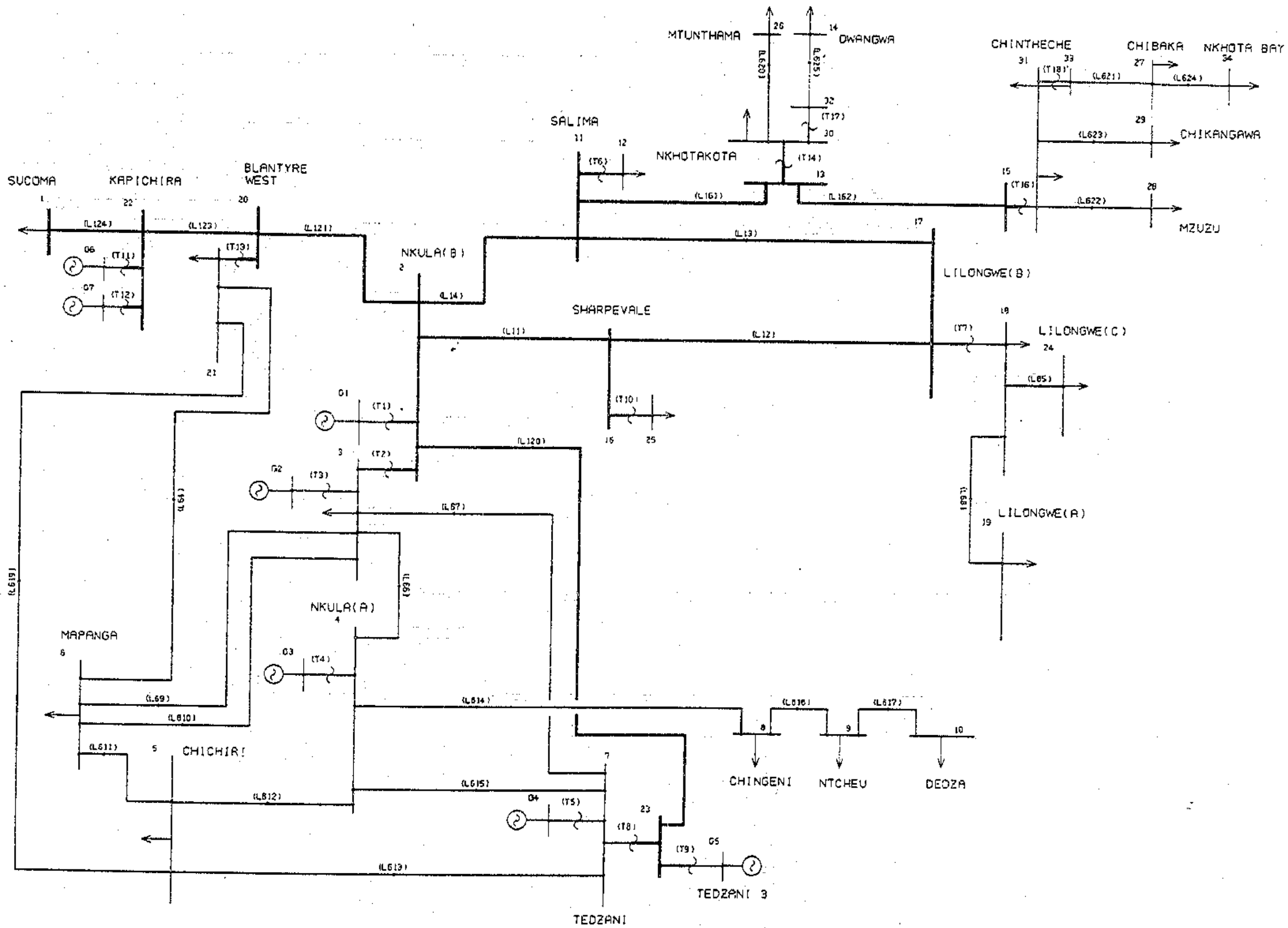



Fig 6 − 3　Node Blanch in 1999 Peak Case−1

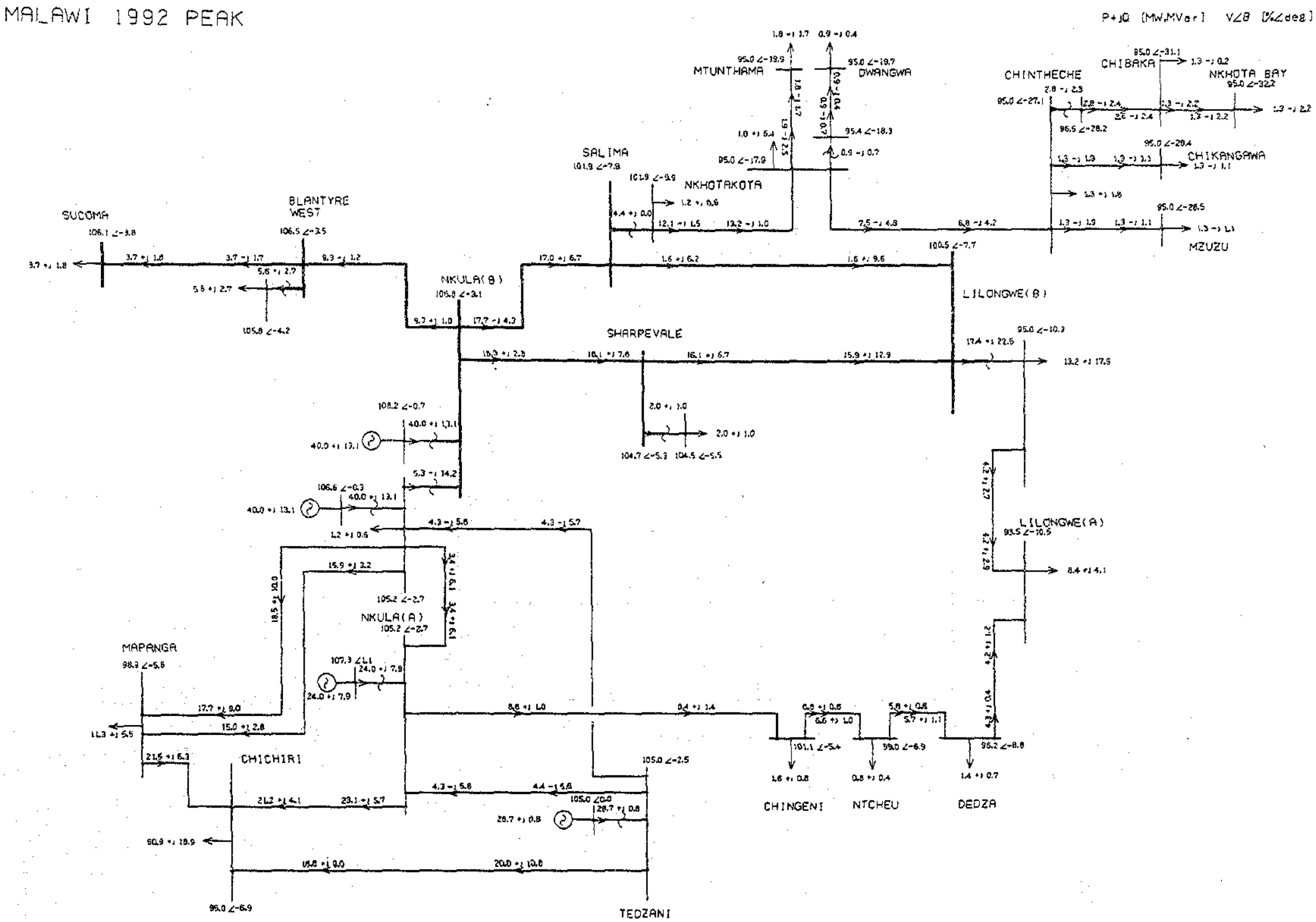



Fig 6 — 4 Power Flow in 1992 Peak

# MALAWI 1994 PEAK CASE-2

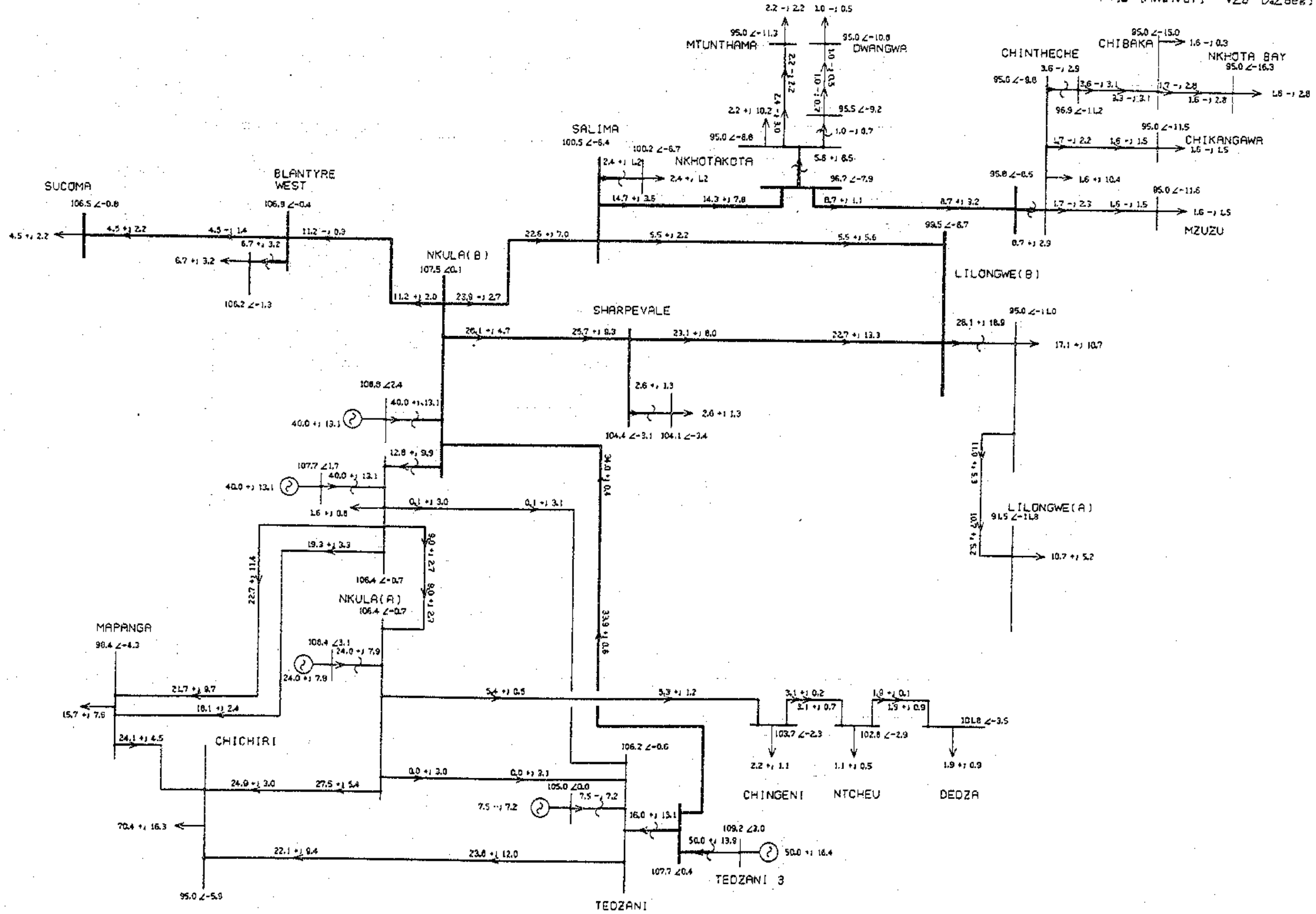



Fig 6 — 5 Power Flow in 1994 Peak Case—2

MALAWI 1997 PEAK

P+jQ (MW,MVar) V∠θ (%∠deg)

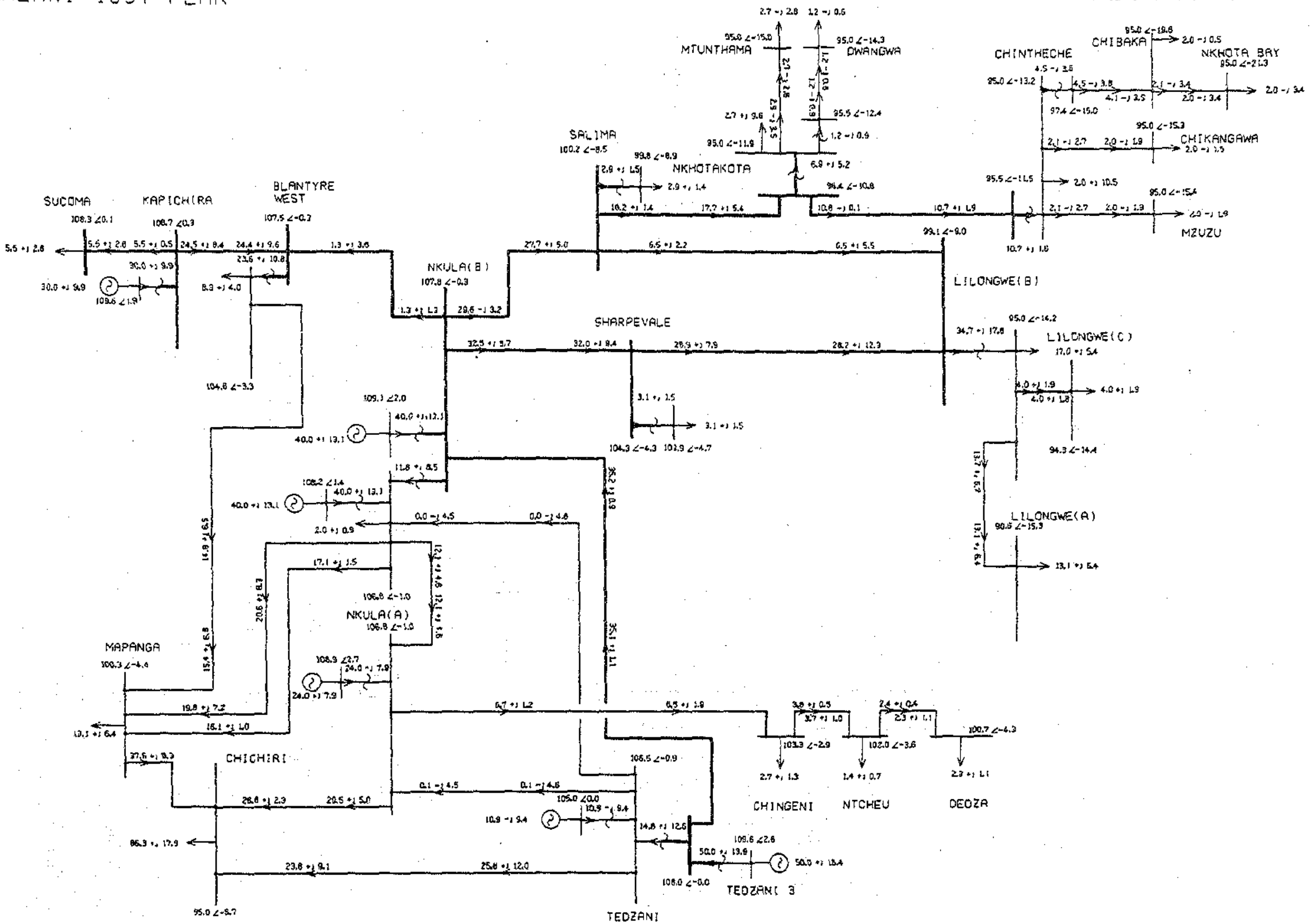



Fig 6 — 6 Power Flow in 1997 Peak

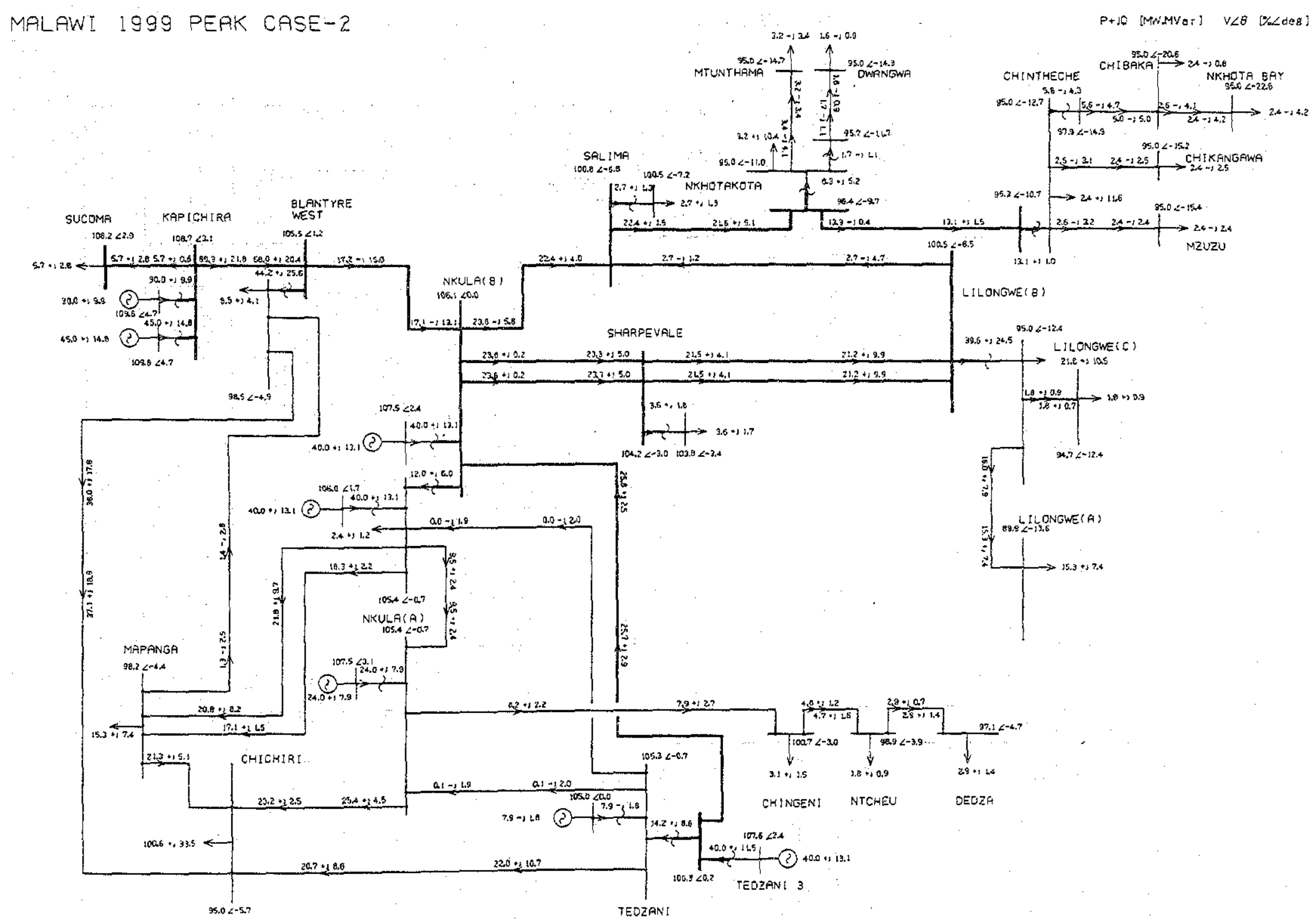



Fig 6 — 7 Power Flow in 1999 Peak Case—2

# MALAWI 2005 PEAK CASE-2

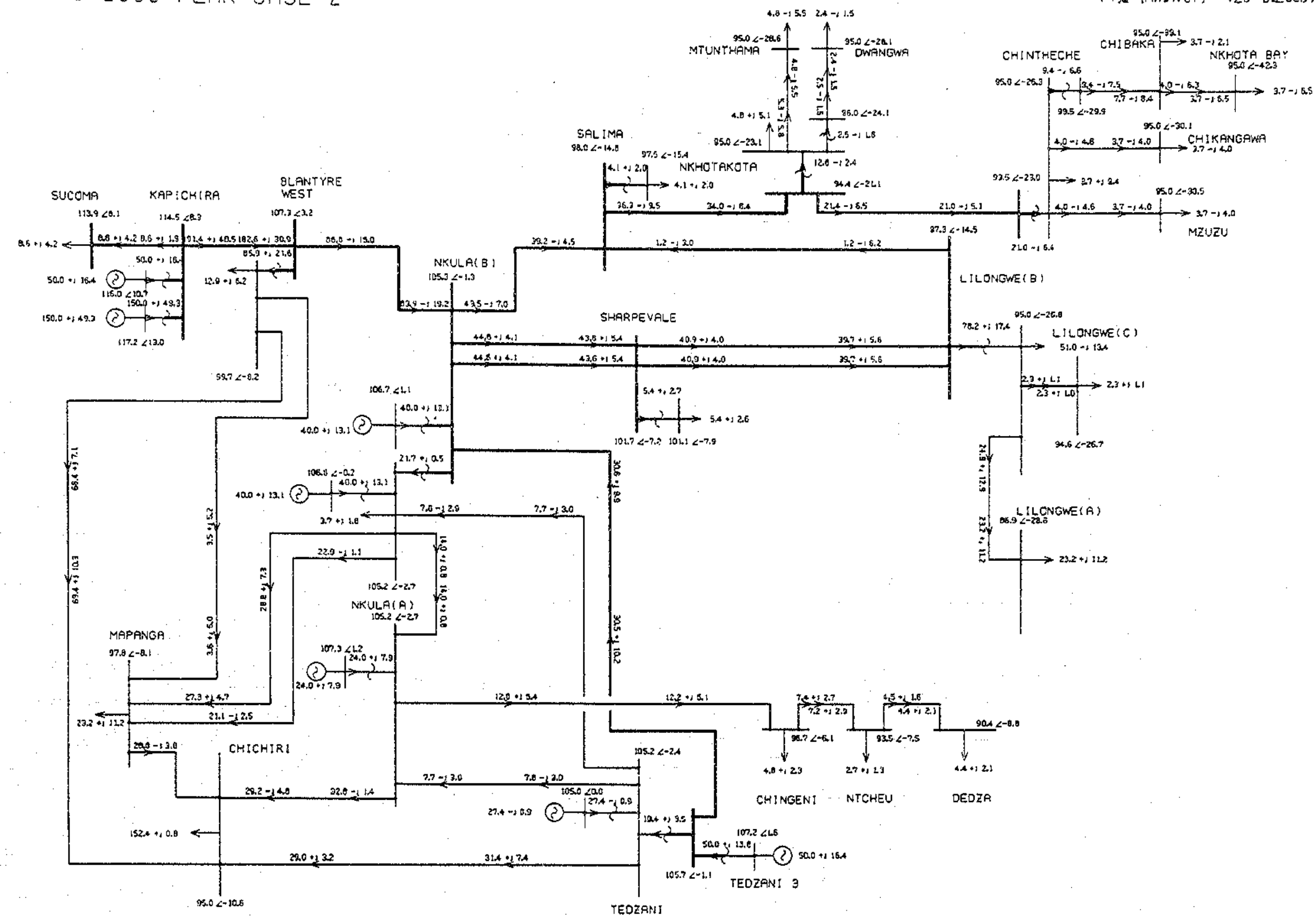



Fig 6 − 8 Power Flow in 2005 Peak Case−2

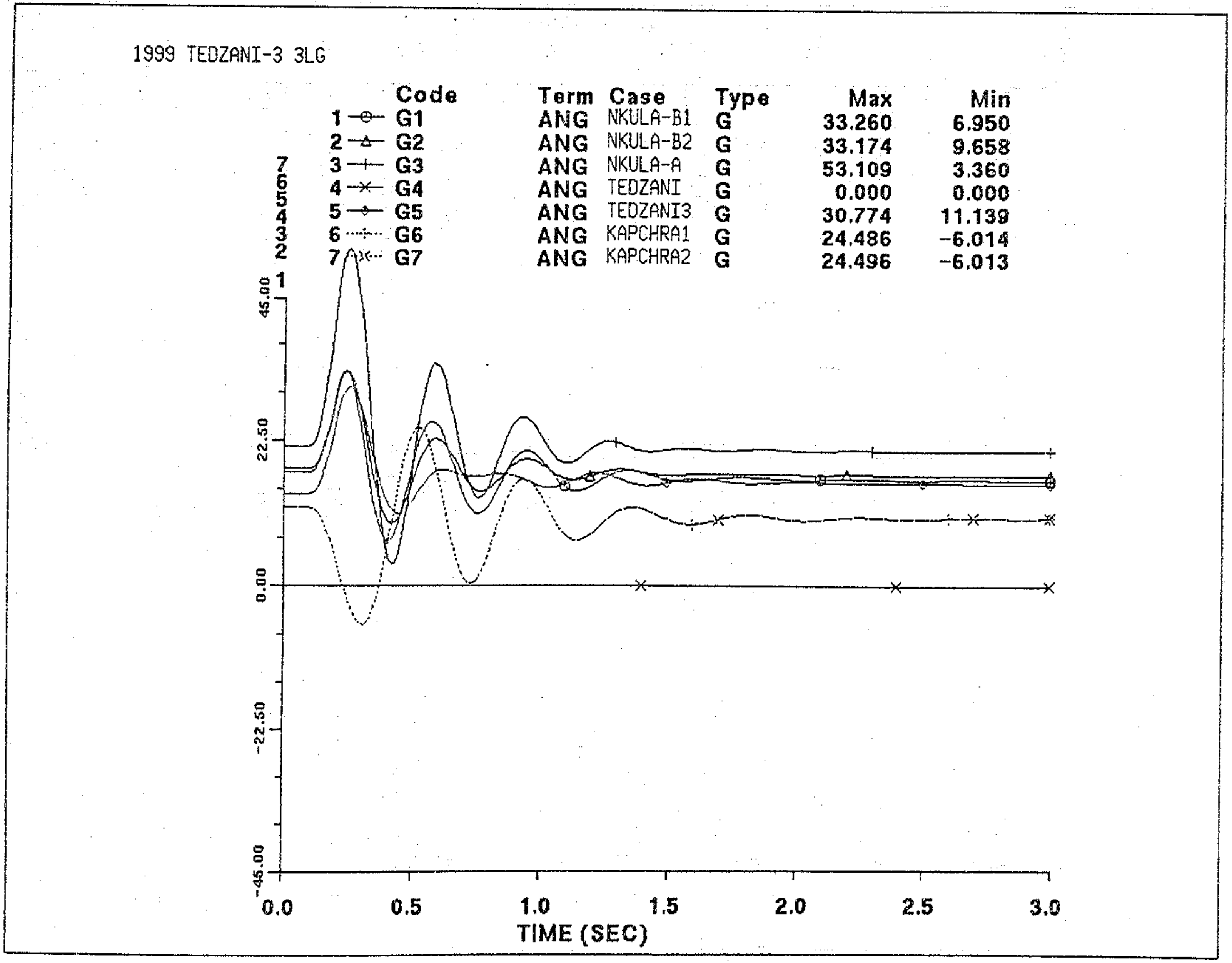

1999 TEDZANI-3 3LG
Code Term Case Type Max Min
1 G1 ANG NKULA-B1 G 33.260 6.950
2 G2 ANG NKULA-B2 G 33.174 9.658
3 G3 ANG NKULA-A G 53.109 3.360
4 G4 ANG TEDZANI G 0.000 0.000
5 G5 ANG TEDZANI3 G 30.774 11.139
6 G6 ANG KAPCHRA1 G 24.486 -6.014
7 G7 ANG KAPCHRA2 G 24.496 -6.013
45.00
22.50
0.00
-22.50
-45.00
0.0
0.5
1.0
1.5
2.0
2.5
3.0
TIME (SEC)

Fig 6 — 9

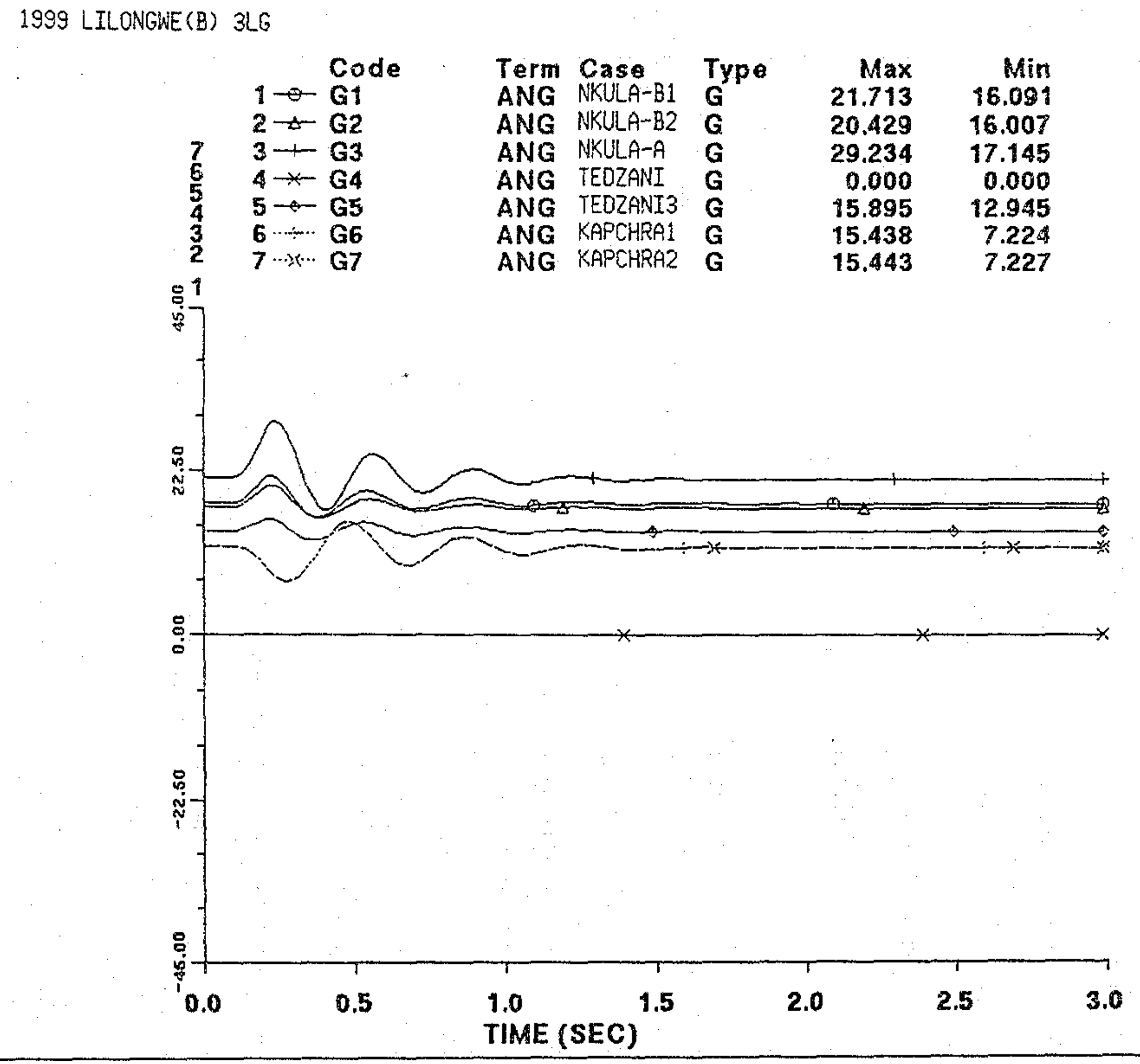

1999 LILONGWE(B) 3LG
Code Term Case Type Max Min
1 G1 ANG NKULA-B1 G 21.713 16.091
2 G2 ANG NKULA-B2 G 20.429 16.007
3 G3 ANG NKULA-A G 29.234 17.145
4 G4 ANG TEDZANI G 0.000 0.000
5 G5 ANG TEDZANI3 G 15.895 12.945
6 G6 ANG KAPCHRA1 G 15.438 7.224
7 G7 ANG KAPCHRA2 G 15.443 7.227
45.00
22.50
0.00
-22.50
-45.00
0.0
0.5
1.0
1.5
2.0
2.5
3.0
TIME (SEC)

Fig 6 —10

MALAWI 1999 PEAK CASE-2

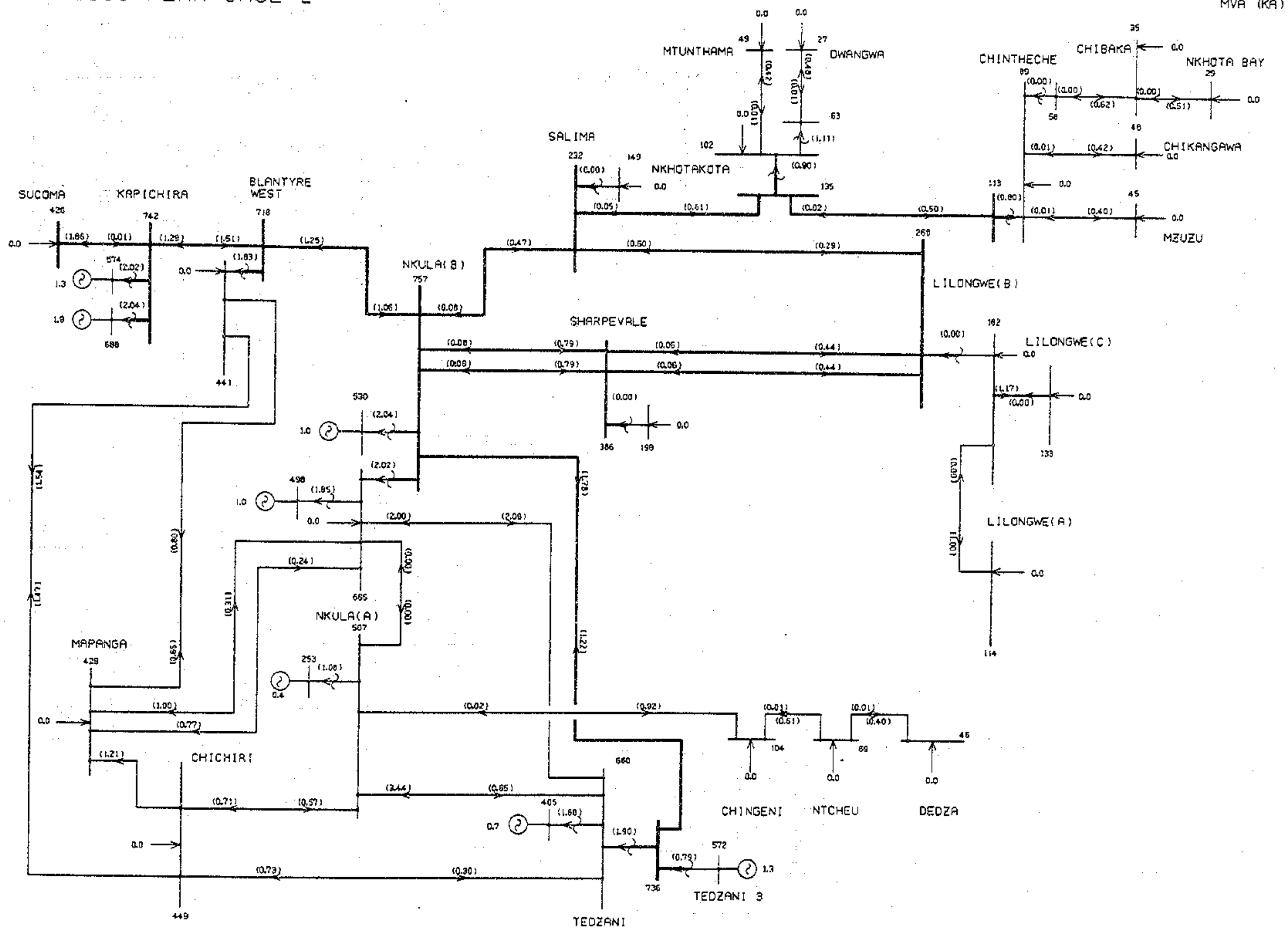



Fig 6 -11 Short Circuit Capacity in 1999 Peak Case-2

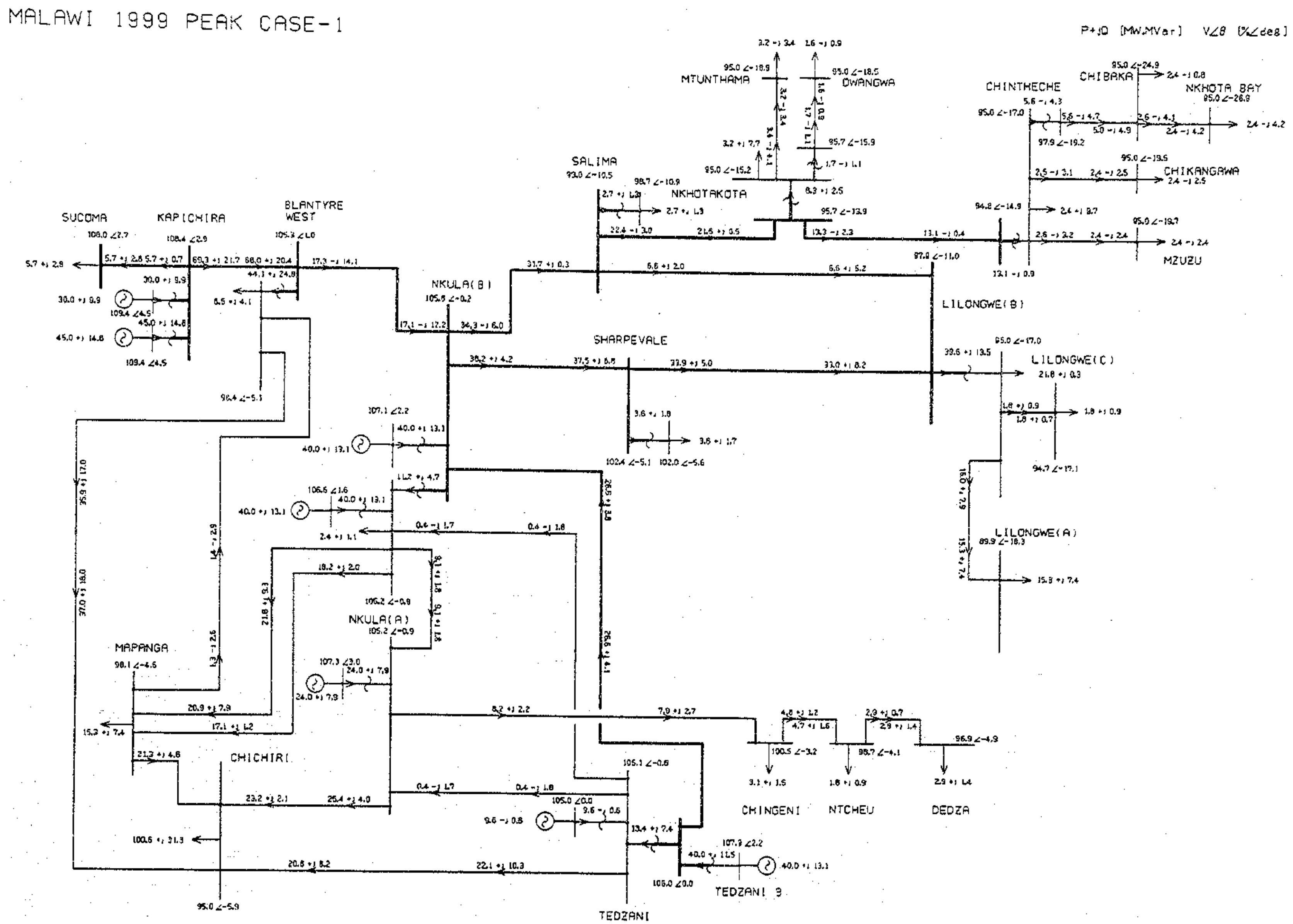



Fig 6 −12 Power Flow in 2005 Peak Cose−1

## Table 6 — 1 CONSTANT OF GENERATOR AND TRANSFORMER

| NORD No | STATION | No | CONSTANT | NOTE |
|---|---|---|---|---|
| G 1 | Nkula (B) | 6<br>7 | MW = 20<br>MVA = 22.2 Xq = 60 Xd = 100 Xd' = 25 Xd" = 17.6 Xℓ = 15 $X_2$ = Xd"<br>F = 50 Xo = 10 M = 3 Tdo' = 4.0 Tdo" = 0.05 Tqo" = 0.1 To = 0.1<br>kV = 11 | 1992 No7 Ge completion |
| G 2 | 〃 | 4<br>5 | | |
| G 3 | Nkula (A) | 1<br>2 | MW = 8 F = 50 Xq = 70 Xd = 110 Xd' = 40 Xd" = 30 Xℓ = 25 $X_2$ = Xd"<br>MVA = 8.8 kV = 11 Xo = 18 M = 2 Tdo' = 3.0 Tdo" = 0.05 Tqo" = 0.1 To = 0.1 | |
| | | 3 | MW = 10 F = 50 Other constants are same as G 3<br>MVA = 11.1 kV = 11 | |
| G 4 | Tedzani | 1<br>2<br>3<br>4 | MW = 10<br>MVA = 11.11 Xq = 70 Xd = 100 Xd' = 40 Xd" = 30 Xℓ = 25 $X_2$ = Xd"<br>F = 50 Xo = 18 M = 2 Tdo' = 3.0 Tdo" = 0.05 Tqo" = 0.1 To = 0.1<br>kV = 11 | |
| G 5 | Tedzani Ⅲ | 1<br>2 | MW = 25 F = 50 Other constants are same as G 1<br>MVA = 28 kV = 11 | 1994 No1, No2 Ge completion |
| G 6 | Kapichira | 1<br>2 | Same as G 5 | 1997 No1, No2 Ge completion |
| G 7 | 〃 | 3<br>4<br>5 | Same as G 5 | 1999 No3, No4, No5 Ge completion |
| T 1 | Nkula (B) | 6 | Step up Tr. 25MVA, 11kV/132kV, Xps = 6% Xst = 8% Xtp = 9% | |
| T 2 | 〃 | - | Tie Tr. 25MVA, 132kV/66kV, Xps = 6% Xst = 3% Xtp = 3% | |
| T 3 | 〃 | 5<br>4 | Step up Tr. 25MVA, 11kV/66kV, Xps = 6% Xst = 8% Xtp = 9% | |
| T 4 | Nkula (A) | 1<br>2<br>3 | Step up Tr. 10MVA, 11kV/66kV, Xps = 9.5% Xst = 8% Xtp = 9% | |
| T 5 | Tedzani | 1<br>2<br>3<br>4 | Step up Tr. 11.5MVA, 11kV/66kV, Xps = 7.7% Xst = 3.8% Xtp = 3.8% | |

Table 6 − 2

| NORD No | STATION | No | CONSTANT | NOTE |
|---|---|---|---|---|
| T 6 | Salima | - | Tie Tr, 25MVA, 6.2% 132/66/11kV, Xps = 6.2% Xst = 7% Xtp = 7% | |
| T 7 | Lilongwe (B) | - | Tie Tr, 25MVA, 6.2% 132/66/11kV, Xps = 6.2% Xst = 7% Xtp = 7% | |
| T 8 | Tedzani Ⅲ | - | Tie Tr, 55MVA, 7 % 132/66/11kV, Xps = 6.5% Xst = 7% Xtp = 7% | |
| T 9 | 〃 | 1<br>2 | Step up Tr. 30MVA, 6.5% 11/132kV, Xps = 6.5% Xst = 3.25% Xtp = 3.25% | |
| T 10 | Sharpevale | 1 | Tie Tr, 25MVA, 6.5% 132/66/33kV, Xps = 6.5% Xst = 7% Xtp = 7% | 1992 completion |
| T 11 | Kapichira | 1<br>2 | Step up Tr. 30MVA, 6.5% 11/132kV, Xps = 6.5% Xst = 3.25% Xtp = 3.25% | 1997 completion |
| T 12 | Kapichila | 3 | Step up Tr. 30MVA, 6.5% 11/132kV, Xps = 6.5% Xst = 3.5% Xtp = 3.5% | 1999 completion |
| T 13 | Blantyre West | 1 | Tie Tr, 25MVA, 6.2% 132/66/11kV, Xps = 6.2% Xst = 7% Xtp = 7% | |
| T 14 | Nkotakota | 1 | — 〃 — | |
| T 15 | | | Missing number | |
| T 16 | Chintheche | 1 | Tie Tr, 25MVA, 6.2% 132/66/11kV, Xps = 6.2% Xst = 7% Xtp = 7% | |
| T 17 | Nkotakota | 1 | Tie Tr, 10MVA, 6.2% 66/33kV, Xps = 9.5% Xst = 8% Xtp = 9% | |
| T 18 | Chintheche | 1 | Tie Tr, 10MVA, 6.2% 66/33kV, Xps = 9.5% Xst = 8% Xtp = 9% | |

## Table 6 − 3 CONSTANT OF TRANSMISSION LINE

| BRANCH | SECTION | | VOLTAGE kV | DISTANCE km | CONDUCTOR SIZE | %Z (Pos. phase) 100MVA base R + j X, (Y/2) %/Km | NOTE |
|---|---|---|---|---|---|---|---|
| L 1 1 | Nkula (B) #1 | Sharpevale #1 | 132 | 110 | 605 MCM ACSR | 0.05 + j 0.23 (0.025) | 1992 completion |
| 1 2 | Sharpevale #1 | Lilongwe (B) #1 | 〃 | 140 | 〃 | 〃 | 〃 |
| 1 3 | Salima | 〃 | 〃 | 75 | 175mm² AAAC | 0.1 + j 0.22 (0.023) | |
| 1 4 | Nkula (B) | Salima | 〃 | 250 | 〃 | 〃 | |
| 1 5 | Missing number | | | | | | |
| 1 6 | 〃 | | | | | | |
| 1 7 | Kapichira | Blantyre West | 〃 | 79 | 〃 | 〃 | 1997 completion |
| 1 8 | Nkula (B) #2 | Sharpevale #2 | 〃 | 110 | 505MCM ACSR | 0.05 + j 0.23 (0.025) | 1998 completion |
| 1 9 | Sharpevale #2 | Lilongwe (B) #2 | 〃 | 140 | 〃 | 〃 | 〃 |
| 1 2 0 | Nkula (B) | Tedzani Ⅲ | 〃 | 8 | 175mm² AAAC | 0.1 + j 0.22 (0.023) | |
| 1 2 1 | Nkula (B) | Blantyre West | 〃 | 43.98 | 〃 | 〃 | |
| 1 2 2 | Blantyre West | Sucoma | 〃 | 68.49 | 125mm² AAAC | 0.1466+ j 0.228 (0.023) | |
| 1 2 3 | 〃 | Kapichira | 〃 | 29.4 | 175mm² AAAC | 0.1 + j 0.22 (0.023) | |
| 1 2 4 | Kapichira | Sucoma | 〃 | 39.45 | 125mm² AAAC | 0.1466+ j 0.228 (0.023) | |
| 1 6 1 | Salima | Nkhotakota | 〃 | 109 | 〃 | 〃 | |
| 1 6 2 | Nkhotakota | Chintheche | 〃 | 156 | 〃 | 〃 | |
| 6 1 | Salima | Nkhotakota | 66 | 109 | 125mm² AAAC | 0.586 + j 0.927 (0.006) | } 1994 completion (voltage up to 132kV) |
| 6 2 | Nkhotakota | Chintheche | 〃 | 156 | 〃 | 〃 | |
| 6 3 | Missing number | | | | | | |
| 6 4 | Blantyre West | Mapanga | 〃 | 24 | 100mm² ACSR | 0.852 + j 0.943 (0.006) | |
| 6 5 | Lilongwe (B) | Lilongwe (C) | 〃 | 12 | 〃 | 〃 | 1995 completion |
| 6 6 | Nkula (A) | Nkula (B) | 〃 | - | - | | Very short section |
| 6 7 | Nkula (A) | Tedzani | 〃 | 7.5 | 175mm² ACSR | 0.42 + j 0.8838 (0.006) | |
| 6 8 | Lilongwe (B) | Lilongwe (A) | 〃 | 23 | 100mm² ACSR | 0.852 + j 0.943 (0.006) | |
| 6 9 | Nkula (B) | Mapanga | 〃 | 43.7 | 175mm² AAAC | 0.42 + j 0.8838 (0.006) | |
| 6 1 0 | 〃 | 〃 | 〃 | 〃 | 100mm² ACSR | 0.852 + j 0.943 (0.006) | |
| 6 1 1 | Chichiri | 〃 | 〃 | 13.6 | 〃 | 〃 | |
| 6 1 2 | Nkula (A) | Chichiri | 〃 | 43.4 | 〃 | 〃 | |
| 6 1 3 | Chichiri | Tedzani | 〃 | 58.8 | 175mm² ACSR | 0.42 + j 0.8838 (0.006) | |
| 6 1 4 | Nkula (A) | Chingeni | 〃 | 70 | 125mm² ACSR | 0.586 + j 0.927 (0.006) | |
| 6 1 5 | Nkula (A) | Tedzani | 〃 | 7.5 | 175mm² ACSR | 0.42 + j 0.8838 (0.006) | |
| 6 1 6 | Chingeni | Ntcheu | 〃 | 43.8 | 125mm² ACSR | 0.586 + j 0.927 (0.006) | |
| 6 1 7 | Ntcheu | Dedza | 〃 | 65 | 〃 | 〃 | |
| 6 1 8 | Lilongwe (A) | Dedza | 〃 | 80 | 〃 | 〃 | |
| 6 1 9 | Chichiri | Blantyre West | 〃 | 7 | 100mm² ACSR | 0.852 + j 0.943 (0.006) | 1997 completion |
| 6 2 0 | Nkhotakota | Mtunthama | 〃 | 78.6 | 75mm² AAAC | 1.088 + j 0.966 (0.006) | |
| 6 2 1 | Chintheche | Chibaca | 33 | 20 | 50mm² AAAC | 5.776 + j 3.471 (0.003) | |
| 6 2 2 | Chintheche | Mzuzu | 66 | 78 | 75mm² AAAC | 1.088 + j 0.966 (0.006) | |
| 6 2 3 | Chintheche | Chikangawa | 〃 | 71.5 | 75mm² AAAC | 〃 | |
| 6 2 4 | Chibaca | Nkhotakota | 33 | 10 | 50mm² AAAC | 5.776 + j 3.471 (0.003) | |
| 6 2 5 | Nkhotakota | Dwangwa | 〃 | 50 | 100mm² AAAC | 2.911 + j 3.324 (0.003) | |

# CHAPTER 7 OUTLINE OF THIS PROJECT

CHAPTER 7 OUTLINE OF THIS PROJECT

## 7-1 Outline of Transmission Line

The area between Nkula B power station and Balaka is a gently sloped land varying from 350 to 730 m above sea level, with scattered bushes and alternating savannah and cultivated fields. An existing 132 kV transmission line and a National Highway road (Route M-6) run along the planned route, thus making the route easily accessible.

The area between Bakala and Sharpevale substation is a gently sloped hilly area 730 to 620 m above sea level, with alternating bushes and cultivated fields. The area has an existing 132 kV transmission line and a National Highway road (Route M-17) running along the planned route, thus making the route easily accessible.

The area between Sharpevale and Golomoti is a gently sloped hilly area varying from 620 to 530 m high above sea level, with alternating bushes and cultivated fields as above. The area has an existing 132 kV transmission line and a National Highway road (Route M-17) running along the planned route, thus making the route easily accessible.

In the area between Golomoti and Nkhoma (Route D-21), the route runs up a hillside 530 to 1,670 m above sea level, with occasionly steep mountains with forests and bushes. The survey for the route should be carried out carefully for long-span points and locations with great differences in altitude. This area has few roads except for many walking tracks, and is rather difficult to reach in term of line construction.

The area between Nkhoma and the Lilongwe B substation is an undulating hilly area 1,280 m to 1,100 m above sea level, with alternating bushes and cultivated fields.

The area has few roads except for many walking tracks, and is rather difficult to reach in term of the construction.

Figure 7-1 shows the line route of 132 kV overhead transmission line.

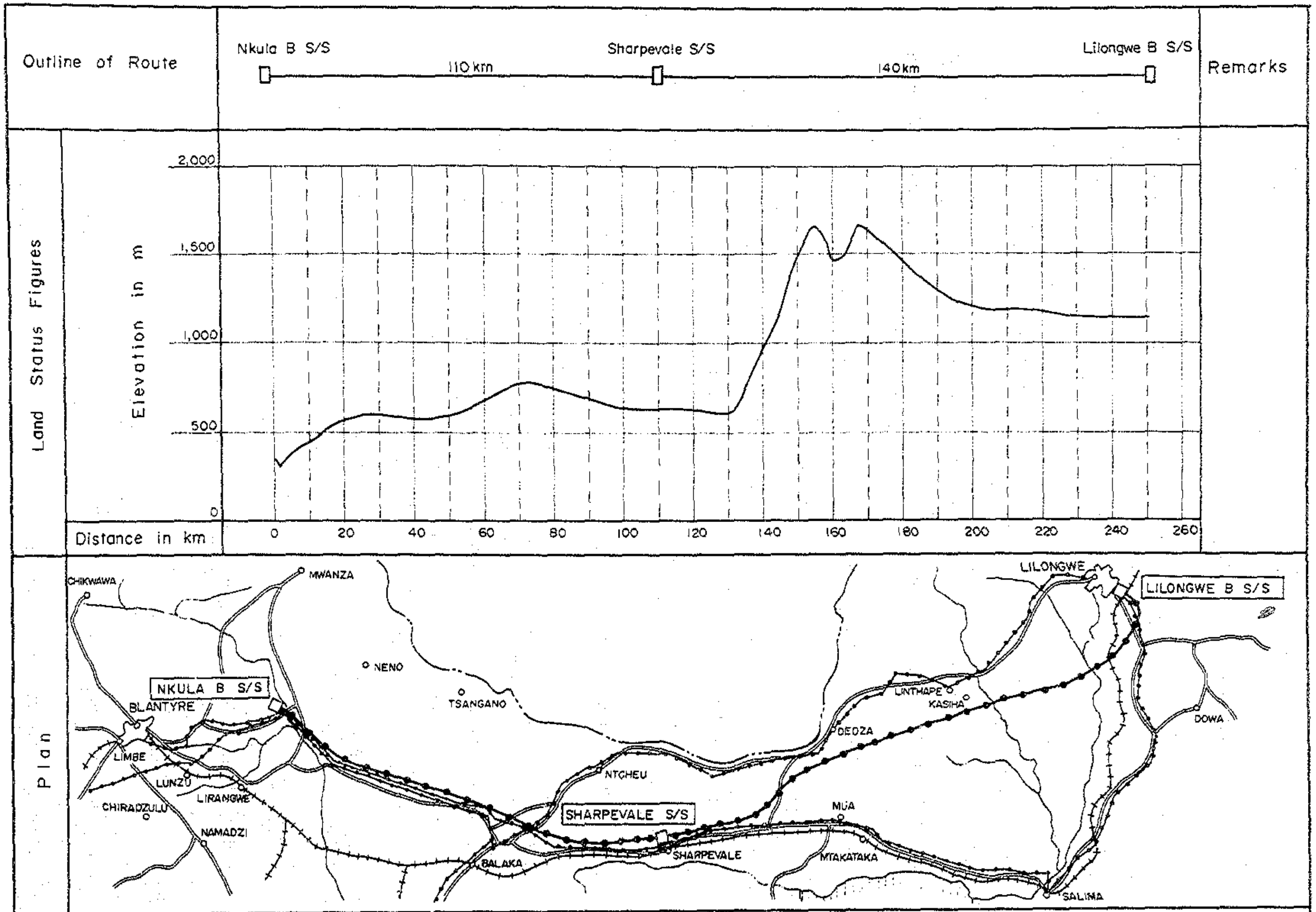



Fig 7 − 1 OUTLINE OF NKULA B — LILONGWE B TRANSMISSION CONSTRUCTION PROJECT

## 7-2 Location of Substations

Locations of transmission line terminal stations and new substations were determined as follows:

(1) Terminal Station on Nkula Side

As the terminal point on the Nkula side under This Transmission Project, the Nkula A Power Station (Primary voltage: 66 kV) or the Nkula B Power Station (Primary voltage: 132 kV) are conceivable. Since the voltage of more than 132 kV will be necessary in view of the transmission capacity and the length of this transmission line, however, it was decided to terminate the line from Nkula B Power Station and additionally utilize the existing switchyard structure in an expansion area planned to be used.

(2) Terminal Point on Lilongwe Side

As the terminal point on the Lilongwe side under this Transmission Project, the Lilongwe A Substation (Primary voltage: 66 kV) or the Lilongwe B Substation (Primary voltage: 132 kV), both already established, are conceivable. Since the switchyard space for additional construction has been secured within the Lilongwe B Substation and also since the Primary voltage is 132 kV, the Lilongwe B Substation was chosen as the terminal point.

(3) New Establishment of Sharpevale Substation

Considering that the planned transmission is long-distance one and giving thought to future needs for reinforcing the northern power system, connection with the existing (132 kV) transmission line between Nkula and Salima, linkage with the 66 kV system in the Dedza area and power transmission to the resort area around Lake Malawi, it was decided to establish a new substation in the Sharpevale area, the median point of the planned transmission line.

The Sharpevale Substation projected will be located almost in the middle of the power transmission route connecting the Nkula B

Power Station and the Lilongwe B Substation. It is situated at a point about 110 km apart from the Nkula B Power Station and around 140 km from the Lilongwe B Substation.

The planned site of the Substation is about 8 km apart from nearby Sharpevale village along National Highway M6 in the direction of Blantyre. At the planned site of the substation 200 m from the road towards the mountain side, there are no rock exposures nor marshy land nor small streams. It is flat, tilled ground.

(4) Environment around Projected Substations

All of Nkula B Power Station, the Lilongwe B Substation and the new establishment point of Sharpevale Substation have no problems in their surroundings nor experience pollution.

## 7-3 Scale of Transmission Line

The present project is being formulated for the purpose of establishing a stable power supply as well as coping with the prospective increase in power demand in the central and north region of the country by means of constructing the transmission line connecting Nkula B power station and Lilongase B substation.

The 132 kV transmission line under planning is summarized as follows:

| | | | |
|---|---|---|---|
| (1) | Section | : | Nkula B P/S - Sharpevale S/S - Lilongwe B S/S |
| (2) | Overall length | : | 250 km, approx. |
| (3) | Voltage | : | 132 kV |
| (4) | System | : | AC, 3 phase, 3 wire |
| (5) | Frequency | : | 50 $H_Z$ |

| | | |
|---|---|---|
| (6) | Number of circuits : | Single circuit (double circuit designed, single circuit stringed) |
| (7) | Conductor : | ACSR 605 MCM (Peacock) |
| (8) | Overhead ground wire: | AC 55 $mm^2$ |
| (9) | Insulator : | Eleven (11) units per string of suspension insulator of ball and socket type with a diameter of 254 mm |
| (10) | Support : | Self-supporting square steel-tower with double circuits vertical formation |

## 7-4 Scale of Substation

With the demand forecast and system analysis results of This 132 kV Overhead Transmission Line Project taken into consideration of power demand to the central, northern and Lake Malawi region, the scale and circuit composition are set as follows:

(1) Expansion of the Nkula B Power Station

(a) 132 kV transmission line terminal equipment 1 circuit

| | | | | | |
|---|---|---|---|---|---|
| i) | Circuit breaker: | 145 kV | 800 A | 20 kA | 1 unit |
| ii) | Disconnector : | 145 kV | 800 A | 20 kA | 3 units |

(2) New Establishment of Sharpevale Substation

| | | |
|---|---|---|
| (a) | 132 kV transmission line terminal equipment | 2 circuits |
| (b) | Main transformer | 1 unit |
| (c) | 132 kV bus | 1 set |
| (d) | 66 kV bus | 1 set |
| (e) | Control, protection equipment | 1 set |
| (f) | Control building | 1 set |

(g) Items of the main equipment

i) Main transformer: 132 kV/66 kV/33 kV, 25 MVA, auto transformer equipped with OLTC 1 unit

ii) Circuit breakers: 145 kV 800 A 20 kA 4 units

iii) Disconnectors : 145 kV 800 A 20 kA 10 units

(3) Expansion of the Lilongwe B Substation

(a) 132 kV Transmission Line Terminal Equipment 1 circuit

i) Circuit breaker : 145 kV 800 A 20 kA 1 unit

ii) Disconnector : 145 kV 800A 20 kA 3 units

The circuit configuration for each substation mentioned above is shown in the attached drawings Fig. 7-2, Fig. 7-3, and Fig. 7-4.

(4) Configuration of the Sharpevale Substation

(a) Site of the Sharpevale Substation

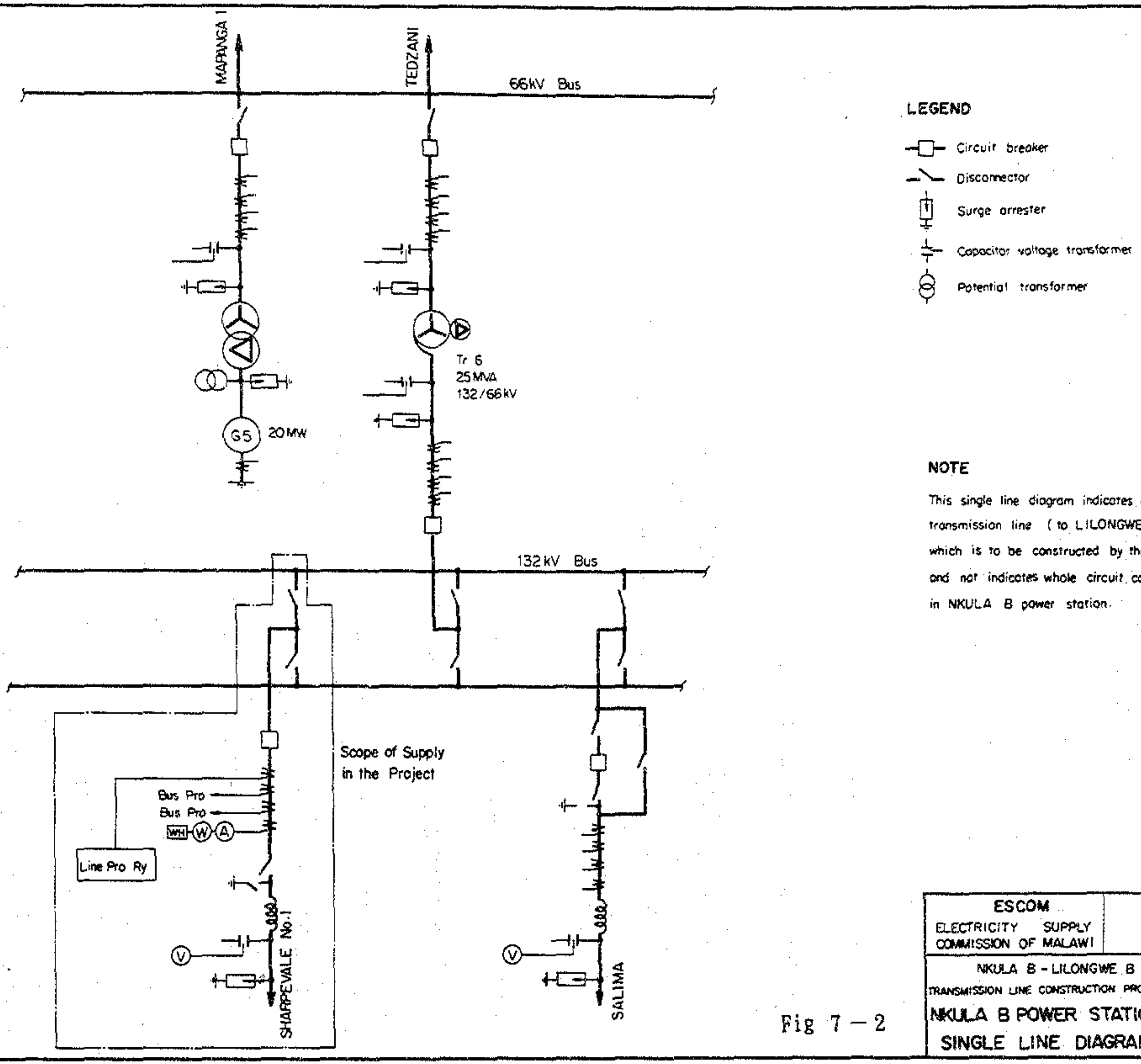
If the final stage of the Sharpevale Substation is assumed to be as follows, the site for the projected substation will be about 13,300 $m^2$ (93.5 m x 142 m):

| | | |
|---|---|---|
| i) | 132 kV transmission lines | 6 circuits |
| ii) | 132 kV bus-tie circuit | 1 circuit |
| iii) | Main transformer | 1 bank |
| iv) | 66 kV transmission lines | 2 circuits |
| v) | 33 kV transmission lines | 3 circuits |
| vi) | Control building | 1 set |

## 7-5 Scale of Telecommunication System

The scale of telecommunications system facilities to be installed under This 132 kV Overhead Transmission Line Project are as follows:

| | Model | Specifications | Nkula B | Sharpevale | Lilongwe B |
|---|---|---|---|---|---|
| (1) | Power line carrier equipment (PLC) | 2Ch, 40 dBm | 2 units | 4 units | 2 units |
| (2) | Blocking coil | 600Ω, 800 A | 2 units | 6 units | 2 units |
| (3) | Carrier relay signal transmission equipment | 200-baud transmitting/receiving equipment | 1 unit | 2 units | 1 unit |
| (4) | Fault locator | C-type | -- | 1 unit | -- |
| (5) | Automatic exchange (PBX) | 50 circuits | 1 unit | -- | -- |
| (6) | " | 20 circuits | -- | 1 unit | 1 unit |
| (7) | VHF base station | 100 W | -- | 1 unit | -- |
| (8) | VHF, car mounted | 80 W | | 2 units | |
| (9) | VHF, portable | 1 W | -- | 4 units | -- |
| (10) | Telemeter | Terminal equipment | 1 pair | 1 pair | 1 pair |




**NOTE**

This single line diagram indicates one new transmission line (to LILONGWE (B)) which is to be constructed by the project and not indicates whole circuit connection in NKULA B power station.

| ESCOM<br>ELECTRICITY SUPPLY COMMISSION OF MALAWI | EPDC<br>CONSULTANT TOKYO JAPAN |
|---|---|
| NKULA B - LILONGWE B<br>TRANSMISSION LINE CONSTRUCTION PROJECT | SCALE |
| NKULA B POWER STATION<br>SINGLE LINE DIAGRAM | DRAWING No. |

Fig 7 — 2

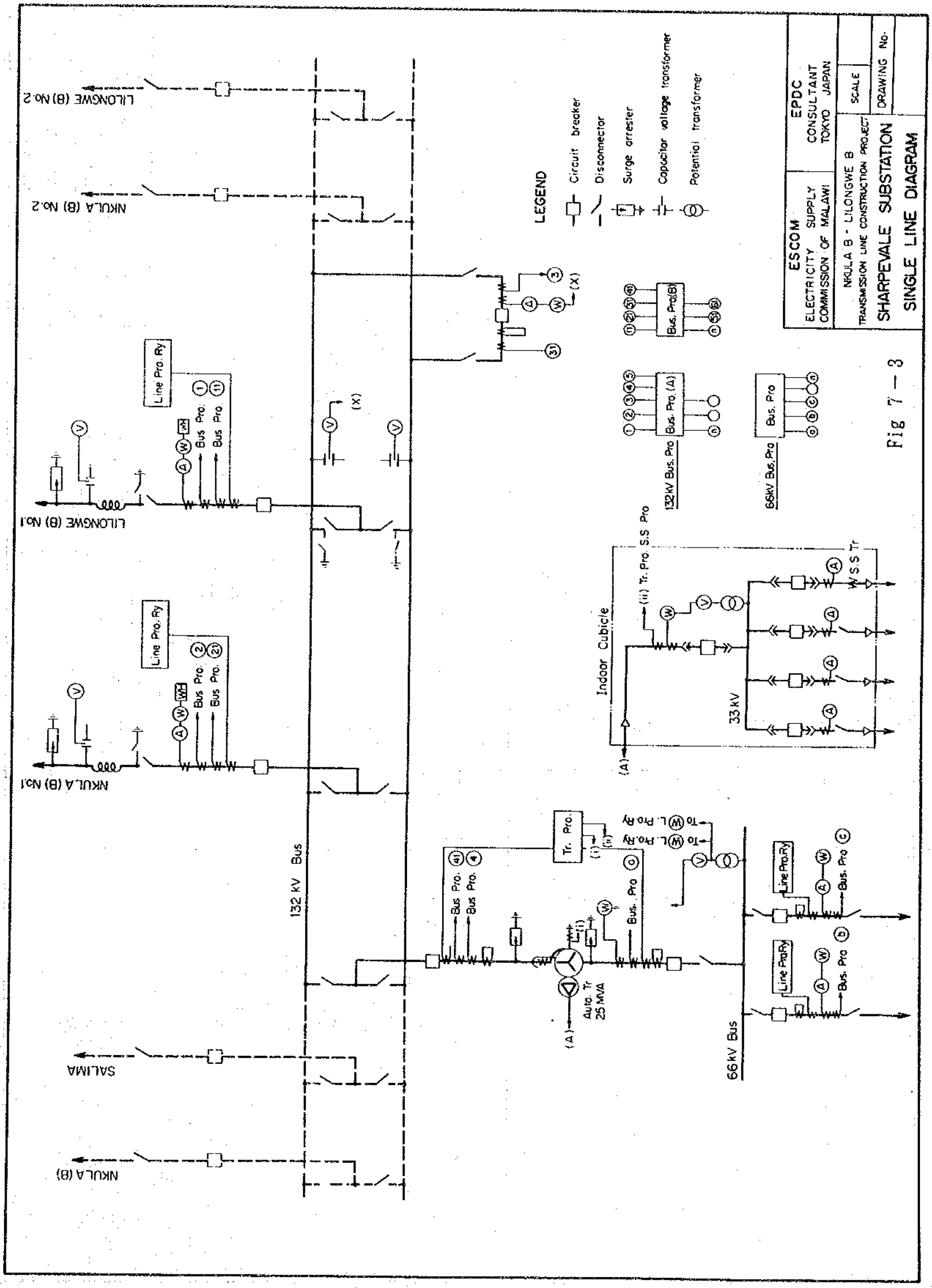
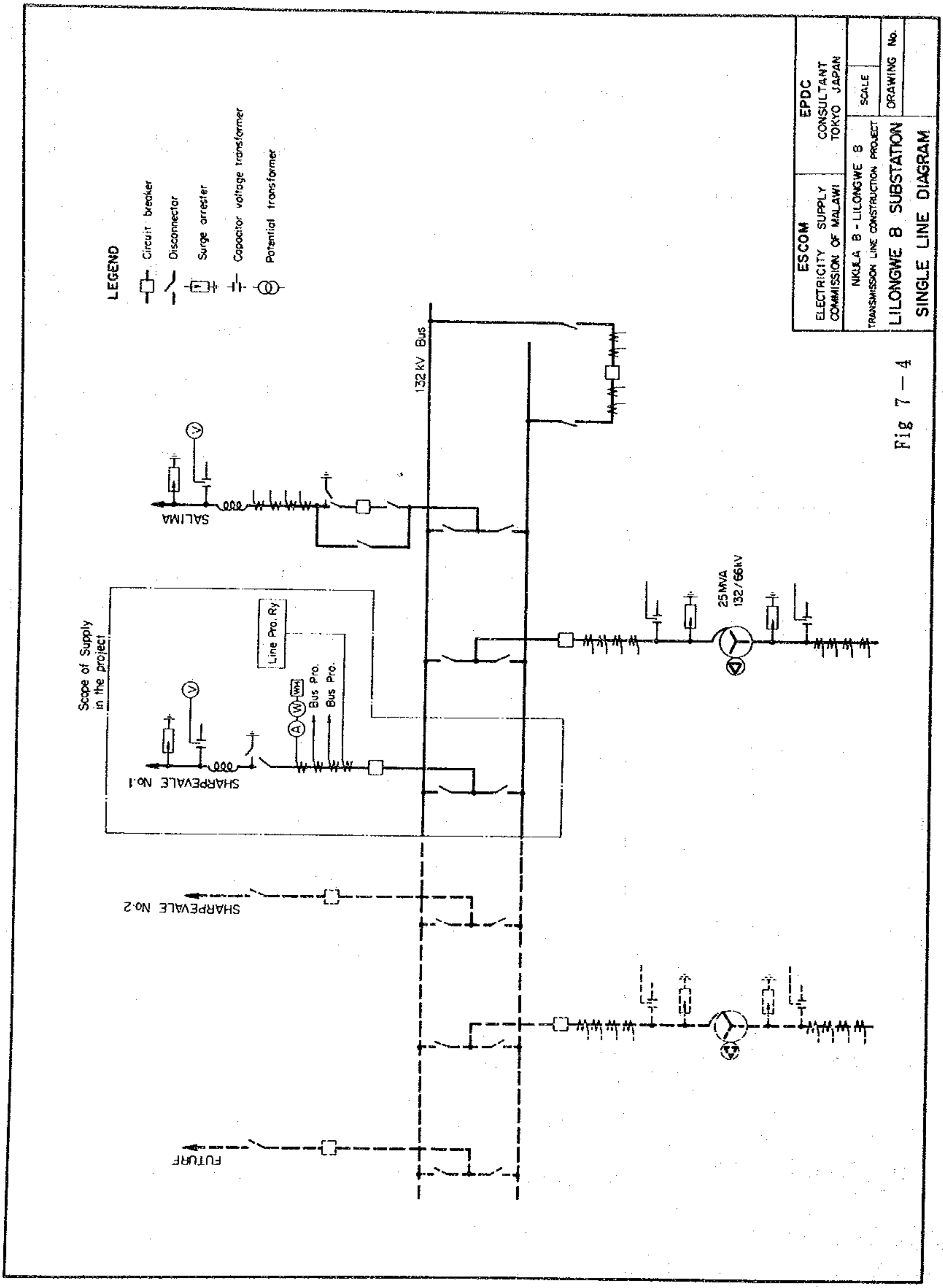

ESCOM
ELECTRICITY SUPPLY COMMISSION OF MALAWI
EPDC
CONSULTANT TOKYO JAPAN
NKULA B - LILONGWE B
TRANSMISSION LINE CONSTRUCTION PROJECT
SCALE
DRAWING No.
SHARPEVALE SUBSTATION
SINGLE LINE DIAGRAM
LEGEND
Circuit breaker
Disconnector
Surge arrester
Capacitor voltage transformer
Potential transformer
LILONGWE (B) No.2
NKULA (B) No.2
LILONGWE (B) No.1
NKULA (B) No.1
SALIMA
NKULA (B)
132 kV Bus
66 kV Bus
33 kV
Line Pro. Ry
Bus Pro.
132kV Bus. Pro
66kV Bus. Pro
Bus. Pro.(A)
Bus. Pro.(B)
Indoor Cubicle
Tr. Pro. S.S Pro
S.S Tr
Tr. Pro.
Auto. Tr
25 MVA
To W L.Pro.Ry
Line Pro.Ry

Fig 7 — 3



LEGEND
Circuit breaker
Disconnector
Surge arrester
Capacitor voltage transformer
Potential transformer
132 kV Bus
SALIMA
Scope of Supply in the project
Line Pro. Ry
Bus Pro.
Bus Pro.
SHARPEVALE No.1
SHARPEVALE No.2
FUTURE
25MVA 132/66kV
ESCOM
ELECTRICITY SUPPLY COMMISSION OF MALAWI
EPDC
CONSULTANT TOKYO JAPAN
NKULA B - LILONGWE B TRANSMISSION LINE CONSTRUCTION PROJECT
SCALE
LILONGWE B SUBSTATION SINGLE LINE DIAGRAM
DRAWING No.


Fig 7 — 4

# CHAPTER 8 SCHEDULE AND COSTS FOR PROJECT

# CHAPTER 8 SCHEDULE AND COSTS FOR PROJECT

## 8-1 Construction Schedule

Preparation and construction of this project should be advanced in accordance with the construction schedule in Fig. 8-1 aiming at startup at the end of March 1992. For the above purpose, the finance agreement should be made at the end of September 1989. Since the implementation design and preparation of tender specification will take fairly long period of time, it is necessary to start design work, and preparation of specification in October, 1989 and to complete final design and technical specification at the end of February, 1990.

The supposed international tender will be required at least six (6) months for tender proceeding, term of tender and examination of proposals and quotation. Hence, the above procedures need to be smoothly advanced.

The required term of the construction work for the transmission lines will be twenty-four (24) months in total taking into consideration the site survey with field measurement, detailed design, fabrication, transport, site installation work and field test.

## 8-2 Construction Cost

On the basis of the preliminary design, we made a calculation for the quantity of construction including spare materials and maintenance tools, and further for the total construction cost as shown in Table 9-1, taking site situation into consideration with teams and conditions as described hereunder:

(1) Scope of Work

The construction cost of the transmission lines is estimated as follows with the scope of work:

(a) Transmission Line

Between Nkula B Power Station and Lilongwe B Substation (via Sharpevale Substation)

(b) Substation

i) Outgoing equipment for Nkula B Power Station

ii Sharpevale Substation

iii) Outgoing equipment for Lilongwe B Substation

(c) Communication Equipment

Communication equipment relating to the equipment under planning

(2) Compensation Cost, etc.

Site acquisition cost, compensation cost, cost of ancillary facilities such as ESCOM permanent employee's accommodation and cost of auxiliary equipment are not included for the construction cost. However the compensation for the transfer of buildings that are under the transmission lines, etc. is taken in consideration.

(3) Procurement of Equipment and Materials

(a) It has been decided that the following equipments and materials shall be imported from foreign countries.

- Steel towers
- Conductor
- Overhead ground wires
- Insulators
- Major transformers
- Disconnecting
- Switchgear
- Current transformers for instrument

(b) The materials for the works such as portland cement and reinforcing bars shall be locally procured in Malawi.

(4) Contractor

All the 132 kV transmission line construction shall be executed by a contractor in Malawi on a turn-key basis. The materials and equipment to be used in the works shall be supplied by the Contractor, and the installation works at site shall be executed by local workers.

(5) Conversion Rate

The conversion rate for used this project is of unit rate as of the end of February, 1989 and conversion rate as one (1) Japanese Yen is 0.0212 Malawi Kwacha and One (1) US Dollar is 2.6695 Malawi Kwacha and 125.92 Yen.

(6) Customs Duty and Tax

Subject to confirmation by Malawi government, the customs duty for the equipment and materials to be used in this project, the tax duty for engineering fee, and the income tax for foreign engineers have not been earmarked for the construction works on the basis of assumption that they are exempted from taxation.

(7) The Year on which the Estimation is based and interest

The construction costs relating to this project have been estimated on the basis of unit cost as of the end of February, 1989, with annual interest rate of one percent (1.0%) for both domestic and foreign currencies during the construction works.

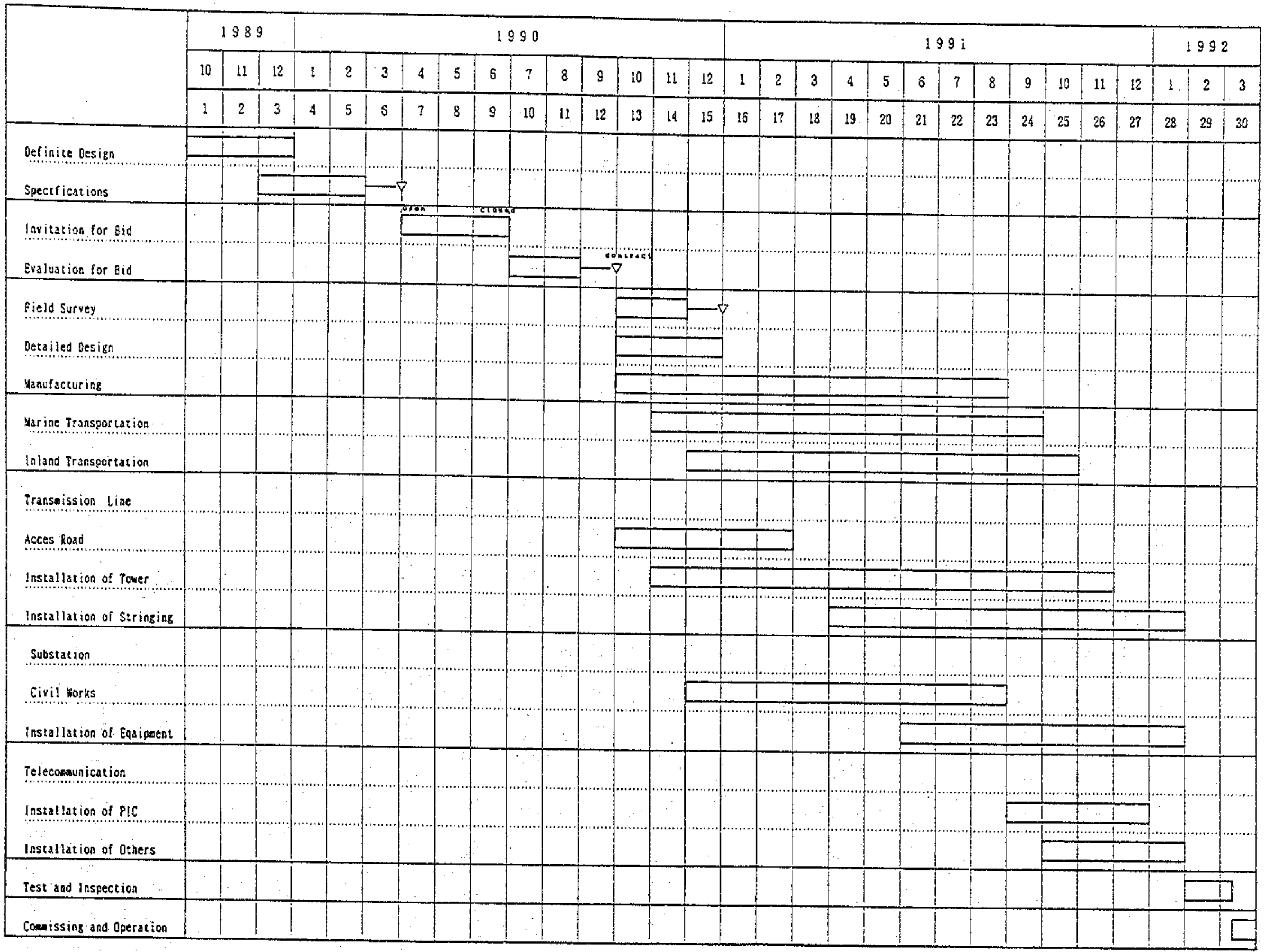



Fig 8-1 CONSTRUCTION SCHEDULE OF NKULA B-LILONGWE B TRANSMISSION LINE

Table 8－1 Project Construction Costs

Unit : $10^3$ US Dollar

| Descriptions | Foreign Currency | Domestic Currency | Total |
|---|---|---|---|
| a) Transmission line | 12,954 | 6,489 | 19,443 |
| b) Substations | 3,414 | 3,502 | 6,916 |
| c) Communication facilities | 1,079 | 228 | 1,307 |
| I. Sub-Total of Direct Cost | 17,447 | 10,219 | 27,666 |
| d) Compensation of House and other | 0 | 199 | 199 |
| e) Maintenance Equipment | 635 | 0 | 635 |
| f) Administration Expense | 0 | 238 | 238 |
| g) Engineering fee | 2,382 | 596 | 2,978 |
| h) Contingency | 2,046 | 1,125 | 3,171 |
| II. Sub-Total of Indirect Cost | 5,063 | 2,158 | 7,221 |
| III. Construction Cost (I + II) | 22,510 | 12,377 | 34,887 |
| IV. Interest during the Construction | 360 | 198 | 558 |
| V. Total Project Cost (III + IV) | 22,870 | 12,575 | 35,445 |

Note : 1) Ratio of Contingency is 10%.

2) Ratio of Interest during the construction is 1.0%.

Table 8-2 Fund Requirement of Nkula B-lilongwe B Transmission Line Construction Project

Unit : $10^3$ US Dollar

| Description | Construction Cost | | | Annual Fund Requirement | | | |
|---|---|---|---|---|---|---|---|
| | Material Cost (Foreign Currency) | Installation cost (Domestic Currency) | Total Cost | 1989 | 1990 | 1991 | 1992 |
| Transmission Line cost<br>Materials Cost | 12,954 | 0 | 12,954 | 0 | 1,049 | 10,610 | 1,295 |
| Installation Cost | 0 | 6,489 | 6,489 | 0 | 818 | 5,022 | 649 |
| Sub-Total | 12,954 | 6,489 | 19,443 | 0 | 1,867 | 15,632 | 1,944 |
| Substation Cost<br>Nkula B Substation | 335 | 159 | 494 | 0 | 0 | 445 | 49 |
| Sharpevale Substation | 2,681 | 3,015 | 5,696 | 0 | 0 | 5,126 | 570 |
| Lilongwe B Substation | 398 | 328 | 726 | 0 | 0 | 654 | 72 |
| Sub-Total | 3,414 | 3,502 | 6,916 | 0 | 0 | 6,225 | 691 |
| Telecommunication Facilities Cost<br>Nkula B Substation | 232 | 35 | 267 | 0 | 0 | 240 | 27 |
| Sharpevale Substation | 639 | 162 | 801 | 0 | 0 | 721 | 80 |
| Lilongwe B Substation | 208 | 31 | 239 | 0 | 0 | 215 | 24 |
| Sub-Total | 1,079 | 228 | 1,307 | 0 | 0 | 1,176 | 131 |
| Total of Direct Cost | 17,447 | 10,219 | 27,666 | 0 | 1,867 | 23,033 | 2,766 |
| Compensation Cost of House & Others | 0 | 199 | 199 | 79 | 60 | 60 | 0 |
| Maintenance Equipment Cost | 635 | 0 | 635 | 0 | 635 | 0 | 0 |
| Administration Expenses | 0 | 238 | 238 | 24 | 95 | 95 | 24 |
| Engineering Fee | 2,382 | 596 | 2,978 | 413 | 1,209 | 966 | 390 |
| Contingency | 2,046 | 1,125 | 3,171 | 52 | 387 | 2,415 | 317 |
| Total of Indirect Cost | 5,063 | 2,158 | 7,221 | 568 | 2,386 | 3,536 | 731 |
| Construction Cost | 22,510 | 12,377 | 34,887 | 568 | 4,253 | 26,569 | 3,497 |
| Interest during the Construction | 360 | 198 | 558 | 1 | 27 | 181 | 349 |
| Grand Total Project Cost | 22,870 | 12,575 | 35,445 | 569 | 4,280 | 26,750 | 3,846 |

Note : 1) Ratio of Contingency is 10%.
2) Ratio of Interest during the construction is 1.0%.

# CHAPTER 9 ECONOMIC ANALYSIS AND FINANCIAL ANALYSIS

# CHAPTER 9 ECONOMIC ANALYSIS AND FINANCIAL ANALYSIS

## 9-1 Basic Concept of Economic/Financial Analyses

In the economic analysis, the relative economy of this Project is evaluated by comparing the total present worth cost of this Project with that of an Alternative Project. The Alternative Project is a hypothetical gas turbine power plant, having an output equal to the receiving end power of this project, which is assumed to be constructed near Lilongwe.

In the financial analysis, the financial soundness of this Project is evaluated by calculating the discount rate with which the present worth of the total operating revenues of this Project (the energy sales revenue) becomes equal to that of the total expenses of this Project, or the financial internal rate of return.

## 9-2 Parameters Used in Economic/Financial Analyses

### 9-2-1 Construction Cost of This Project

The construction cost of this Project is the cost calculated in Chapter 8. The plant life is assumed to be 35 years.

### 9-2-2 Construction Cost of Alternative Project

The sending end output of the alternative gas turbine power plant is assumed to be equal to the receiving end output of this Project. By taking into account the reduction of gas turbine power plant output due to the station service rate, repair/shutdown rate and peripheral temperature, the installed capacity of the gas turbine power plant is assumed to be 42 MW.

Multiplying the installed capacity by the unit cost, the construction cost of the alternative gas turbine plant can be calculated as below.

42,000 x 390 US$ = 16.38 million US$ (43.73 million M.Kw)

The capital expenditure for construction of this plant is assumed to be 20% of the total for the first year and 80% for the second year. That is:

Expenditure for the first year : 3.28 million US$ (8.76 million M.Kw)

Expenditure for the second year : 13.10 million US$ (34.97 million M.Kw)

### 9-2-3 O&M Cost

The O&M cost (including administration expenses) of this Project is assumed to be 2.5% of the construction cost. The O&M cost (including administration expenses) of the Alternative Project is assumed to be 5% of the construction cost.

### 9-2-4 Fuel Cost

ESCOM's purchase price of light oil, which will be used as fuel for the gas turbine plant of the Alternative Project, was 1.556 M.Kw/ℓ according to the actual purchase record in March, 1989. Converting this price to Yen at a rate of 0.3746 US$/M.Kw, we obtain 0.583 US$/ℓ. Multiplying this figure by the fuel consumption rate (at sending end) 0.372 ℓ/kWh, we obtain the sending end fuel cost of 0.2168 US$/kWh.

### 9-2-5 Cost of Supplied Power

It is assumed that the electric power from hydroelectric power plants in the southern part of Malawi will be supplied to the Lilongwe area after this Project is completed. The cost of such power has been calculated as presented below based on the financial data of ESCOM for 1988.

The total electricity sales in 1988 was 477.46 GWh, the operating expenses 25.69 million M.Kw, and the interest payment 9.26 million M.Kw. As almost all electricity sales by ESCOM is sustained by hydroelectric power, we defined the supplied power cost of this Project as the sum of the above operating expenses and interest payment divided by the total electricity sales, which was:

$$(25.69 + 9.26)/447.46 = 0.0732 \text{ M.Kw/kWh} = 0.0732 \times 0.3746 = 0.0274 \text{ US\$/kWh}$$

### 9-2-6 Unit Electricity Price

The average unit price of electricity sold, as assumed by ESCOM for the year 1992 when this Project is commissioned to commercial operation, that is, 0.1347 M.Kw/kWh = 0.0505 US$/kWh, was used as the unit electricity price with which the operating revenues from this Project is calculated.

## 9-3 Economic Analysis

### 9-3-1 Comparison by Levelized Costs

The relative economic advantage between this Project and the Alternative Project was compared in terms of the levelized costs, assuming the social discount rate of 10% which is generally adopted as the opportunity cost of capital. Here, the year 1989 was selected as reference and it was assumed that the two projects will be commissioned to commercial operation in 1992. The evaluation was performed for a period ending in 2026 on this Project, and a period ending in 2016 on the alternative Project.

The O&M costs are calculated as below based on the assumptions in 9-2-3.

| | | |
|---|---|---|
| This Project | : | 34.88 x 0.025 = 0.872 million US$/year |
| Alternative Project | : | 16.38 x 0.05 = 0.819 million US$/year |

The power received by the loads in Lilongwe area was assumed to be 30 MW with a load factor of 60%, that is, $1.577 \times 10^8$ kWh/year. In reality, this figure should change from year to year. This Project, however, is proved to be more economical if the received power is more than 2.9 MW, which is the result of the sensitivity analysis. Therefore, the fuel cost can be estimated as $1.577 \times 10^8 \times 0.2168 =$ 34.19 million US$/year, and the power supply cost as $1.577 \times 10^8 \times 0.0274 = 4.32$ million US$/year.

The results of this evaluation are presented in Tables 9-1 and 9-2. The levelized annual costs are 8.83 million US$ (23.57 million M.Kw) for this Project and 36.85 million US$ (98.35 million M.Kw) for the Alternative Project. The Alternative Project is 28.02 million US$ more expensive, or 4.17 times, than this Project. That is, this Project is far more economical.

### 9-3-2 Economy of Double Circuit Tower

In this Project, it is planned to construct a transmission line of double circuit tower design, on which a single circuit is strung first, and then another circuit is to be strung to deal with the future increase of power demand in Lilongwe area. The reason why this plan has been adopted instead of constructing two transmission lines of single circuit tower design step by step for meeting the demand growth is as follows.

In comparsion between the two plans in terms of the total present worth with the year 1989 as reference, the plan of constructing double circuit tower line, with one circuit strung at each time, is more economical if the second circuit is to be strung within 11.5 years after the commissioning of the first circuit. As indicated by the annual power flows presented in Chapter 6, the second circuit is required by 1999, which is the 8th year after commissioning of the Project. Therefore, it has been decided to construct a double circuit transmission line for this Project and to string one circuit at a time.

Table 9-1 Levelized Annual Costs of This Project

(in million US$, with 10% discount rate)

| No. | Year | Construction Cost | O&M | Power Supply Cost | Total |
|---|---|---|---|---|---|
| | 1989 | 0.57 | | | 0.57 |
| | 90 | 4.25 | | | 4.25 |
| | 91 | 26.57 | | | 26.57 |
| 1 | 92 | 3.49 | 0.872 | 4.32 | 8.69 |
| 2 | 93 | | 0.872 | 4.32 | 5.19 |
| 3 | 94 | | 0.872 | 4.32 | 5.19 |
| 4 | 95 | | 0.872 | 4.32 | 5.19 |
| 5 | 96 | | 0.872 | 4.32 | 5.19 |
| 6 | 97 | | 0.872 | 4.32 | 5.19 |
| 7 | 98 | | 0.872 | 4.32 | 5.19 |
| 8 | 99 | | 0.872 | 4.32 | 5.19 |
| 9 | 2000 | | 0.872 | 4.32 | 5.19 |
| 10 | 01 | | 0.872 | 4.32 | 5.19 |
| 11 | 02 | | 0.872 | 4.32 | 5.19 |
| 12 | 03 | | 0.872 | 4.32 | 5.19 |
| 13 | 04 | | 0.872 | 4.32 | 5.19 |
| 14 | 05 | | 0.872 | 4.32 | 5.19 |
| 15 | 06 | | 0.872 | 4.32 | 5.19 |
| 16 | 07 | | 0.872 | 4.32 | 5.19 |
| 17 | 08 | | 0.872 | 4.32 | 5.19 |
| 18 | 09 | | 0.872 | 4.32 | 5.19 |
| 19 | 10 | | 0.872 | 4.32 | 5.19 |
| 20 | 11 | | 0.872 | 4.32 | 5.19 |
| 21 | 12 | | 0.872 | 4.32 | 5.19 |
| 22 | 13 | | 0.872 | 4.32 | 5.19 |
| 23 | 14 | | 0.872 | 4.32 | 5.19 |
| 24 | 15 | | 0.872 | 4.32 | 5.19 |
| 25 | 16 | | 0.872 | 4.32 | 5.19 |
| 26 | 17 | | 0.872 | 4.32 | 5.19 |
| 27 | 18 | | 0.872 | 4.32 | 5.19 |
| 28 | 19 | | 0.872 | 4.32 | 5.19 |
| 29 | 20 | | 0.872 | 4.32 | 5.19 |
| 30 | 21 | | 0.872 | 4.32 | 5.19 |
| 31 | 22 | | 0.872 | 4.32 | 5.19 |
| 32 | 23 | | 0.872 | 4.32 | 5.19 |
| 33 | 24 | | 0.872 | 4.32 | 5.19 |
| 34 | 25 | | 0.872 | 4.32 | 5.19 |
| 35 | 26 | | 0.872 | 4.32 | 5.19 |
| Total Present Worth: | | 26.38 | 6.32 | 31.30 | 64.01 |

Levelized total annual costs = 8.83

Note: The levelized total annual costs can be obtained by multiplying the total present worth costs by capital recovery factor at 10% discount rate for 35 years of 0.10369, and $1.1^3$ which is a coefficient to convert the figures based on the reference year to those based on the commissioning year.

Table 9-2 Levelized Annual Costs of Alternative Project

(in million US$, with 10% discount rate)

| No. | Year | Construction Cost | O&M | Power Supply Cost (Fuel) | Total |
|---|---|---|---|---|---|
| | 1989 | | | | 0 |
| | 90 | 3.28 | | | 3.28 |
| | 91 | 13.10 | | | 13.10 |
| 1 | 92 | | 0.819 | 34.19 | 35.01 |
| 2 | 93 | | 0.819 | 34.19 | 35.01 |
| 3 | 94 | | 0.819 | 34.19 | 35.01 |
| 4 | 95 | | 0.819 | 34.19 | 35.01 |
| 5 | 96 | | 0.819 | 34.19 | 35.01 |
| 6 | 97 | | 0.819 | 34.19 | 35.01 |
| 7 | 98 | | 0.819 | 34.19 | 35.01 |
| 8 | 99 | | 0.819 | 34.19 | 35.01 |
| 9 | 2000 | | 0.819 | 34.19 | 35.01 |
| 10 | 01 | | 0.819 | 34.19 | 35.01 |
| 11 | 02 | | 0.819 | 34.19 | 35.01 |
| 12 | 03 | | 0.819 | 34.19 | 35.01 |
| 13 | 04 | | 0.819 | 34.19 | 35.01 |
| 14 | 05 | | 0.819 | 34.19 | 35.01 |
| 15 | 06 | | 0.819 | 34.19 | 35.01 |
| 16 | 07 | | 0.819 | 34.19 | 35.01 |
| 17 | 08 | | 0.819 | 34.19 | 35.01 |
| 18 | 09 | | 0.819 | 34.19 | 35.01 |
| 19 | 10 | | 0.819 | 34.19 | 35.01 |
| 20 | 11 | | 0.819 | 34.19 | 35.01 |
| 21 | 12 | | 0.819 | 34.19 | 35.01 |
| 22 | 13 | | 0.819 | 34.19 | 35.01 |
| 23 | 14 | | 0.819 | 34.19 | 35.01 |
| 24 | 15 | | 0.819 | 34.19 | 35.01 |
| 25 | 16 | | 0.819 | 34.19 | 35.01 |
| Total Present Worth: | | 12.55 | 5.58 | 233.15 | 251.28 |

Levelized total annual costs = 36.85

Note: The levelized total annual costs can be obtained by multiplying the total present worth costs by capital recovery factor at 10% discount rate for 25 years of 0.11017, and $1.1^3$ which is a coefficient to convert the figures based on the reference year to those based on the commissioning year.