

THE FUTURE OF  
ELECTRICITY SUPPLY  
IN  
WEST BENGAL  
(INDIAN UNION)

Thesis presented for the degree of Ph. D. in Engineering  
in the University of Edinburgh

by

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# THE FUTURE OF ELECTRICITY

## SUPPLY IN WEST BENGAL

(INDIAN UNION)

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### 1. INTRODUCTION

This thesis aims to give an independent and critical survey of the problems of public supply of electrical energy in West Bengal generally. It first considers the progress and development in the years preceding 17th August 1947, when the Indian sub-continent was granted independent status and the partition of the country between Pakistan and the Indian Union was initiated. Next, a survey is given of the new conditions obtaining after partition. The desirability of electrical supply development is discussed and the published suggestions of the Government of Bengal considered.

A short-term scheme is described for the immediate introduction of a supply to a rural district east of Calcutta. The district considered, having eight centres of consumption, is submitted to a careful and conservative estimate of its load potentialities, with due regard to the geographical, climatic and sociological conditions obtaining. The load development is predicted/

predicted on a basis of statistical material derived from a variety of sources; technical methods of engineering the scheme with economy are considered, and some attention is given to the formation of suitable tariffs.

The thesis has, as background, the results of several years' experience of the problem as it developed, both before and after Partition. It embodies the material gathered by direct study in the district concerned; by study of rural electrification schemes in Britain arranged by courtesy of the supply industry in Britain, the Central Electricity Board, and later the British Electricity Authority; and by calculation and design work in the South East Scotland Electricity Board's offices and in the Department of Electrical Engineering of the Heriot-Watt College (University of Edinburgh).

The details and discussion of the supply scheme for the district east of Calcutta, described in the second part of the thesis, are the original work of the author. It is his intention, as a servant of the Electricity Development, Government of West Bengal, to present the results obtained to the Administration of his Department in the hope that the wider distribution of the benefits of electrical supply may be more swiftly made available to the/

the people of West Bengal.

PART I

2. CONDITIONS PRIOR TO PARTITION

2.1. The Electricity Act, 1910

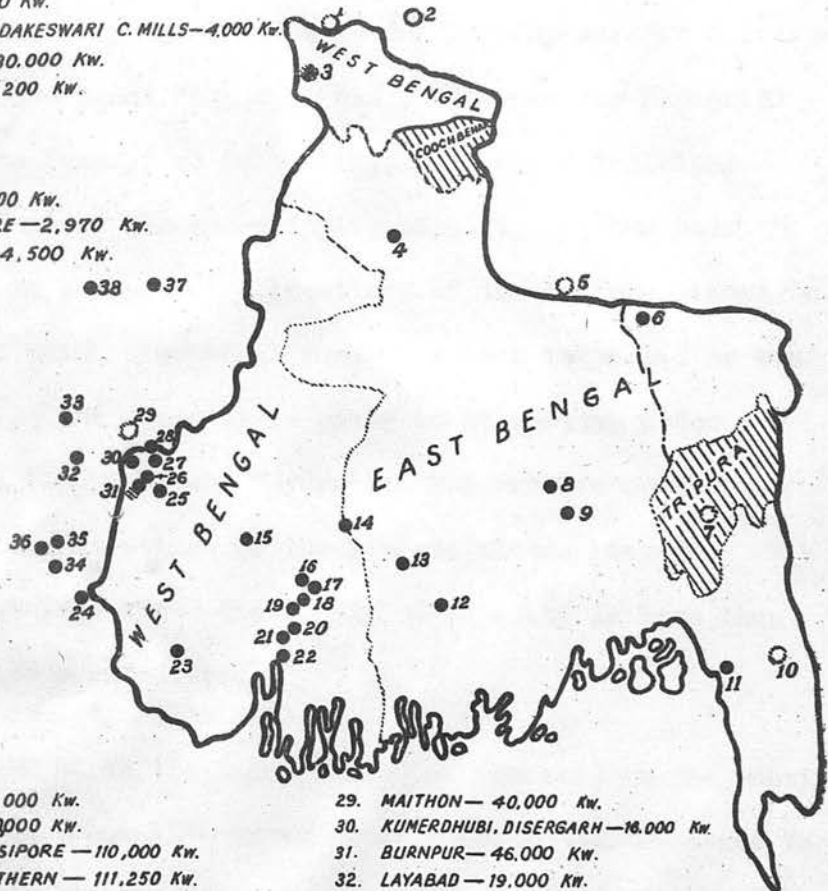
The Indian Electricity Act of 1910 empowered the Provincial Government to grant a licence to any local body, private company or individual, authorising the generation and supply of electricity for public or private consumption within a specified area. If a local authority did not itself obtain the right of supply for its own districts in the first instance, the Act provided for the compulsory purchase of the company systems by the local authority after a period specified in the licence, or at specified intervals thereafter.

One result of this Act has been that the main structure of the industry in urban areas consists of Undertakings which can supply electricity only to very small areas a few miles in radius and limited to one local authority or district. While operating under the Act, there was, however, a steady progress of electrical industry in Bengal. At the end of 1938/

1. TISTA — 300,000 Kw.
2. JALDHAKA — 30,000 Kw.
3. DARJEELING — 1960 Kw.
4. SAIDPUR — 1650 Kw.
5. SOMESWARI — 30,000 Kw.
6. CHATTAK — 3,000 Kw.
7. GUMTI — 20,000 Kw.
8. DACCA — 3,000 Kw.
9. NARAYANGANJ - DAKESWARI C. MILLS — 4,000 Kw.
10. KARNAPHULI — 30,000 Kw.
11. PAHARTALI — 3,200 Kw.
12. KHULNA
13. JESSORE
14. KRISNANAGAR
15. BURDWAN — 1,800 Kw.
16. CHANDERNAGORE — 2,970 Kw.
17. KACHRAPARA — 4,500 Kw.

**LEGEND**

- HYDROELECTRIC POWER STATION
- DO (PROPOSED)
- THERMAL POWER STATION
- DO (PROPOSED)



18. GOURIPUR — 42,000 Kw.
19. MULLAJORE — 9000 Kw.
20. CALCUTTA · COSSIPORE — 110,000 Kw.
21. " · SOUTHERN — 111,250 Kw.
22. BIRLA JUTE MILL — 14,00 Kw.
23. KHARAGPUR — 10,200 Kw.
24. GHATSILA — 10,464 Kw.
25. RANIGUNJ — 4800 Kw.
26. ASANSOLE
27. SEEBPUR — 8000 Kw.
28. KULTI — 4750 Kw.

29. MAITHON — 40,000 Kw.
30. KUMERDHUBI, DISERGARH — 18,000 Kw.
31. BURNPUR — 46,000 Kw.
32. LAYABAD — 19,000 Kw.
33. GIRIDIH — 4650 + 2500 Kw.
34. JAMSEDPUR (1) — 82,500 Kw.
35. DO (2) — 43,000 Kw.
36. DO (3) — 9200 Kw.
37. BHAGALPUR — 1150 Kw.
38. JAMALPUR — 5050 Kw.

**FIG. 1**

1938, the number of public supply undertakings working under electric licences or sanctions had increased to 57 as compared with only 9 in 1928. All the licences granted, except that of Darjeeling, were for company-managed concerns, and the Government of Bengal did not render any financial assistance (except to Darjeeling, which is a Municipal Undertaking). The accompanying map, Fig. 1, has been prepared to indicate the locations of the various places in Bengal in which electrical power has been installed or was proposed. The capacity is given in kilowatts, under the heads "Thermal" and "Hydro". The numbers on the map indicate the locations of the various places listed. Those districts where the installed capacity is less than 500 kW have been omitted.

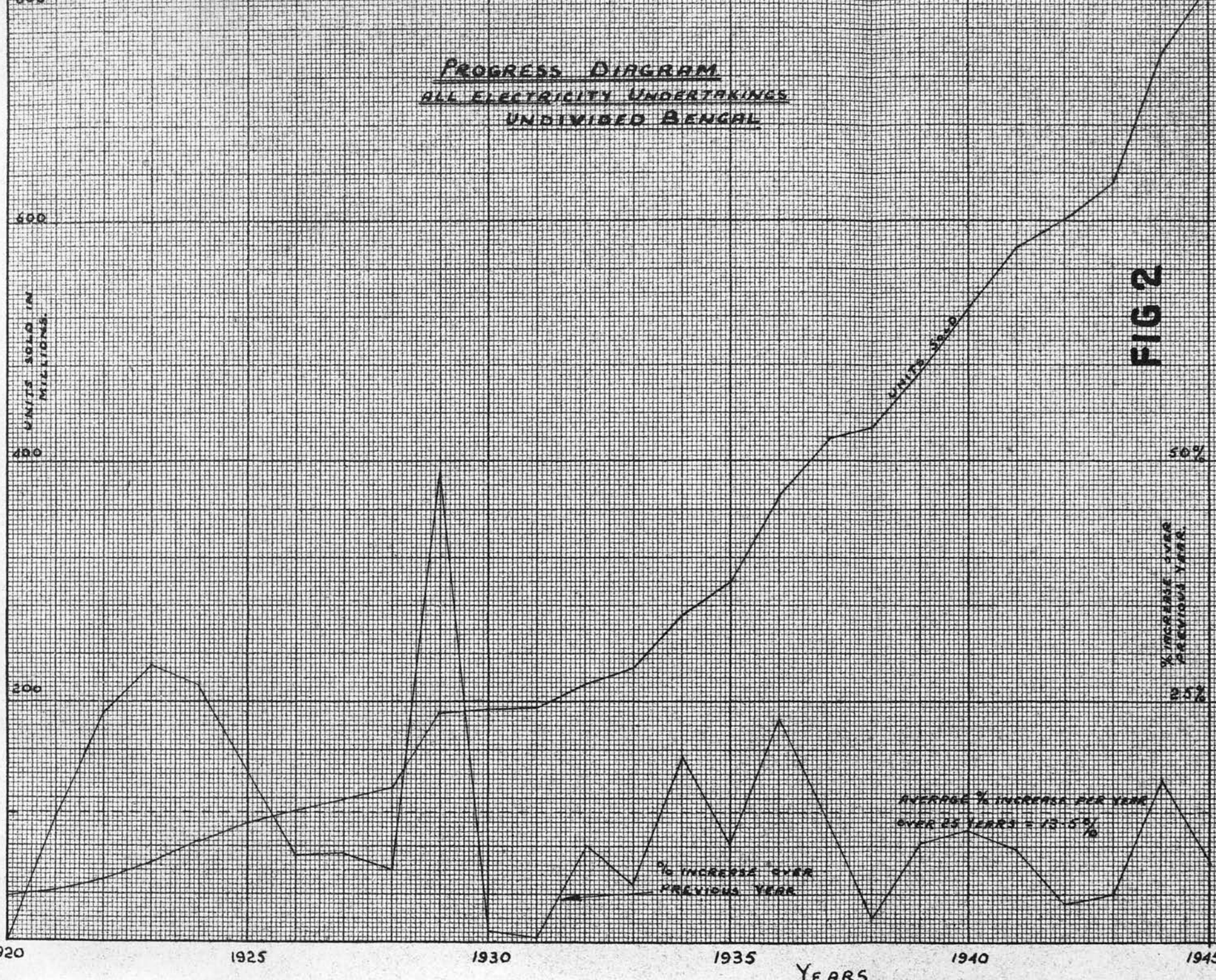
Fig. 2 shows the total number of kWh sold in the province year by year from 1920 up to 1945. The annual increase in units sold over the last 25 years is only about 13.5% per year on the average, as will be evident from the graph.

## 2.2. The Development Report, 1939

In 1939, an Officer was appointed by the Government of the Province to make proposals and recommendations for accelerating/

PROGRESS DIAGRAM  
ALL ELECTRICITY UNDERTAKINGS  
UNDIVIDED BENGAL

**FIG 2**



accelerating development in Bengal. His published Report showed the position of the electrical supply industry in Bengal, in the United Provinces, Punjab, Madras, Bombay and Mysore. One chapter dealt more fully with recommendations for Bengal and the relevant parts are as follows :-

"Rivers in Bengal are wide stretches of water and  
"change their courses often. This may put obstacles in  
"the way of developing any electrical grid scheme.  
"This could be circumvented by splitting up the province  
"into large areas not intersected by wide rivers. ...

"The whole area may be divided into five parts<sup>+</sup>  
"as follows :-

- (1) "Hydro-electric power station erected at the foot  
"of the hills near the River Teesta or the River  
"Jaldaka to supply electricity throughout North  
"Bengal, including the Doers and Cooch Bihar State.  
"Towards the East, the supply may be extended to  
"the neighbouring areas of North Assam, and towards  
"the West, to North Bihar.

+ See Fig. 3.

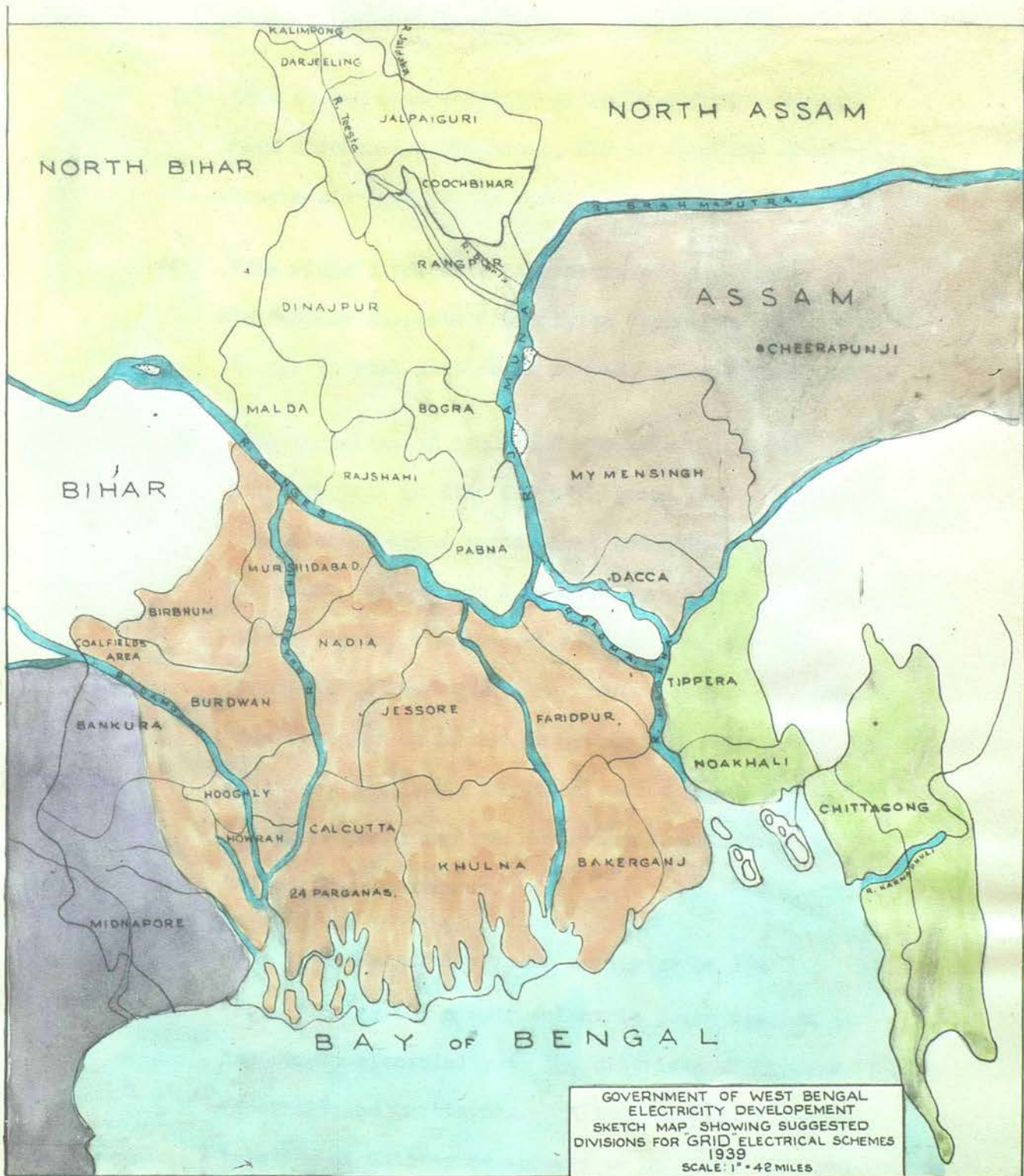


FIG. 3

- (2) "The second area comprising the Presidency, Burdwan  
"and surrounding divisions, may be supplied from  
"steam stations on the coalfields and from Calcutta.
- (3) "The river difficulty in Bankura and a portion of  
"Midnapore suggests a supply to them from the proposed  
"large thermal station in the adjoining part of Bihar.
- (4) "The districts of Dacca and Mymensingh present  
"difficulties in view of their great distance from  
"the coal deposits in the West and non-feasibility  
"of their supply from a generating station on the  
"River Teesta. A thermal station near the coal  
"supplies at Cherrapunji may be a solution which in  
"its turn may be of use in Sylhet and adjoining  
"district of Assam. Hydro-electric developments  
"at Cherrapunji may run unwarrantable risks owing  
"to earthquake tremors.
- (5) "The River Karnafully needs survey as to its  
"capabilities for a hydro-electric power station  
"to supply electricity to the districts of Tippera,  
"Noakhali and Chittagong. Alternatively, a thermal  
"station at Chittagong appears to be a workable proposition."  
The/

The above division into five areas was suggested for electrical development avoiding wide river crossings by transmission lines.

3. CONDITIONS SUBSEQUENT TO  
PARTITION

3.1. Geographical

Since the 17th of August 1947, the political economy of Bengal has been totally changed, the province having been split up into EAST and WEST BENGAL by the findings of the Bengal Boundary Commission, as approved by Sir Cyril Radcliffe.

The award of the Commission assigned to East Bengal the whole of the Chittagong and Dacca Divisions, and to West Bengal the whole of the Burdwan Division. The Rangpur, Bogra, Rajshahi and Pabna districts of the Rajshahi Division, and the Khulna district of the Presidency Division were included in East Bengal, and the districts of Calcutta, the 24 Parganas, and the Murshidabad of the Presidency Division and the Darjeeling district of the Rajshahi Division were included in West Bengal. See Fig. 4.

The five districts of Nadia, Jessore, Dinajpur, Jalpaiguri and Malda have been divided between the two provinces.



The map, Fig. 4, shows the demarkation of the two parts of Bengal - the Eastern part going to Pakistan and the Western part falling within the Dominion of the Indian Union. It is this part of the province to which the following report refers.

3.2. Present Position in West Bengal

Twenty-four public supply undertakings working under licence or sanction give supplies to about 37 of the towns in West Bengal. Of these, nine Undertakings obtain bulk supplies, and the fifteen remaining generate their own energy and sell in bulk to nearby Undertakings. Most of these Undertakings use either early types of reciprocating steam engine or small diesel sets for generating plant in their respective areas. Only the Calcutta Electric Supply Corporation Ltd., and two other Undertakings supplying the coalfields and industrial areas, employ steam turbines for generation. The present power position in the Province is shown in Table I and in the map, Fig. 5.

restricted because of insufficient boiler capacity.  
in capacity is installed capacity less capacity of largest generating unit.  
1953.

**INSTALLED PLANT CAPACITY OF THE LICENSEES IN WEST BENGAL.**

Name of Licensee	Capacity in kW
(1) The Amawal Electric Supply	Bulk supply from 1 x 48 (Steam)
(2) Bonhwa Electric Supply	1 x 96 1 x 144
(3) The East India Electric Supply Ltd. (Bombaria)	Bulk supply from 1 x 96 (Diesel)
(4) The Bankura Electric Supply Co.	1 x 96 (Diesel)
(5) The Barrackpore Electric Supply	1 x 96 (Diesel)
(6) The Berhampore Electric Supply Co. Ltd.	1 x 96 (Diesel)
(7) The Riverside (Bhatnagar) Electric Supply Co. Ltd.	1 x 144
(8) The Burdwan Electric Supply Co. Ltd.	Bulk supply from 2 x 200 (Steam)
(9) C.E.S.C. Consopore Power Station	1 x 375
(10) C.E.S.C. Jalajore Power Station	1 x 12,500 (Steam)
(11) C.E.S.C. Southern Power Station	2 x 7,500 2 x 9,750 2 x 30,000
(12) Derjeeling Electric Supply	6 x 30,000 (Steam)
(13) The Dighergarth Power Supply Co. Ltd.	4 x 7,500 (Steam)
(14) The Durgapore Electric Supply Co. Ltd.	4 x 20,000 1 x 20,000 1 x 20,000 1 x 20,000
(15) The East India Electric Supply (Hooghly & Chinsura)	2 x 200 (Steam)
(16) The Jalpaiguri Electric Supply Co. Ltd.	1 x 100 1 x 80 1 x 242
(17) The Kalimpong Electric Supply Co. Ltd.	2 x 40 (Diesel)
(18) The Krishnagar Electric Supply Co.	1 x 32 (Diesel)
(19) The Kuruwang Hydro-Electric Supply Co.	2 x 75 (Hydro)
(20) The Malda Electric Supply Co. Ltd.	2 x 200 (Hydro)
(21) The Midnapur Electric Supply Co.	2 x 400 (Diesel)
(22) The Mubadai Electric Supply	1 x 30 (Diesel)
(23) The Nalhati Electric Supply Co.	2 x 100 (Steam)
(24) The Ranaghat Electric Supply Co. Ltd.	1 x 48 1 x 96
(25) The Santalpukur Electric Supply Co. Ltd.	1 x 144
(26) The Associated Power Co. Ltd. (Seabpur).	Bulk supply from 10,575 46,000 2,500 4,000 4,500 1,100 1,500

**PRIVATE GENERATION.**

- (27) Anupnagar 10,575
- (28) Bampur 46,000
- (29) Kallipahar 2,500
- (30) Kallipahar 4,000
- (31) Kallipahar 4,500
- (32) Refractory & Ceramic Factory 1,100
- (33) Victoria Colliery 1,500

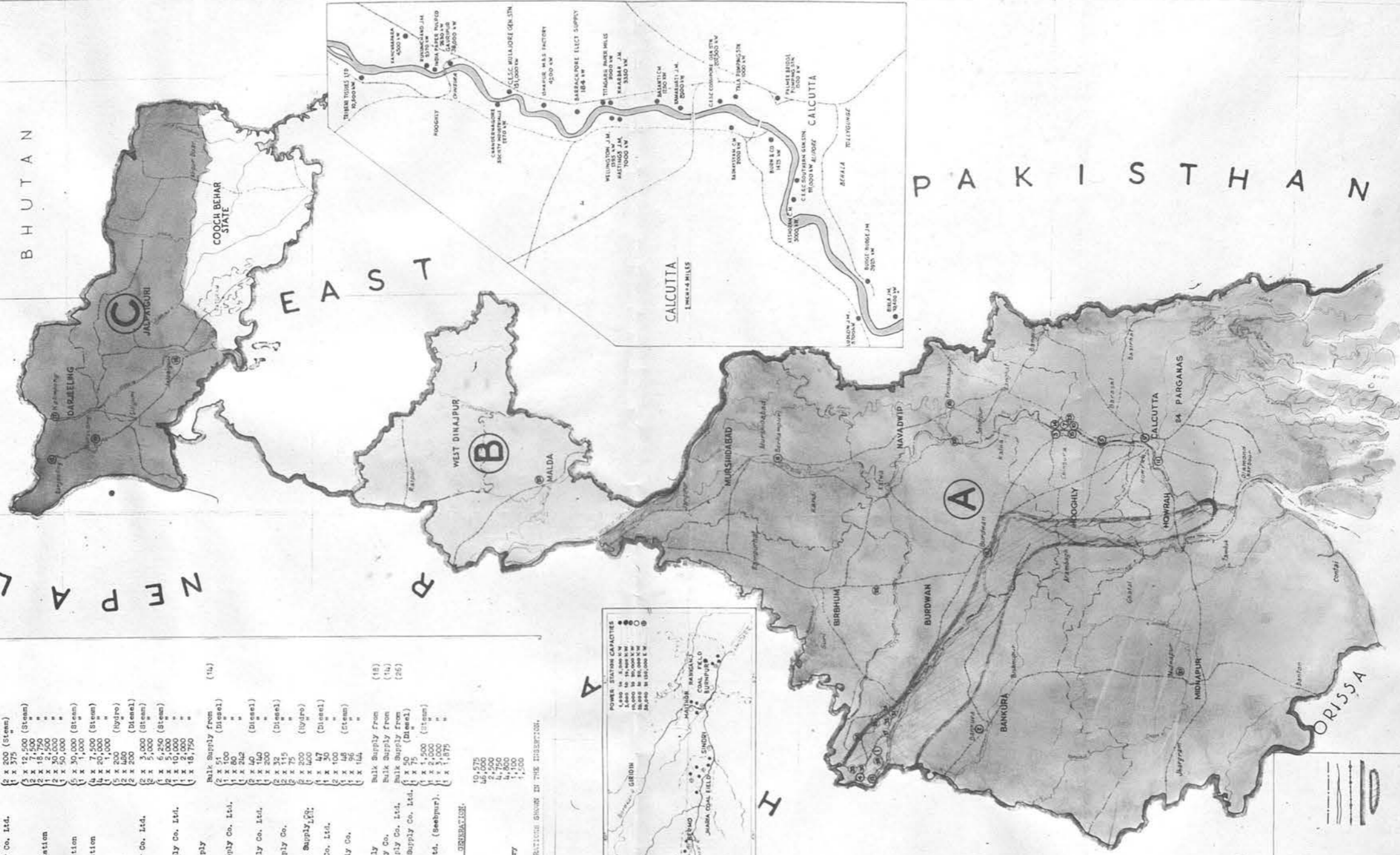
H.R. OTHER PRIVATE GENERATION SHOWN IN THE DISTRICT.



**A**

**FIG. 5**

S I K K I M



**LEGEND**

- DISTRICT BOUNDARY
- RIVER
- RAILWAY WITH STATION
- PROVINCIAL BOUNDARY
- D.V.C. BASIN AREA



**MAP OF WEST BENGAL SHOWING EXISTING & PROJECTED POWER STATIONS**

Units generated in West Bengal during the year 1948 totalled 970 million kWh, an increase of 15% over 1947. The Calcutta power stations accounted for 822 million units, about 85% of the total. At present, apart from the city of Calcutta and the coalfield areas, the demand for electrical energy is insignificant. The aggregate installed capacity on 31st December, 1948, was 349,305 kW, of which the generating plant in Calcutta accounted for 294,750 kW, i.e. about 84% of the total.

### 3.3. Calcutta Local Area

The Calcutta Electric Supply Corporation Ltd., a public limited Company incorporated under the British Companies Act, is by far the largest undertaking in the Province. Starting in 1897 with a capacity of only 1000 kW, it gradually expanded to 294,750 kW at the end of 1948.

From time to time after it started business in the City of Calcutta under the original licence, the area of its business activities was extended by the granting of licences for additional areas outside the city, until it was found to be operating fourteen different licences with varying dates on which the Government of Bengal had the option of terminating them by purchase. By the Consolidated Licence of/

of 1946, all these licences were brought together, with the Government of Bengal having the option to take over the Company's whole undertaking with all current contracts, as from the 1st January 1950 or thereafter at intervals of twenty years. Two years' notice of intention to exercise the option is necessary.

Although public announcements were made by the Government of Bengal from time to time that it would exercise its option, in view of the fact that the terms of purchase (viz. the fair market value) were too high, the Government decided not to take over the Company, and under the licence now the Company have an extension of tenure for at least another twenty years.

3.3.1. TYPES OF LOAD. The area covered by the Company's activities includes the City of Calcutta; Howrah on the opposite side of the River Hooghly; and a strip of industrial and residential area on either side of the river extending above and below Calcutta, a distance of some 45 miles and comprising a total area of some 500 square miles, with a population of eight millions. See Fig. 5. inset.

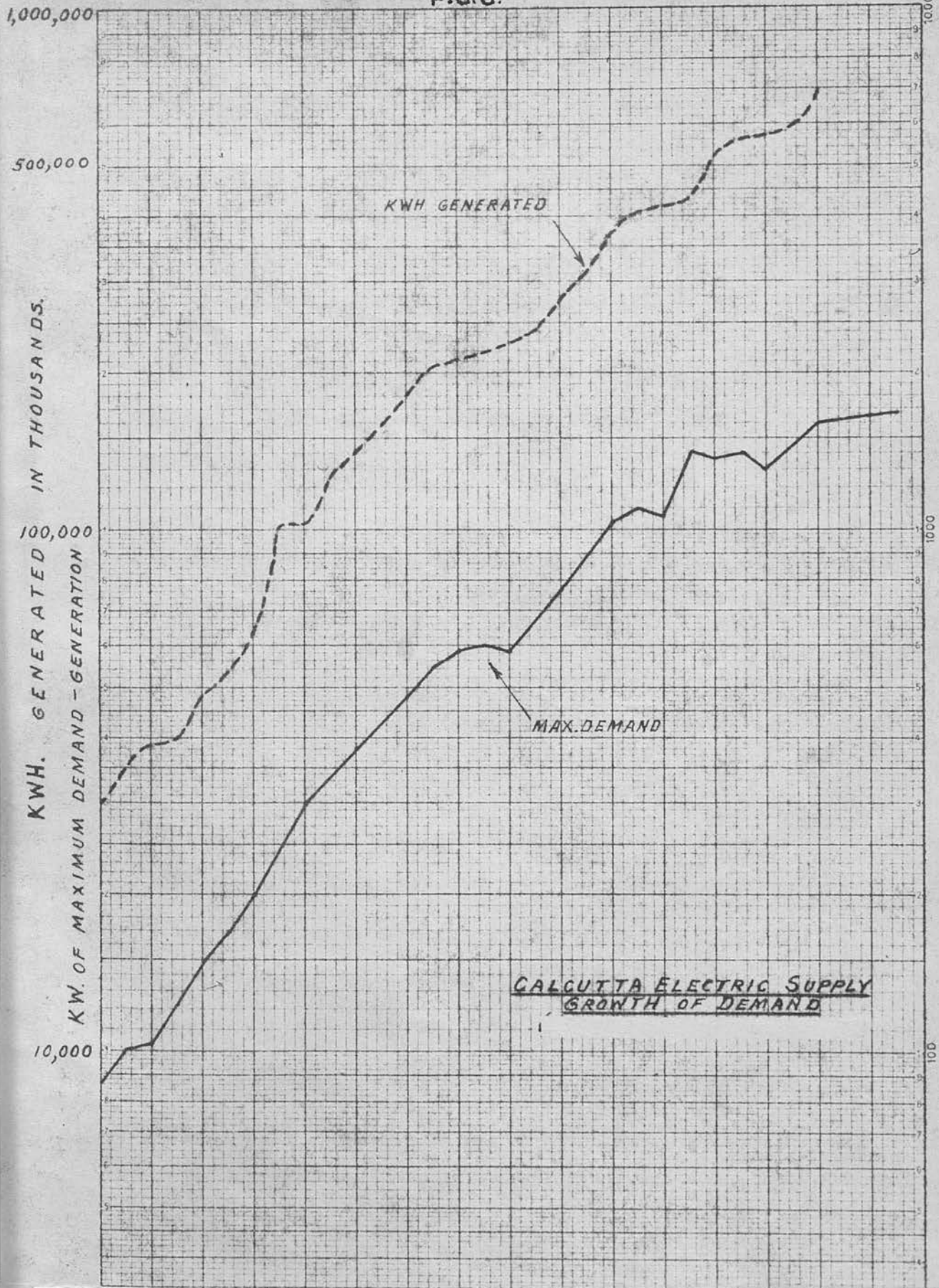
Within the above area, the Company supplies electrical energy to approximately 130,000 domestic consumers, to approximately 6,500 low and medium-voltage industrial consumers, and to approximately 450 high-voltage consumers for industrial purposes, including :-

- 39 Jute Mills.
- 18 Cotton Mills.
- 8 Paper Mills.
- 41 Oil Mills.
- 13 Lead Mills.
- 19 Steel Works and Rolling Mills.
- 61 Engineering Workshops.
- 15 Rubber Works.
- 18 Chemical Works.
- 19 Jute Presses.
- 13 Ice and Cold Storage Factories.
- 12 Film Studios.
- 6 Tobacco and Match Factories.
- 17 Pumping Stations.
- 3 Distributing Licences.

The maximum demands of these h.-v. consumers aggregated 146,500 kW in 1948. The growth of this load is shown on the chart, Fig.6.

The Company also supplies energy for public lighting purposes to the Calcutta Corporation, to Howrah Municipality, and to some 30 other Municipalities, Union Boards and Public Bodies. The Calcutta Tramways Company Ltd., which operates the/

FIG. 6.



the main system of public transport in Calcutta and Howrah, is a large consumer whose service is entirely dependent on this Supply. Calcutta Corporation also uses electricity for a portion of its public water-supply service.

3.3.2. GENERATING PLANT. The energy required for all these purposes is at present generated by the Company at the following generating stations :-

TABLE II : CALCUTTA GENERATING STATIONS

Station	Year first commissioned	Installed Capacity, MW	Effective Generating Capacity, MW
Cossipore	1912	92.5	50
Southern	1926	111.25	70
Mulajore	1940	<u>91.0</u>	<u>75</u>
	TOTALS	<u>294.75</u>	<u>195</u>

Besides the three main generating stations given above, there are 20 rotary sub-stations for a.c.-d.c. conversion, and 63 a.c. sub-stations; 500 miles of 6-kV cable and nearly 150 miles of higher-voltage cable are maintained in the area.

3.4. Projects in Hand

The Calcutta Electric Supply Corporation has now undertaken to/

to increase the generating capacity of the undertaking by (1) building a new Cossipore Station adjoining the old station in which plant is now under erection to provide additional 110 MW of generating capacity; and (2) the extension of the Mulajore generating station to provide a further 60 MW. It is expected that the first generator in New Cossipore will be brought into commission before the end of 1949 and the first in Mulajore before the end of 1950.

The Southern Generating Station has an installed capacity of 111 MW but it is estimated that if the expected load is to be met, further extensions are urgently required. There are proposals, therefore, to build a new station and instal two 30-MW sets to start with.

The Gourepore Electric Supply Co. Ltd., which mainly supplies industrial loads in the area approximately 30 miles North of Calcutta, is installing a new generating set with a capacity of 18.75 MW, expected to be ready by 1950.

The Associated Power Co.'s Station at Seebpore is being augmented to supply additional load of 1.875 MW. This power station together with an interconnected steam station at Dishergarh/

Dishergarh (Radhanagar) supplies the collieries in Ranigunj, besides giving energy in bulk to the Asansol, Ranigunj and Barakar Undertakings.

In addition to the above projects now being carried out within the Province of Bengal, the unified development of the Damodar River is being actively prosecuted by the Government of Indian Union. This is a comprehensive multi-purpose project including in its scope, irrigation, power, navigation and flood control. The project is estimated to cost Rs.55 crores (approx. £41.25 million), of which about half is proposed for allocation to "Power". The Scheme was drawn up under the general direction of Mr W. L. Voorduin, formerly Head Planning Engineer, T.V.A., is being executed and will be operated by the "Damodar Valley Corporation", a semi-public autonomous body established by the Government of India for the purpose. Power available from the multi-purpose Damodar Development would be 350,000 kW when combined thermal and hydro-electric plants are considered.

#### 4. NATIONAL POLICIES

##### 4.1. Electricity Supply Legislation as a National Policy

In all progressive countries the power resources are regarded/

regarded as national assets, and organisations are set up for their conservation, development and proper working. Beneficent legislation is framed and amended from time to time to ensure that there shall be available to the public a cheap and abundant supply of energy, with the interests of consumers safeguarded from exploitation. Legislation is an essential part of the development of electricity supply.

The Indian Electricity Act 1910 was originally drawn up in line with the earlier Electric Lighting Acts of Great Britain and has not been modified on any essential points. But Britain has passed through a long period of evolutionary development, the principal features of which will be evident by a reference to her legislative history.

#### 4.2. Conditions in Britain and the U.S.A.

With the cessation of hostilities in 1945, the new Labour Government in Great Britain advocated the nationalisation of electricity supply. The structure of the industry, based upon companies with a limited tenure and upon companies and municipal undertakings with an indefinite tenure, was changed and the electrical supply has been run as a nationalised industry since April 1948.

The/

The country is now cut up into fourteen areas and sub areas. These areas run with some degree of autonomy. Generation and grid transmission (which is really an interconnection between stations) is operated by the British Electricity Authority, and distribution by local Electricity Boards.

In America, by far the most advanced country in the world so far as electrification is concerned, nationalisation is not favoured; however, for extension of lines to rural areas, loans have been advanced from the Federal Treasury by the Rural Electrification Administration.

4.3. Advantages and Drawbacks of State Ownership

There are still two very distinct schools of thought regarding the best means of supply development. The first maintains that, by encouraging existing or new licensees with either cheap loan or outright subsidies to expand into sub-economic and rural areas, the work would be carried out expeditiously, because private enterprise is better equipped than Government departments to undertake such work. The other school maintains that the Government itself should carry out the expansion and derive any profits which may eventually accrue therefrom. The exponents of this policy maintain that the State's ability to/

to borrow money at "cheap" rates and its acceptance of a small return must lessen the cost of the service. It is also maintained that the control of a public necessity by a small group of private individuals is not in the public interest.

The reasons which are usually advanced against nationalisation or State Ownership are the lack of incentive, the absence of the "profit motive" and the system of promotion by seniority rather than merit. Further, under "Departmental" operation the control of finance and consequently expansion are not in the hands of those in charge of the technical sides of the enterprise.

A means of combating these disadvantages of State Ownership adopted in some countries is to set up semi-autonomous bodies in the form of Statutory Commissions or Boards to operate Public Utilities. The Government of India, considering this the best way, has lately enacted the Electricity (Supply) Act, 1948, which makes it possible for any Province to establish such a Board.

4.4. General Features of the Indian Electricity (Supply) Act 1948

Electrical development in India is mostly limited to the local areas of a few municipalities with the result that the production/

production of electricity is extremely low. It is with a view to remedying the present defects that legislation has recently been brought into effect which envisages the creation of a Provincial Electricity Board to plan a regionally co-ordinated scheme of electrical development. It is a corporate body required to operate like a private concern, free from Government control, but subject to Government supervision. One of the fundamental principles laid down in the Act is that the Board shall not be operated at a loss.

The Provincial Electricity Board will perform a two-fold function. In the first place, it will be charged with the duty (1) of promoting the all-round development of electricity in the most efficient and economical manner, with particular reference to areas not yet served, and (2) to effect the rationalisation of the supply. The Board may establish new generating stations or control existing ones, interconnect stations by means of transmission lines. The Board may also buy energy in bulk from the owners of controlled stations or sell it to them and to other licensees. In short, by ensuring that electric generation is concentrated in the most efficient stations distributed over the entire region and that the bulk supply is centralised under its own direction, the/

the Provincial Board will have the power to develop a grid system not only in new areas but also in the areas of old licensees by controlling their operations. It is not, however, contemplated that the existing statutory rights and obligations of a licensee, under the Indian Electricity Act, 1910, shall be derogated by a board unless a licensee is not himself carrying out his development duties satisfactorily.

It is intended that the Board will exercise a form of financial control over privately-owned undertakings with a view to ensuring the investors a reasonable return and, at the same time, securing to the consumer as much reduction in the cost of electricity as possible.

The Act does not set out entirely to "nationalise" the industry, but only to control it and extend the scope of Government operation of electrical service.

The Board may receive financial assistance from the Government during the early years of its existence. This assistance is not in the form of grants, but of advances from treasury subsequently consolidated into loans, the Board being obliged to pay interest and repay the principal in specified/

specified period of time.

Profits from the operation of the Board are to be retained in part for expansion and other purposes beneficial to electrical development of the Province, and the remaining part is to go towards repayment of interest-free loans and to Provincial revenues. The proportion is determined according to a formula given in the Act.

#### 4.5. General Proposal for West Bengal

To accelerate electrical development in the Province, it has been decided that development should be actively pursued in areas outside the existing licensed areas. The Electricity Development Organisation has been started for planning schemes of electrification in the Province in an economic manner, and for the execution of such schemes as are approved by the Government. The intention of the Government is to proceed actively with the installation of plant in all large unelectrified towns and undertake rural distribution schemes, where such will assist in the development of rural economy. It has further been proposed that the towns which have no prospect of coming under State regional schemes may be allowed to be developed by private enterprise, and applications for the grant of licences for the supply of electricity in such towns have/

have been invited. The aim of the Government is to encourage expansion by the existing licensees within the areas of their supply but the Government's policy is generally to exercise its option to acquire the licences as they fall due.

4.5.1. PLANNING DETAILS. This Province has been divided into three Zones shown in the map, Fig.5. Of these, Zone 'C' will be fully supplied when some of the hydro-electric projects erected at the foot of the hills near the river Teesta or Jaldhaka materialise. Such hydro-electric projects would afford supply of electricity throughout the North Bengal, including Doars and Cooch Behar State. Such projects will necessarily take some years. Meanwhile, these places must be fed by isolated stations. Zone 'B' must also be developed by some individual stations for the time being. Zone 'A', comprising Presidency and Burdwan divisions, may be supplied from Calcutta and from the Damodar Valley Corporation's Transmission System.

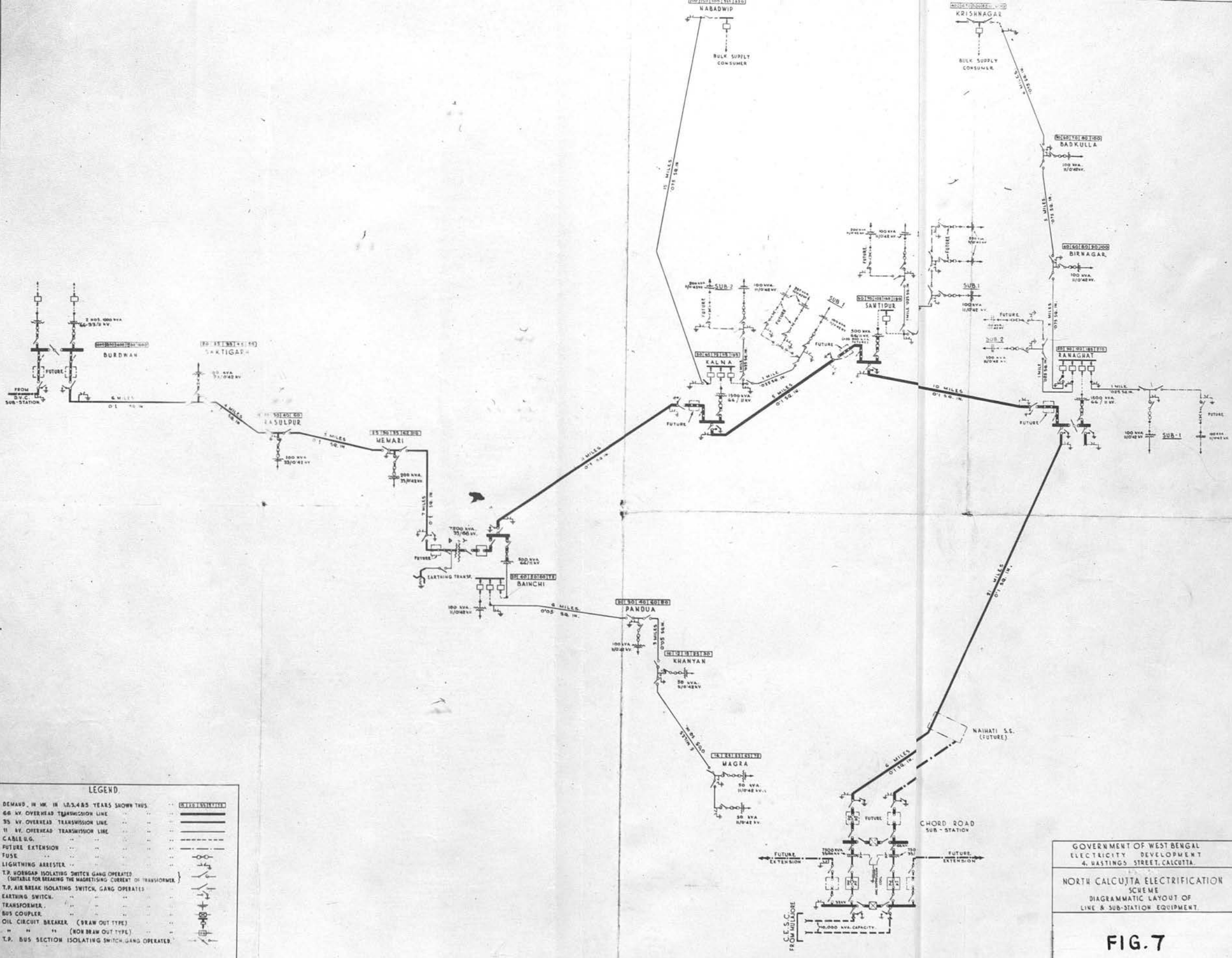
With regard to the supplies of electricity to the small towns; it is obvious that separate generating units will not be economical while the prices of capital goods are so high. It is, therefore, proposed to develop, at present, approximately 70 miles around Calcutta.

As a first step therefore, the Government has accepted a scheme for transmission and distribution of electricity in the North of Calcutta areas with the object of supplying electricity at a moderate rate in the towns and semi-rural villages.

Energy will be purchased in bulk from the Calcutta Electric Supply Corporation Ltd. at Mulajore at 33 kV and transmitted at 66 kV from Chord Road Receiving Station to Ranaghat, Santipur, Kalna and Bainchi. At Bainchi, power will be stepped down to 33 kV and from there one line will be erected to Burdwan via Memari, Rasulpur and Saktigarh, and another to Mogra via Pandua and Khanyan.

Further a 33/11-kV line will be run from Ranaghat to Krishnagar via Birnagar and Badkulla, and a second 33/11-kV line will feed Nabadwip from Kalna with a provision for future extension to Katwa. These lines will be insulated for 33 kV, but will operate initially at 11 kV. See Fig. 7.

It is expected that this scheme will be ready for operation by 1951; and supplies, both for domestic and industrial purposes, will be made available to Ranaghat, Santipur, Kalna/



**LEGEND.**

DEMAND IN MW IN 1934 & 5 YEARS SHOWN THUS	
66 KV OVERHEAD TRANSMISSION LINE	
33 KV OVERHEAD TRANSMISSION LINE	
11 KV OVERHEAD TRANSMISSION LINE	
CABLE U.G.	
FUTURE EXTENSION	
TUBE	
LIGHTNING ARRESTER	
T.P. HOBBSIAN ISOLATING SWITCH GANG OPERATED (SUITABLE FOR BREAKING THE MAGNETISING CURRENT OF TRANSFORMER)	
T.P. AIR BREAK ISOLATING SWITCH, GANG OPERATES	
EARTHING SWITCH	
TRANSFORMER	
BUS COUPLER	
OIL CIRCUIT BREAKER (DRAW OUT TYPE)	
" " " (NON DRAW OUT TYPE)	
T.P. BUS SECTION ISOLATING SWITCH GANG OPERATED	

GOVERNMENT OF WEST BENGAL  
ELECTRICITY DEVELOPMENT  
4, HASTINGS STREET, CALCUTTA.

NORTH CALCUTTA ELECTRIFICATION  
SCHEME  
DIAGRAMMATIC LAYOUT OF  
LINE & SUB-STATION EQUIPMENT.

**FIG. 7**

Kalna, Birnagar, Badkulla, Bainchi, Pandua, Khanyan, Mogra, Memari, Basulpur and Saktigar, all of which are at present unelectrified. When this scheme is completed, any factory within or near Burdwan, Nabadwip, Krishnagar and Naihati - an area comprising about 750 sq. miles - will be able to obtain supply at moderate rates. This should prove a great advantage to industrial planning in and around Calcutta, and help the dispersal of industries throughout this area, part of which is served with navigable waterways, roads and the whole of which is served with a good railway system.

The Electricity Development Directorate will undertake bulk supply to industrial power consumers and to the existing licensees in the area, thereby enabling these licensees to take supply at rates cheaper than those they are generating at present.

It is realised that there is a pressing need for rapid extension of electric supply in the area and therefore the scheme is being carried out as expeditiously as possible to cater for present loads as well as expected future demands for some years to come.

At/

At the beginning of 1949, orders were placed for the construction of 57 miles of 66-kV transmission line and 39 miles of 33/11-kV transmission line with the British Insulated Callender's Cables Ltd. Orders for 11-kV indoor switchgear have been placed with Steam & Mining Equipment (India) Ltd., and for 11-kV outdoor switchgear with G. E. C. (India) Ltd. Contracts for low-tension distribution lines have been made with three local firms (Associated Engineering Industries Ltd., Eastern Electric Co. and S.S. Bagchi). Orders have been given for 66-kV sub-station equipment to International General Electric Co. Ltd. Orders for transformers have been placed with the English Electric Co. Ltd., Parry & Co. and the British Insulated Callender's Cables Ltd. Surveys for 70 miles of route for 66 and 33/11-kV transmission lines have been carried out.

Pending the completion of the North Calcutta Electrification Scheme, the towns of Ranaghat, Santipur and Kalna are expected to be supplied with power before the end of 1949 by diesel sets purchased under the Diesel Electric Pool system for giving supplies to small isolated towns before they are connected to the main grid line. Supplies will be distributed at 400v 3-phase, 4-wire, with a frequency of 50 c/s. For lighting and/

and heating, 1-ph. supplies will be given at 230v, while power (except for small sized motors) will be 3-phase, 400v. Large factories in the area, however, will be able to take supplies at high voltage when the grid commences operation in early 1951.

In addition to the above North Calcutta Electrification and the Diesel Pool Schemes which are being implemented at present, the Electricity Development Directorate undertook the running of the Barrackpore Electric Supply Undertaking in December 1947, when its tenure of licence terminated. Pending the formation of a Provincial Electricity Board the execution of other schemes as may be approved will be the responsibility of this Directorate. The question of the formation of a Provincial Electricity Board to prepare regionally co-ordinated plans of electricity development is engaging the serious attention of the Government. The Board will be an autonomous body and it will operate like a commercial concern subject to Government supervision and will be charged with the duties of carrying out this expansion and co-ordinating the development of electricity throughout the Province.

##### 5. DEVELOPMENT POLICIES

Assuming that the Government in due course forms a Provincial/

Provincial Electricity Board charged with the duties promulgated in the Electricity (Supply) Act of 1948; then in accordance with Chapter V of the Act, three methods of operation are possible:

5.1.1.           OWNING AND OPERATING CONTROLLED STATIONS AND TRANSMISSION SYSTEMS AND CONTRACTING FOR ENERGY SALES TO ONE OR MORE BULK PURCHASERS.   This method virtually obtained with the Central Electricity Board in Britain prior to the passing of the Nationalisation Act of 1947.   Actually, the Board only owned one station but it had the complete operating control of 136 others.   It also owned practically all the main transmission lines in the country and a considerable portion of the sub-transmission lines.   The Board, however, did not sell, except in special circumstances, to individual consumers but only to licensed undertakings.   There is a somewhat similar case in India in the Tata Power Licence in that this Company may only sell in bulk to mills taking over 500 MWh per annum, or to distributing licensees.

The advantage of this method of operation is that the capital for the distribution system, as well as the operating costs of the distribution and consumers' departments, are eliminated, while the metering and billing sections are cut to/

to a minimum. The disadvantage is that in an area under development, a large amount of capital is tied up during the load building, and as licensees may not always be competent, the consumer may not receive the full benefits.

5.1.2. OWNING AND OPERATING GENERATING STATIONS TRANSMISSION AND DISTRIBUTION SYSTEMS, AND SELLING TO BOTH BULK AND INDIVIDUAL CONSUMERS. This is in line with the recommendation of the McGowan Committee Report set up in 1936 for the purpose of reorganising the Electricity distribution in Great Britain. The McGowan Committee recommends:

"The transfer to the Power Companies, where appropriate, of small undertakings in or adjacent to the Power Act area"

.....

"At the end of a prescribed period, which in no case should exceed 50 years, the consolidated undertaking of the retained power companies, including the part at present non-purchasable should be liable to be purchased by some form of public authority on the basis of capital expenditure less Depreciation".

5.1.3. PURCHASING ENERGY IN BULK, OPERATING TRANSMISSION AND  
The Companies were apparently to have no guaranteed life.  
The/

The McGowan Committee claims an advantage for large undertakings covering large areas and advocated far-reaching changes that (a) could be put into operation without any dislocating reconstruction of the framework of its present organisation and (b) which would have improved it while at the same time adequately recognising the claims of those who had built it.

This method of operation gives the owners of a Power Supply Company complete control of policy from the generation of power to its ultimate use and, as there is no middle-man, profits from efficient and progressive management go to the owners. The effect of these profits, however, is eventually passed on to the consumers in the form of rate reductions. As load building in undeveloped areas will take time, an undertaking operating under this method will seldom reach the profit-earning stage during the first five years. This is due to the high initial cost of the generating station which is usually built with regard to its ultimate life and equipped to carry the anticipated load during the first 4 or 5 years.

5.1.3. PURCHASING ENERGY IN BULK, OPERATING TRANSMISSION AND DISTRIBUTION SYSTEMS, AND SELLING TO INDIVIDUAL CONSUMERS. This method is, in a measure, a complement of (5.1.1.) and has/

has the advantage of a comparatively small initial capital outlay. The load-building policy to the ultimate consumer is in the hands of the operators, but it has a disadvantage in that the tariff policy is controlled from outside sources.

Where money is not plentiful, where development is desired without the prospects of immediate tangible returns and a well established power company is in the vicinity, the above would prove the wisest choice. The Government, as the middle-man, would be in direct contact with the consuming public and, by propaganda or canvassing, could effectively promote the use of electricity.

It is therefore expected that the Provincial Electricity Board, when formed, will purchase energy in bulk from the existing well-established generating stations and undertake the scheme of selling electricity in bulk to licensees existing at present and distributing the energy to individual consumers in other unelectrified towns and villages.

It should be appreciated that, at the present stage of electrical development in the province, the question of a comprehensive grid and inter-connection between different regional/

regional power stations does not arise. It will arise only when a few large-sized regional stations have been built and are in operation.

5.2. Comparison of Policies

The three methods of operation outlined in (5.1.), although often distinct in commercial operation, are not necessarily so when Government-sponsored. As an instance, after the enactment of the Electricity Act 1947, the North of Scotland Hydro Electric Board became responsible from April 1st, 1948, for generation, transmission, and distribution in an area of approximately 21,600 sq. miles, which includes the cities of Aberdeen, Dundee and Perth, the towns of Inverness and Oban, the area of the Grampian Electricity Supply Company, and the Undertakings of a number of smaller local authorities and companies. It now operates 9 hydro-electric stations, 6 steam stations and 32 diesel stations, with a total capacity of 250,500 kW. Units generated at these power stations during the calendar year 1948 (including the first three months when many of them were not under the Board's control) amounted to 741,357,500 kWh, of which water-power produced almost 50 per cent. The Board exported to the British Electricity Authority's grid in Central Scotland 79,085,200 kWh during the period April 1st to December 31st, 1948

5.2.1.

The following is a summary of the policies adopted by other Provinces in India - See Fig. 8.

BOMBAY The largest schemes in Bombay are the enterprises of the Tata Hydro-Electric Co. The whole scheme has been working under several licences and the Government has not rendered any financial assistance.

Apart from this large scheme, it is understood that the Government of Bombay's policy is to link the smaller towns to the existing Undertakings. Distribution and sales will be undertaken by the Government only where no suitable licensee can be found. It is the declared policy of the Government, however, to take over eventually the licences as they fall due.

A point of note is that the cotton mills and the Tata Hydro-Electric Undertakings are analogous to the jute mills and the Calcutta Electric Supply Corporation's scheme, so far as load is concerned.

MADRAS In 1935 the Government of Madras decided to embark on an electrification programme for the Province, to develop as Government-owned utilities some of their water power sources, and to own and operate all new generating stations. It distributes large industrial loads from the Governmental grid/

FIG. 8

# INDIA

SHOWING  
EXISTING AND PROJECTED POWER STATIONS  
AND  
MAIN TRANSMISSION LINES

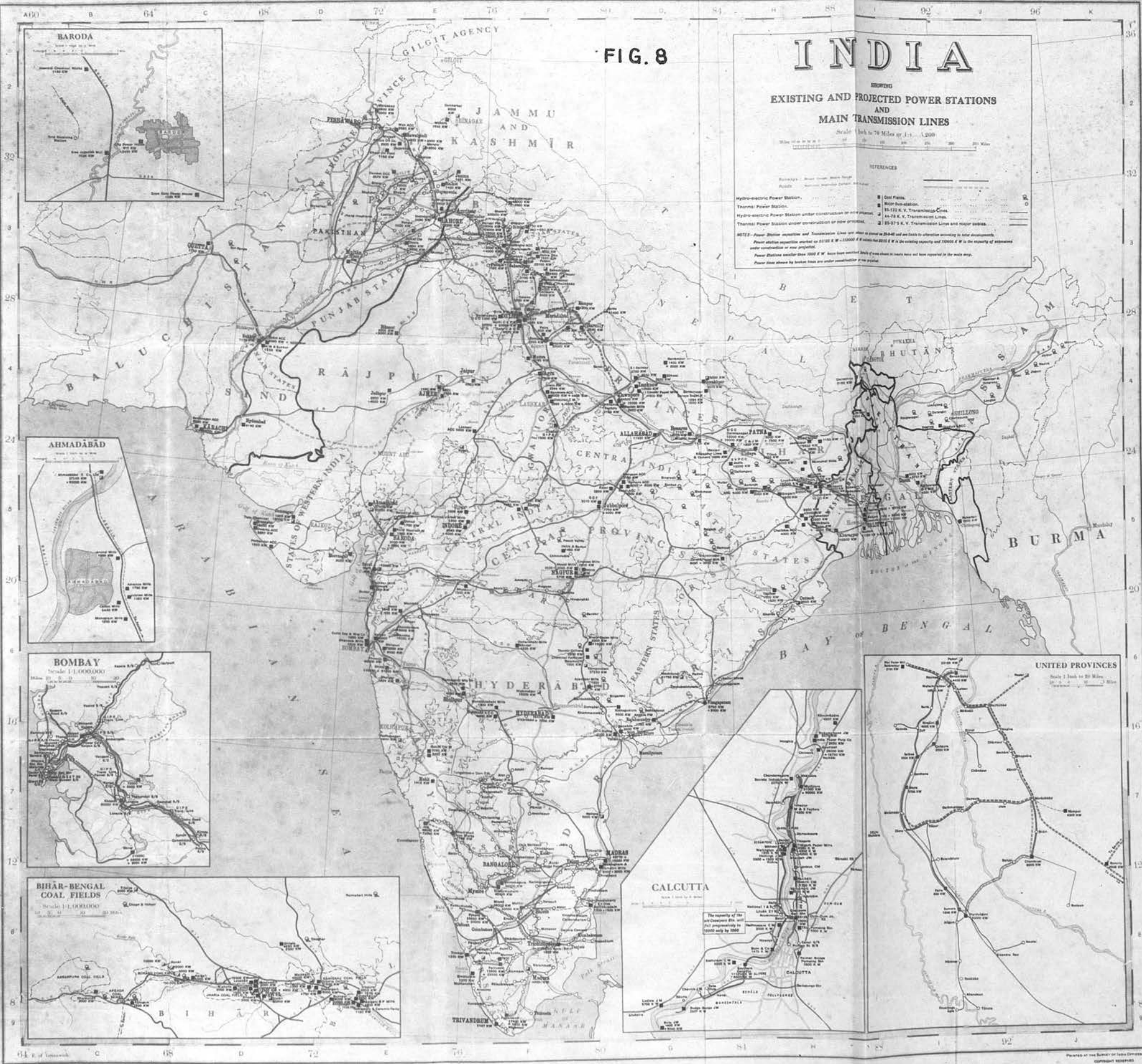
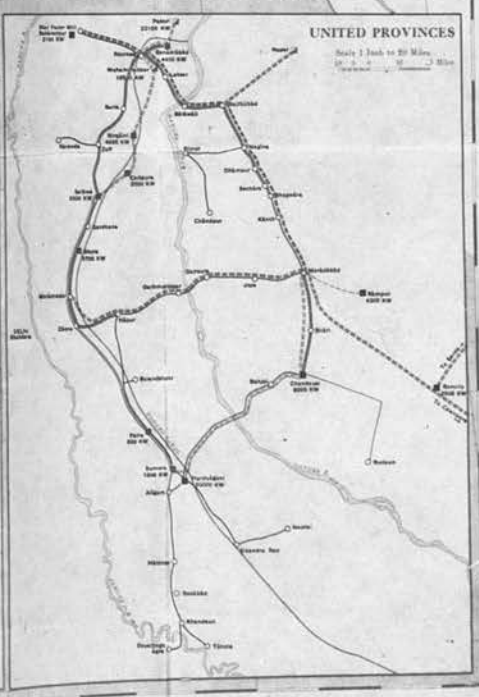
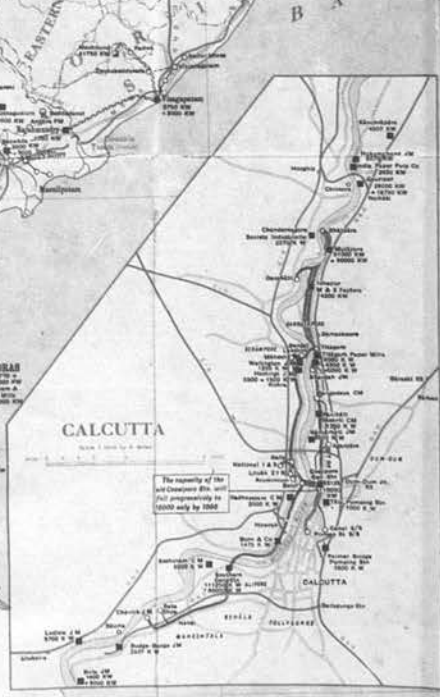
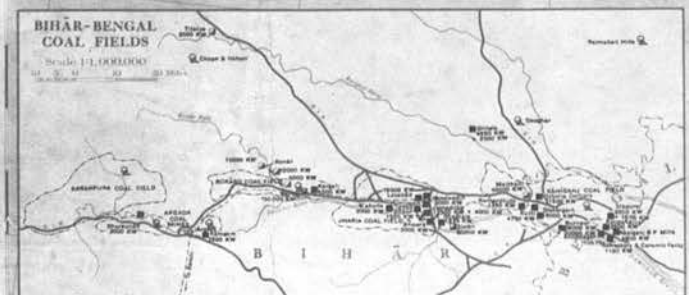
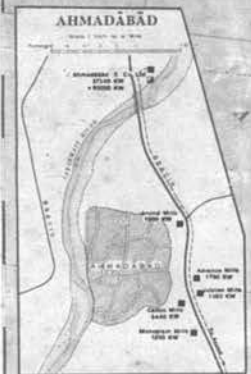
Scale 1 Inch to 75 Miles or 1:11,250,000

Scale 1 Inch to 75 Miles or 1:11,250,000

REFERENCES

- Hydro-electric Power Station
- Thermal Power Station
- Hydro-electric Power Station under construction or proposed
- Thermal Power Station under construction or proposed
- Coal Fields
- Water Reservoirs
- 15-22 K. V. Transmission Lines
- 44-75 K. V. Transmission Lines
- 220-375 K. V. Transmission Lines and major cables

NOTE: Power Station capacities and Transmission Lines are shown as stated in 1934-35 and are liable to alteration according to later developments. Power station capacities marked as 10,000 K. W. or 10,000 H. P. indicate the capacity of the station under construction or now projected. Power Station smaller than 1000 K. W. have been omitted. It is assumed that the capacity of the station is not less than 1000 K. W. Power lines shown by broken lines are under construction or proposed.



grid and gives retail supply in several villages and townships, but there are a large number of local-authority and company-operating licences supplying energy.

UNITED PROVINCES This Province also proposes to own all generating stations and take up distribution in rural areas not touched by licensees. In 1926, the Government of the Province took up the development of the Ganges Canal as a source of electrical energy. Its system has reached a lucrative stage and is being widely expanded. All hydro and steam stations are linked up and most of the Undertakings in the Province are supplied in bulk from the 'grid', which also supplies large industries and energy for irrigation.

BIHAR The present scheme for an electricity 'grid' in Bihar aims at developing the southern portions (where the fields are dry) and Chota Nagpur (from which comes the bulk of the world supply of mica); a good industrial load is also expected from the collieries. In the first instance, the Government of the Province intends to purchase power in bulk from the Central Government's Fertilizer Factory at Sindri. Later, it expects to utilise the output of the generating stations/

stations on the Damodar Valley to implement its requirement. At present, its plans are to sell energy in bulk to the existing licensees or to individual consumers.

ORISSA This Province is building a thermal station in the Northern area at Cuttack to give supply to the local licensee, which will shut down its diesel generating station. The power will also be used for developing local industries outside the licensee's area of supply and transmitted to Puri for the use of the licensee there. Plans are being prepared for an electric grid in the area.

CENTRAL PROVINCES The Central Provinces Government is building a large central station and running an extensive transmission system for supply to the licensees around Nagpur and Kamptee, as well as to large consumers in this area. It is also planning to erect a transmission system to interconnect Jubbulpore and Katni in the North and close down inefficient stations en route. Its present plans do not call for an extensive distribution system for supply to small individual consumers.

5.2.2. APPLICATION TO WEST BENGAL. With the exception of Madras, the Provinces exemplified in 5.2.1 have not shown the same inclination/

inclination to take up distribution to ultimate consumers where private enterprise is already in the field; but they buy in bulk, where practicable, for retail sales, and generate only where supply is not available and transmit to the consuming centres.

The policy followed by Madras Government of direct contact through sales with the ultimate consumers has, it is believed, produced the best results.

Assuming that it is decided to proceed in West Bengal with a large scale electrification programme of generation, transmission, and distribution, it is to be considered whether the means of organising and controlling such development are readily available. Staff will be required at Headquarters and in the field. Has Bengal this manpower available?

Pending development by the Government of available power resources in the Province, it will be found advantageous to buy in bulk for transmission and retail sales. In other words, by adopting the normal commercial procedure and having contact through sales with the ultimate consumers, the Province is sure to be benefited most in every phase of development and thereby will be able to train up its own manpower.

5.3. Suggested Organisation of Development Directorate

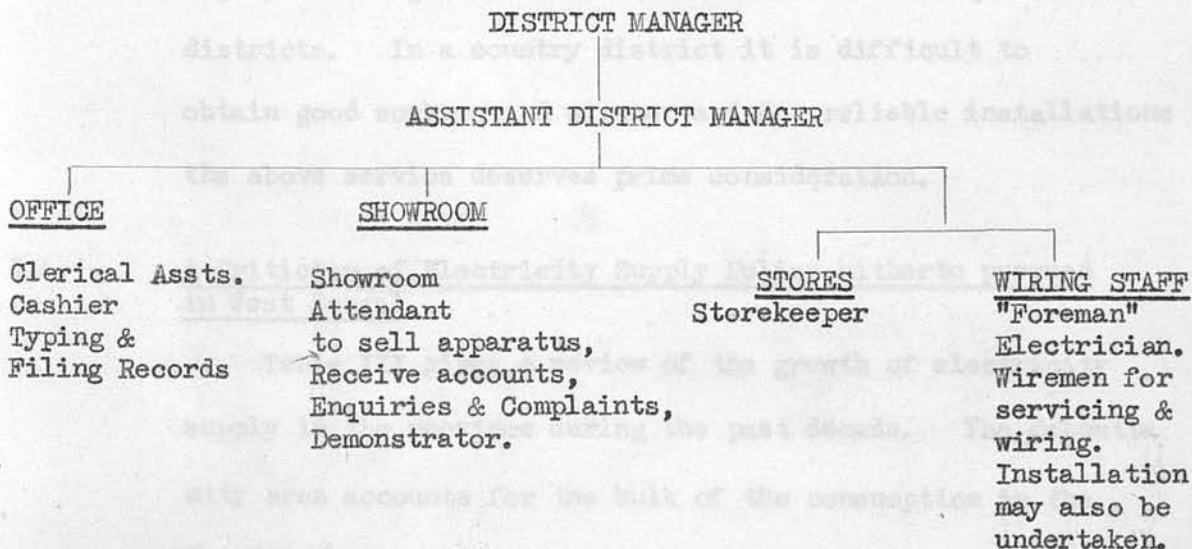
5.3.1. **MANAGEMENT.** The Electricity Development Directorate would be administered by the Ministry of Commerce and Industry, through the intermediary of an elected Board of Management called the Electricity Committee. The Chief Electrical Engineer, appointed by the Ministry of Commerce and Industry, would control the organisation through the different section heads.

The Chief Electrical Engineer should be responsible for all the engineering side of the Supply Organisation and should control the general policy of the department, advise the Committee on any change which may be necessary in policy and deal with all public relation problems.

5.3.2. **FINANCE.** Capital for financing any scheme of development of supply in unelectrified towns and villages in Bengal would have to be raised by loans by the Government at interest rates which are much lower than the average dividend rates on share capital of company-owned undertakings. For the first five or six years at least, deficits would have to be met either by outright subsidy, non-interest bearing loans or be carried on to capital until the schemes are eventually self-supporting.

5.3.3. DISTRICTS. The distribution areas should be divided up into districts, each to be operated by a District Manager under the direct control of the Administrative Headquarters at Calcutta. The district organisation would take care of the consumers in one or more of the neighbouring townships or villages, depending on the number of consumers, and the extent of the area. The District Manager and his clerical, sales and operating staff would be located in the most suitable centre for the convenience of the bulk of consumers. The District Manager and his staff may be considered as the "spear head" of the commercial organisation, in the maintenance of close contact with potential consumers and the strengthening of public relations.

5.3.4. DISTRICT ORGANISATION.



The District Manager's responsibilities should include the following :-

- Receiving of applications from new consumers.
- Service quotations.
- Assisted wiring schemes.
- Interviewing prospective consumers and negotiations with them.
- Wiring quotations and specifications.
- Advising consumers (Installation, Tariffs etc).
- Demonstrations.
- Canvassing and development of new areas.
- Electric Street Lighting, Maintenance and Development.
- Consumers' Complaints.
- Installation Work.
- Showroom - Supervision, sales and deliveries.
- Receipt of accounts.
- Meter Reading.

Showrooms would display and demonstrate a range of electrical appliances available for sale and would receive payment of consumers' accounts. Orders would be taken for all kinds of electrical installations and a permanently employed wiring staff should be attached to each of the districts. In a country district it is difficult to obtain good workmen and wiremen and for reliable installations the above service deserves prime consideration.

5.4. A Criticism of Electricity Supply Policy hitherto pursued in West Bengal

Table III gives a review of the growth of electricity supply in the province during the past decade. The Calcutta city area accounts for the bulk of the consumption in the Province/

TABLE III : GROWTH OF SUPPLY IN THE DECADE 1938 - 1948 FOR THE AREA  
NOW COMPRISING WEST BENGAL.

	By all Authorised Undertakers in the Province.		By the Calcutta Elec. Supply Co. only.		By the Gourepore Elec. Supply Co. only.		By the Associated & Dishergarh Power Co. Ltd. only.		The rest of towns in the Province.	
	1938 (1)	1948 (2)	1938 (1)	1948 (2)	1938 (1)	1948 (2)	1938 (1)	1948 (2)	1938 (1)	1948 (2)
Electricity sold to Consumers (MWh).										
lights and fans .....	56,840	124,583	54,803	118,481			477	46	1,514	6,056
power .....	360,895	700,685	294,674	574,033	33,451	63,240	31,611	56,546	1,159	6,866
public lighting .....	5,270	5,791	4,334	4,844					936	947
special contract .....	11,307		10,904						403	
T O T A L S .....	434,312	831,059	364,715	697,358	33,451	63,240	32,088	56,592	4,012	13,869

Province in all load categories. The Gourepore Electricity Supply Company caters for industrial power in a certain portion of the area situated about 20 miles north of Calcutta, while the Associated and Dishergarh Electric Power Company, who have two stations in the coalfield areas of Ranijunj, supply mostly the mining loads.

The rest of the Undertakings, totalling about twenty, are all of small output, mainly catering for domestic loads. Of these, nine receive supply in bulk from one or other of the above three companies and (except for the two hydro-electric stations at Darjeeling and Kurseong, which supply power for public lighting and domestic uses only) all the other plants are on thermal base, run mainly on crude oil.

The low demand for electricity in Moffusil has, in the past, suggested that the possibilities of development in West Bengal are likely to be centred in and around the Calcutta and industrial areas only, and that there is hardly any scope for development elsewhere in the province, even if a cheap supply of electricity were available. This view was given by Messrs Merz and McLellan in 1942 but they expressed the opinion that there might be some possibilities of agricultural load/

load for irrigation and in the draining of water-logged areas, and for chemical industries, if the Government followed a more active and generous policy of development involving possibly temporary financial loss.

On the other hand, public discussions on future industrial planning have created an impression that in Moffusil area, in which electricity prices are high, industrial development is being discouraged. The author feels that both the above conclusions are erroneous and the significance of electricity supply as a location factor is not properly understood.

The influence of electricity costs on the location of industry depends largely on the ratio which these bear to total costs. While it is true that industries in Bengal have developed mostly in the Calcutta area, it should be remembered that this development has been due to such factors as Calcutta's importance as a port and its command of good communications. In Calcutta, industrial and electrical developments have helped each other and, while it is true that in the initial stages the prospects of industrial development gave an impetus to electrical development in this region, it is also true that, later, it was the prospect of getting cheap power that led to the setting up of more factories and industries.

Wide separation of place of work from place of residence presents electrical difficulties which are removed by a location policy which takes the work to the workers rather than the reverse; because, while electricity undertakings want to sell to the industrialist, they also want to sell to his employees. Transmission costs are therefore reduced when factory and home are more or less near together.

In all Western Countries, a policy of industrial decentralisation is being followed by building Trading Estates in thinly-populated areas and developing planned compact industrial units. These can be served with an economy of transmission lines and substations.

There may also arise the problem of locating new industries in thinly-populated districts where strong social reasons obtain for doing so. There appears to be a consensus of opinion that the Government should evolve and execute plans for the improvement of the standard of living of the masses. The ways and means of achieving this are rapid industrialisation and the strengthening of agriculture by mechanisation, irrigation and drainage facilities. Electric power is essential to secure this objective. In this Province as well, it is recognised by all progressive people that/

that electrical service is essential to the life and prosperity of the nation. Its applications extend to every phase of human activity so that our domestic, business and public life become more and more dependent on the advance of electrical science.

5.5.

#### Applications of Electricity

Besides domestic, industrial and street lighting; domestic and industrial power loads; and similar well-recognised applications; an essential feature of a civilized community is an unrestricted supply of clean water, as without such supply, the community is always under the threat of epidemics and diseases. For the provision of a public water supply (the responsibility of the local authority) electrically-driven plant may displace other means of pumping because the initial capital expenditure is less and the installation can be operated and maintained more easily. This is true not only for towns; electricity can be utilised to solve problems in rural districts where water is used directly from unhygienic open tanks. Collaterally, the provision of good water supplies gives an effective means of sewage disposal. With the aid of electric power, quite small sewage disposal schemes can be easily established and economically operated.

In country districts it is possible by the use of electricity to encourage the development of rural industries by creating work for/

for the country people at slack seasons. They are thus enabled to put their otherwise idle time to good use and increase earning and spending power.

#### 5.6. The Potential Load in Bengal

It has been noted before that the industrial load outside the immediate vicinity of Calcutta, the capital of the Province, is inconsiderable except for the mines at the Ranijunj coalfield areas in the north-west of the Province. The major agricultural communities in the rest of the area do not enjoy even the primary urban amenities which are so often beyond their means.

The Ranijunj coalfield area, Fig. 9, is one great industrial activity, although to a limited extent agricultural occupation areas are found. The area coincides closely with the outline of the Associated and Dishergarh Electric Power Co.'s supply area and has attracted to itself large industries requiring cheap local fuel. Under the coal measure, especially in the neighbouring sister province of Bihar, iron ores have been worked and, in conjunction with the coal, have initiated the iron works industry in Bihar (Tata Iron & Steel Co. Ltd.) and in Bengal (The Indian Iron & Steel Co. Ltd.). These are however operated by individual large/

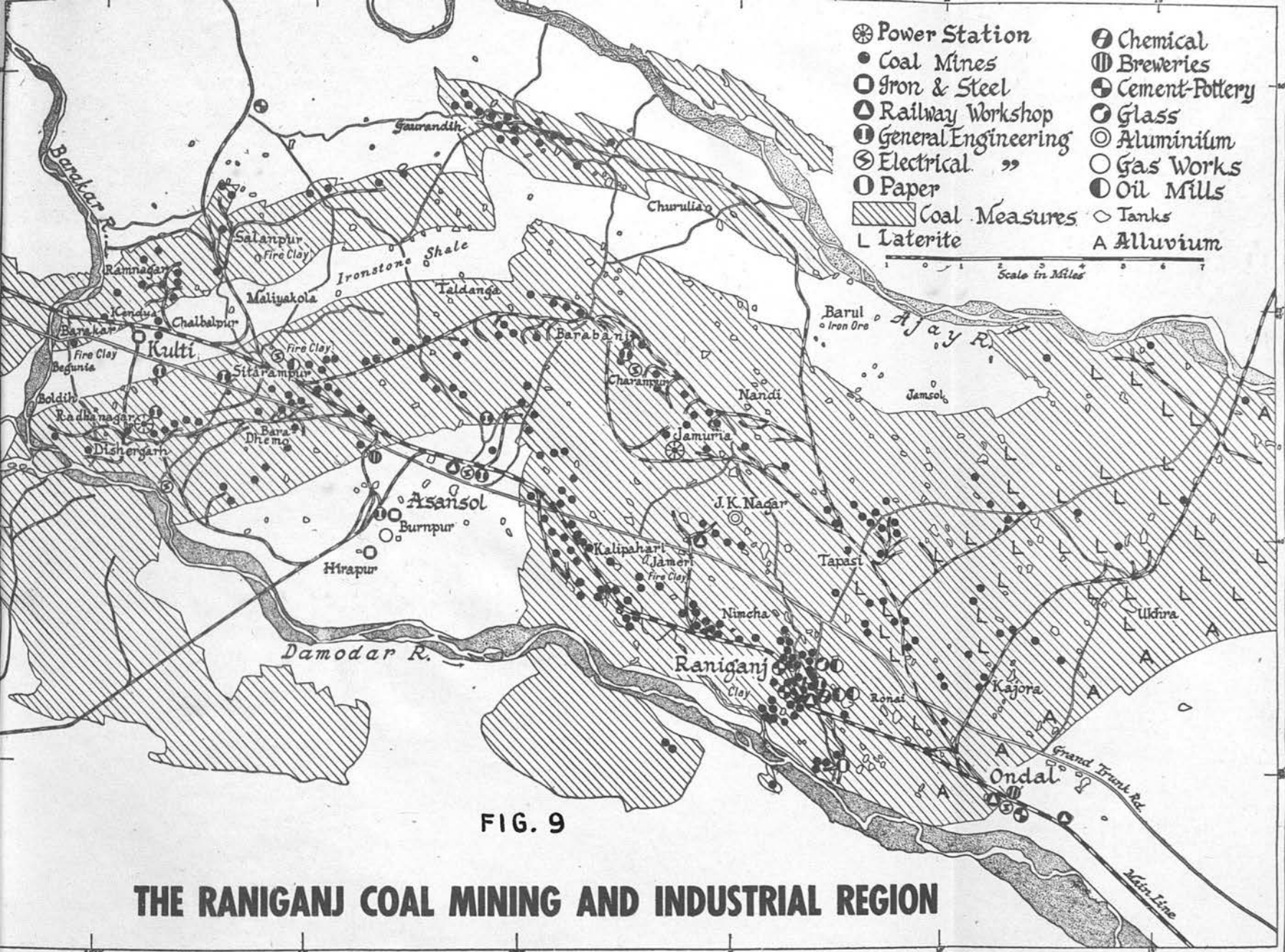


FIG. 9

**THE RANIGANJ COAL MINING AND INDUSTRIAL REGION**

large power stations owned by the industrial groups themselves. The whole area is served adequately by a network of railway lines, roads and river. All this activity has given birth to a number of subsidiary industrial activities, together with a vast trade to serve the needs of a corresponding dense population. Turning now to industries that could be developed, the following are suggested.

5.6.1. COAL. There are about 200 coal mines in W. Bengal, and only about a quarter of these use electric power. The larger portion of the colliery plant, which is steam driven, is old, and with a return to normal conditions extensive replacement by electrical plant may result. Many of the good thick seams are exhausted in this area, leaving thin seams of good quality but costly to mine, and thick seams of poorer quality. The most promising feature of the remaining difficult area is the gradual evolution of successful machine mining by coal cutters, face and truck conveyors, together with extensive mechanical haulage, all of which are particularly suited to the working of thin seams. The future of these seams depends entirely on electrical mining. If all the coal were electrically/

electrically won, the requirements in the industry would be enormous. Further, it is certain that machine mining will increase and also that greater attention will be paid to the preparation of coal for the market.

Coal mining offers, by reason of its extent and by the nature of the load offered, far the best prospect for extensive supply of electric power. Privately-owned steam plant at a colliery no longer shows such an advantage over purchased electrical energy. Cost of power supply per ton of coal is not an important factor from the mining engineer's point of view, in fact it is relatively unimportant compared with mining and labour costs. Any proposal for the development of electrical power would raise the question of power resources and their availability. As there are substantial fuel deposits in the coalfields of the Raniganj area, the development of pulverised fuel plant would enable relatively cheap coal to be utilised showing thereby a marked economy over the burning of good quality coal.

5.6.2. TINPLATE. The tin plate and galvanised sheet industry operates in this Province and in the sister province of Bihar./

Bihar. Several concerns are now utilising electricity in the process of tinning in preference to the older and more laborious method of solder baths. The nature of a tin plate works load is a good one from an electricity supply point of view, having the relatively high load factor of 40 - 50 per cent.

- 5.6.3. IRON AND STEEL. Some of the largest steel works in India are located within the Province and adjacent to coalfield areas. The future of the steel industry is, to a certain extent, bound up with that of the coal and coke industries.
- 5.6.4. CEMENT. These works are confined to neighbourhood where suitable limestone may be quarried. Present and future extension of roadways will provide a long period of intensive working for limestone quarries and crushed stones, these being required in large quantities for this work.
- 5.6.5. TEA. The tea industry, established in the districts of Jalpaiguri, Darjeeling and the Dooars, may offer by some degree of mechanisation a possible load development.
- 5.6.6. CHEMICALS. Large blocks of energy can be supplied at good load factors for driving machinery for electro-chemical process such/

such as the production of caustic soda, chlorine, hydro-chloric acid, and hydrogen for hydrogenation of oil and fats, production of soda ash. Factories for fertiliser production are in contemplation in India, and one is under construction at Sindri for the supply of fertiliser for agricultural requirements. There are also a number of factories producing glass and ceramic products.

5.6.7. OTHER INDUSTRIES. West Bengal has 27 cotton textile mills with over 2,600 looms and 110,000 spindles. There are numerous smaller industries, such as brick works, potteries, saw mills, bakeries, paper mills, printing works, oil mills, together with many others, serving the needs of the resident population. All these do not offer individually or collectively any load comparable with the main colliery, tin plate or steel works loads.

The above list is by no means exhaustive, and special mention of the above has been made because it is felt that a definite planning should be adopted for power generation in the province along with the association of some of the basic industries whose development is intimately related to industrial and economic growth.

Any supply scheme which will provide high voltage transmission/

transmission and retail distribution to the different parts of the Province, will make possible the dispersal of industry over wide areas. Besides the provision of cheap power, the possibilities of obtaining factory accommodation favourably placed in regard to water and transport facilities etc. at rates cheaper than in urban areas will attract capitalists to rural areas where labour can be obtained easily. It is therefore necessary that a National Industrial Council and the Electricity Development Authorities working in close co-operation should devote their energy to attracting light industries and develop trading estates on suitable sites. This would provide employment to workers who are surplus to the needs of agriculture and help to maintain an economic balance.

Industry established in Bengal has many natural advantages in that the agricultural products required for many industries are available in close proximity. The best tea and jute in the world are grown here, besides these there are abundant supplies of coal, tobacco, sugar-cane, oil seeds, lac, raw hides, timber and bamboo. Although Bengal proper lacks some of the necessary mineral resources, there is no dearth of mineral deposits in the sister provinces of Bihar and Orissa. Bengal is a big exporting centre for hides and skins and has an/

an extensive seaboard in the Midnapore region, in the Sunderbans, which offers great scope for the utilisation of brine for salt manufacture, as well as the alkali industry. There is also scope for the development of the cement and chemical fertiliser industries.

A rational location of industry in relation to raw materials, transport, labour and power supplies will make it possible to realise the highest economy of production.

5.6.8. RAILWAY ELECTRIFICATION. Plans are in hand to electrify the East Indian and Bengal Assam Railway, which will take their supply from the C.E.S.C. An electrified suburban railway system is to be run in Calcutta where large number of people require to be moved each morning and each night as quickly as possible over relatively short distances. Considerable quantities of energy will be required but the load factor is not high, although it can be improved once the tracks and the passenger stock have been provided by encouraging services in the off-peak hours.

5.6.9. AGRICULTURE. Electricity is now being extensively applied to farming in all advanced countries of the world and, to a moderate/

moderate extent, in some parts of India. Anyone who has toured in Mysore and in certain districts of Madras and U.P. cannot help being struck by the improvement which has been effected by the introduction of electric power in place of older methods.

Bengal is an agrarian province of which about 75% of the population depend for livelihood on agriculture. The total area of the province is 18 million acres of which about 10 million acres representing 55% of the whole is under cultivation. Apart from forest areas, about 2 million acres, equal to about one fifth of the area now sown, are available for cultivation but are as yet fallow. A greater part could be brought under the plough if irrigation facilities were available. However, even in this respect the area already under cultivation is badly served being dependent on the vagaries of monsoons. The growing seriousness of the world food situation makes the prospect of greater agricultural production of great social importance. Because electrified agriculture would directly affect 75% of the inhabitants of West Bengal, and because of the social implications, its development should have a high priority.



PART II

SECTION A

1. RURAL ELECTRIFICATION

In Part II a study of a specific area is made on technical, economic and sociological bases, and a scheme is devised for the comprehensive supply of electrical energy within a limited number of development years. The area is referred to as the East Calcutta Rural Area.

1.1. Introductory

The population of West Bengal, according to the 1941 census, is 21.2 millions. The urban population is 4.6 millions, chiefly centred at Calcutta (2.1 millions) or aligned on either bank of the Hooghly, opposite, above and below the city. This district accounts for 3.1 millions, so that "Hooghlyside" accommodates two-thirds of the urban population of the Province.

The rural population is 16.6 millions, so that the Province is, sociologically, predominantly rural in spite of the vast concentration/

concentration around Calcutta. The average rural density is 750 persons per sq. mile.

The problem studied here is one of extending electricity supply to that part of the rural population that may be expected to exert an effective demand. The prospects in remoter areas are of such a low order that years must elapse before economic schemes can be even considered.

The Government of the Province has already under construction a scheme of rural electrification covering the areas lying to the north of Calcutta. The problem both in this scheme and in East Calcutta (which forms the basis of this thesis) is one of reconciling the demands of the rural inhabitants for a supply of electricity at a low price, with the necessity for the Supply Authority to obtain sufficient return to meet the necessary interest and redemption charges on capital outlay together with the costs of energy, transmission and distribution. It has been brought out in a later section on "The Formulation of Tariff Structure" that the major difficulty in rural electrification is one of transmission and distribution costs and not of generation, as bulk supplies are available from the Calcutta Stations at a favourable rate.

The problem of rural electrification differs fundamentally from the problem of electricity supply in urban areas where the electric service already exists or is being planned. In the latter case, the only additional capital expenditure required for a consumer is for the service connection, or, at the most, for a short extension of the distribution system. In rural areas, however, where the transmission lines run through sparsely populated districts with isolated villages and comparatively few prospective consumers, an additional consumer might entail considerable extra capital expenditure. The ratio of the additional capital expenditure per consumer to the total cost of supply is thus unduly high. Considered upon their own merits, many of the rural extensions may prove to be uneconomic. As, however, the Government is considering the provision of a supply of electricity to be at least partly in the nature of a social service, the approach must necessarily be somewhat different. Account must be taken of the indirect benefits which may be expected to accrue to agriculture and the general well-being of the rural population from the provision of this service. By placing cheap motive power in the hands of the provincial town dweller and rural cultivator, the general standard of living may ultimately be raised and in turn demands for energy supplies for/

for the less immediate uses stimulated afresh.

In most Indian towns and villages, however, the population will require education in the potentialities of electricity as a means of increasing productivity, and staff will be required with an intimate knowledge of the assistance which electricity can provide in this direction. The valuable work in Britain of the Electrical Development Association, even though the public electricity supply in Great Britain is so well established, will amply repay its study and a quotation from the McGowan report, given below, exemplifies this fact.

"With regard to the general extension of facilities in both urban and rural areas, it is not enough that such facilities should be made available. Consumers must be encouraged to adopt them. To this end, supply authorities must employ efficient and specially trained personnel and must be prepared to carry out intensive canvassing and demonstrating, backed up by well thought out educational advertisement."

1.2. BRITISH AND AMERICAN RURAL SCHEMES

1.2.1. BRITAIN. In order to investigate the means by which electricity could be brought quickly within the reach of those living/

living in strictly rural areas, the Electricity Commissioners in England established two experimental schemes in Bedford and Norfolk. In each scheme it was envisaged that in the earlier years the scheme would not be self-supporting and financial assistance was given by the Treasury to the Local Authority, to extend over a period of ten years and to meet 75% of the annual deficit on the working of the scheme, such advances being repayable from the surplus of the succeeding years. These schemes have come up to expectations, and have almost entirely repaid the earlier advances.

A study of the accounts and statistics of the Special Rural Electrification Schemes in Great Britain (Bedford, Norwich, Dumfries, Kirkcudbright) for 1940 reveal certain interesting facts.

- (a) Each of the schemes was able to obtain a bulk supply at prices lower than the Grid Tariff for the area. The cost of electricity purchased was only 37 per cent of the total costs, whereas the remaining 63 per cent was accounted for by distribution, management, rates, rents, interest and loan repayments.

(b)/

- (b) With an active sales policy, a load factor of about 30% could be reached in 5 years.
- (c) The financial position at the end of the fifth year depended on the degree to which the scheme endeavoured to satisfy the demands. Generally speaking, these schemes which aimed at a high degree of saturation of demand (i.e. a high ratio of actual to possible consumers) showed a deficit at the end of the fifth year. On the other hand, by serving the most remunerative consumers first, a surplus was obtained.
- (d) All four schemes received some kind of special financial assistance (interest grants from the State, suspension of loan repayment etc.) in the absence of which a loss would have been recorded at the end of the fifth year.

In the case of one of these schemes, no profit was shown until its tenth year of operation, by which time the accumulated trading deficit had reached £28,500 for a comparatively small scheme covering an area of little over 100 sq. miles.

1.2.2.

U.S.A. In America the Roosevelt Government set up in 1935 the Rural Electrification Administration, and placed very large sums/

sums of money at its disposal for investment in rural electricity supply. Loans are advanced from the Federal Treasury by the Rural Electrification Administration for extensions of lines in rural areas. In the 24 States, the R.E.A. had up to 1946 approved of loans amounting to over 15 million dollars to 49 Public Utility Co-operatives (Co-operative Associations of farmers) and one public power body which undertake the organisation and management of rural supply under the guidance of the Administration.

The period of the loans was 25 years and the rate of interest varied from 3% to 2.46% during the fiscal years from 1936 to 1941. Up to 1941, some 308,000 miles of line had been put in commission to serve some 780,000 consumers.

The necessary supply is generally obtained by bulk purchase from an adjoining Power Company.

1.2.3. CANADA. In Canada, the Ontario Hydro-Electric Commission - a statutory Board, appointed by the Government and financed by the State - obtained powers in 1921 for bulk transmission and retail distribution of electrical energy direct to the ultimate consumers in the rural areas of Ontario. It was the first organisation where direct sale to individual consumers was undertaken by a State Electricity Board. It was however found necessary/

necessary for the Government to subsidise 50% of the capital cost of high tension lines on rural extensions, including the costs of transformers and service connections to the consumers. By an Act of 1930, it was further provided that any deficit on the annual working was to be made a charge on the revenue of the Province of Ontario and put in a suspense account, as a loan, until the rural power districts concerned operated with a surplus.

1.3. EAST CALCUTTA RURAL ELECTRIFICATION

The problem which is discussed in this section is the practicability of instituting a distribution scheme for an area of about 600 square miles lying east of Calcutta. In this area the average density of population is 1,000 per square mile. It is pre-eminently rural in character, with some eight load centres (rural towns) of no great magnitude. Particulars of these eight load centres are given in Table I, but in using these data there are reservations which should be borne in mind.

The last population census was conducted in 1941: the partition of Bengal arising from the creation of the two Dominions led to large population migrations between East Bengal (Pakistan) and West Bengal (Indian Union), and on balance the latter province has gained in numbers. In time this increase in population density/

density must give rise to additional permanent building development.

TABLE I.

Town	Estimated Population at 31.7.49.	Number of Permanent Dwelling Houses.	Number of Permanent Shops.	No. of Stalls or Bazaar Type Shops.	No. of Public Buildings ++
Barasat .....	25,000	1,400	50	100	50
Habra .....	15,000	750	30	80	10
Gobardanga ..	10,000	700	20	50	10
Bongaon .....	25,000	1,000	50	150	30
Baduria .....	12,000	300	30	50	10
Kolapota ....	500		20	30	-
Basirhat ....	30,000	1,600	80	150	50
Taki & Hashnabad ..	10,000	300	10	50	10

++ "Public Buildings" comprise Hospitals, Local Government Offices, Libraries and Schools.

The most notable social characteristic of this area is the relatively high population density and its continued increase, recent events having created rural densities of up to 1,000 persons/

persons per square mile. The pressure of population on available land and neglect of efficient cropping is resulting in shortages which are adversely affecting the general health.

During the monsoon period, a large quantity of surface water collects and gives rise to malarial conditions, whilst during the dry season, serious water shortage may prevail. At present, water supplies and sewage facilities are of a rudimentary character. Control of the water flow by conservation and irrigation methods would serve the double purpose of assisting agriculture whilst decreasing the incidence of malaria, with all its debilitating effects.

The land is flat alluvial and the area is distributed for the most part in a great number of peasant-type smallholdings centred around villages. About three-quarters of the land is cultivated, a large portion being devoted to paddy and jute, while the remainder is largely pasture.

The economic pattern is primarily that of a one-crop peasant-type rural economy - relying upon the rice crop for subsistence together with a few cattle for draught purposes. The crops grown for sale are mainly sugar cane, mustard seed, jute, linseed, tobacco./

tobacco. The more important of these crops (jute, sugar cane, and tobacco) are processed in the industrial centres in Calcutta.

The industrial activities in the rural towns are represented by small-scale rice-milling, sugar-cane crushing, sawmilling and brick making for local purposes, and such other ancillary trades as blacksmithing and light engineering repairs.

The East Calcutta Rural Area possesses fairly large cottage handicraft industries such as hand-spinning and hand-loom weaving: the mechanization of these and others such as silk-spinning, cotton-ginning and wood-working could, it is believed, all be carried out with the assistance of electric power were it made available. Experimental demonstration installations would be required to introduce the use of mechanised looms etc., and might be undertaken to encourage the use of electricity.

The climate of the area is semi-tropical with seven dry months during the year and five months monsoon with an average rainfall of about 62 ins. During the months of April and September, a mean temperature of 85° F. is experienced. During the early hours of the months of November to February, temperatures may fall as low as 50° F. Darkness falls at approximately 7 p.m. throughout the year.

1.4.

#### BASIS OF CONSUMPTION ESTIMATES

Fig. 10 has been prepared to show the seasonal variations of the total energy sales by public electricity supply undertakings in the electrified towns in Bengal outwith the East Calcutta Rural Area. The moving average of units sold per month has been plotted for the years 1939-45. The actual deviations from the moving average have also been delineated, as it is realised that not only is the resultant total or percentage increase at the close of a period important, but also the measure to which the energy consumption fluctuated during that period, since this will indicate the incidence of the system peak maximum demand. The curves show that the variability in general was well within 10 per cent. Similar results may also be expected in the consumption of electricity in the area now under consideration viz. the East Calcutta area.

1.5.

#### LOAD INCIDENCE

Estimation of load is essential in the preparation of a scheme for electrification. It is necessary to determine at what points and to what extent load may be expected, then to estimate the cost of the high-tension and low-tension equipment; plant must also be projected for the whole of the area and must be adequate for present and future needs. Whether or not it is all put down at once should not affect the layout.

**ELECTRICAL ENERGY DISTRIBUTED**  
**BY AUTHORISED UNDERTAKERS IN BENGAL**  
**DURING 1939 - 1944**  
**STUDY OF THE SEASONAL TREND**

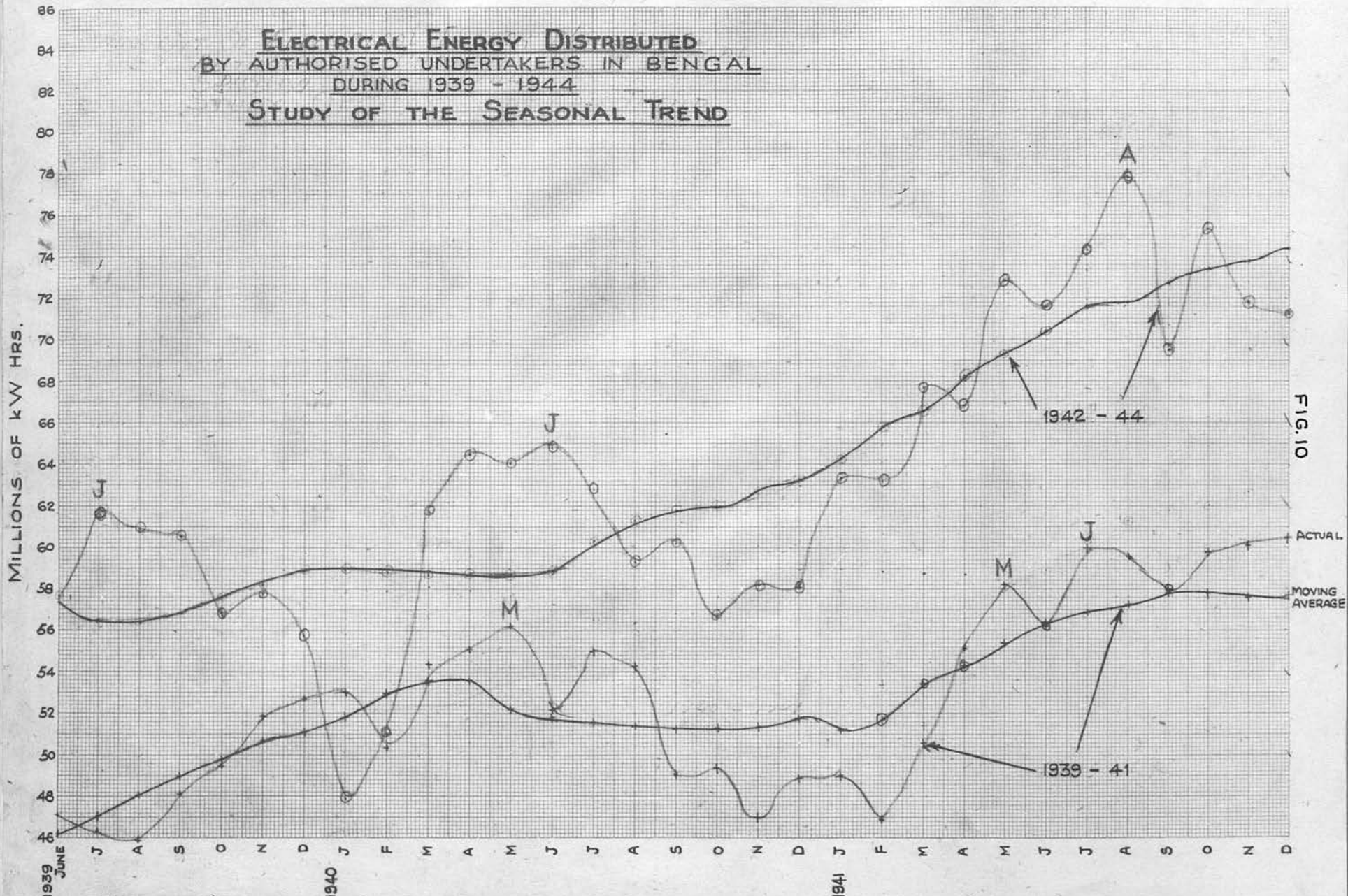


FIG. 10

1.5.1. TOWN LOAD. The total electrical load to be expected can be roughly divided among five classes, viz.

- (a) Domestic
- (b) Commercial
- (c) Industrial
- (d) Street Lighting
- (e) Water Works.

5.1. (1) Domestic

The greatest scope appears to lie in securing domestic load, as in view of the difficulty in obtaining oil for a household illuminant, electricity is likely to be most welcome. Besides, no public water supplies are available in these rural areas and it may be expected that private houses or groups of new houses may instal tanks fed by automatic pumps from tube-wells.

This load must necessarily vary in amount depending upon the size of the houses, and owing to the features described above will be confined to lighting on a fairly stable basis throughout the year for the period between 7 p.m. and 10 p.m.

Fans may be in use in larger households for the torrid months (April to September) during the hottest period of the/

the day (12 noon to 4 p.m.) and, in time, light domestic appliances and radios may be expected to form additional loads.

1.5.1.

(2) Commercial

The eight towns included within the East Calcutta Rural Area are characterised by a large number of small shops which are little more than open stalls, and which may be designated as "bazaar" type shops. A town of 30,000 inhabitants might possess about fifty large permanent shops and some 100 such small stalls. The large shops may employ up to 1 or 2 kW of installed lighting and 2 or 3 fans, whereas the smaller shops will obviously only require one or two 100w. lamps. Permanent shops close at 7 - 8 p.m. but the smaller ones may remain open until 10 p.m.

Most of the larger towns possess a cinema which, in time, will require a supply for a projector (replacing the existing diesel sets), interior lighting, fans and exterior illumination. These cinemas are generally fairly small and give one show per day.

Public buildings, hospitals, schools, are all small in size and will impose a moderate night load.

1.5.1./

1.5.1.

(3) Industrial

As may be expected from the outline above, industrial demands will be restricted to the needs of mills for rice, flour, mustard seed, sugar cane and sawmilling, some of which will be seasonal.

The type of load will be in the main served by 3-phase induction motors varying from 5 - 15 h.p. with some larger motors of up to 30 h.p. in the largest mills. Should some degree of agricultural re-organisation be instituted, the resulting mechanisation could give rise to small engineering industrial loads e.g. for welding and light machine-tool operation.

1.5.1.

(4) Street Lighting

The lighting of important thoroughfares is expected to materialise over a period of 5 years as an electrical load. But the standard of illumination will be low and load may consist mainly of 60w. tungsten lamps in the first instance served from the main distributing lines and poles of the Supply Authority.

1.5.1.

(5) Water Works

There is a potential pumping load of some magnitude/

magnitude in the area. In order that schemes for this purpose may be developed, it will be necessary in some of the poorer districts for capital cost of engineering work and pumping installations to be subsidised on a national basis. Except in the case of two towns in the area, the adoption of such schemes is considered to be a long-term future project and, as such, it is incapable of accurate assessment at present. It is, however, presumed that ultimately water supply schemes must be adopted for all rural towns, and the bulk of the load so created will be secured by the Supply Authorities, if electricity is available.

1.5.2. RURAL LOADS. The great majority of the agricultural plots in Bengal are very small in extent. Co-operative working of lands, and the assistance of the other Government departments for tapping sub-soil water, will bear good results, as has been found in the United Provinces. The possibility of selling water for agriculture, or for a de-watering service by pumping, might be investigated. This constitutes a power demand which electricity could best serve and the costs of which could be recovered as an all-in charge included in the land cess. Further developments in/

in the use of electricity for agricultural purposes, such as modern milling method through the medium of a complete hammer mill, and electrical milking equipment, will only materialise with co-operative working.

Supplies to the remoter villages are unlikely to be economic. The potential electrical requirements are for domestic purposes (lighting) and motive power for the electrification of cottage industries, e.g. hand-loom spinning and weaving and possibly some pumping load. Most of the farm processes are carried out by hand labour and given the present income distribution it is doubtful whether the electrification of these processes is likely to be possible in the next decade or so. The development of electricity service in rural areas especially where agriculture is the foremost industry has been realised in progressive countries by a gradual process extending over a period of time and in view of the relatively low monetary return on heavy capital investment has led other countries to the provision of State subsidies.

The social habits of the village communities would be revolutionised by the development of electricity supplies - but again the present low cash income position will exercise a deterrent effect towards their early provision.

Pending/

Electricity Commissioners for the United Kingdom, are not

Pending any Government decision on subsidy for purely rural supplies, it is evident from the above that, in the first instance, electrification on an economic basis can only be provided for the town loads set out in Table I of this Part. The scheme investigated hereafter attempts to provide for a transmission network for the towns, which could serve as a basis for future rural spurs or ring networks.

## 2. LOAD FORECAST

A survey is attempted of the possible future loads that might be expected from the towns and villages set out in Table I, paragraph 1.3. above.

- In making the survey, two lines of approach are possible -
- (a) A study of existing undertakings.
  - (b) A priori calculations of expected public requirements deduced from a knowledge of the economic and social conditions prevailing in the towns.

### 2.1. The Existing Undertakings

This study is rendered more difficult by the fact that comprehensive statistics, similar to those provided by the Electricity/

Electricity Commissioners for the United Kingdom, are not available for India. A project covering the provision of such information was begun in 1944, but the subsequent division of the sub-continent into two Dominions has prevented its realisation; and in any event comparison with previous years has now been rendered impossible. Statistical information showing the extent to which electricity has been sold by authorised undertaker in the City of Calcutta is given in Table II below.

TABLE II : CITY OF CALCUTTA : ANALYSIS OF ENERGY SALES

Year	++ Population Millions.	Unit Sales per annum, millions of kWh			Average consumption per head of population per annum, kWh	
		Total	Power	Lighting & Fans	All purposes	Lighting
1938.	3.012	364.7	294.7	54.8	121	18
1948.	3.313	697.4	574.0	118.5	210	36

++ 1938 - Population as per 1941 Census.

1948 - do. plus 10% assumed increase.

As Calcutta is the provincial capital, a large seaport, an industrial/

industrial town, and the centre of all communications, the statistics of the City and that of any other industrial undertaking, such as Gourepore or the Associated Power Company supplying industries and the coalfields, will afford no reliable guide on which an estimate of the potentialities of any rural project can be made. The Table also clearly shows the general effect of large industrial consumers on the average consumption per head of population, and also emphasises the value of large industrial loads in the development of electricity.

Taking the whole Province of Undivided Bengal, an analysis of electricity sales during 1946, under three major classes of utilisation, together with the corresponding per capita figure, is shown in Table III below.

TABLE III : UNDIVIDED BENGAL, ENERGY SALES FOR 1946  
Population (1941 Census) : 60,310,000

Load	Total MWh	Per capita kWh
Domestic and commercial (lighting, heating and fan loads)	141,080	2.34
Industrial power and traction	565,940	9.38
Water works	28,060	0.47
TOTAL ...	735,080	12.19

Again, the above includes Calcutta and other industrial undertakings. These include the larger industrial loads and also those of Darjeeling and Kalimpong, which have load characteristics peculiar to themselves arising from their climatic features and their role of holiday and convalescent hill resorts and educational centres. Statistics relating to the province are provided in Table IV.

Information relative to the undertakings in the whole Province of Divided Bengal (West Bengal) is informative but not relevant to the present study which refers exclusively to development of a rural area.

TABLE IV : WEST BENGAL, ENERGY SALES FOR 1948

Population (1941 Census plus 10%), 24,500,000

Load.	Total MWh	Per capita KWh
Domestic and commercial (lighting, heating and fan loads)	124,583	5.1
Industrial power and traction	700,685	28.6
Public lighting	5,791	0.24
TOTAL .....	831,059	33.94

From the figures of the undertakings in Divided Bengal therefore, six towns have been selected as representing a model area (although not geographically contiguous) comparable to the East Calcutta Rural Area in nature. Their load characteristics and sales of electricity are illustrated in the attached Table V. This table shows a wide divergence in the consumption of electricity as measured by the average number of units per head of population. But the general average for the 6 towns lies between 7 and 10 kWh per head of population for the years 1943, 1944 and 1945.

TABLE V : ANALYSIS OF ENERGY SALES AND NUMBER OF CONSUMERS IN SELECTED  
PROVINCIAL TOWNS IN WEST BENGAL

Name of Undertaking	++ Population	1943				1944				1945			
		Total Units Sold in Thous- ands	No. of Con- sumers	Average Units per cons- umer p.a.	Average units per head of population per annum.	Total Units Sold in Thous- ands	No. of Con- sumers	Average Units per con- sumer p.a.	Average Units per head of population per annum	Total Units Sold in Thous- ands	No. of Con- sumers	Average Units per con- sumer p.a.	Average Units per head of population per annum.
Bankura .....	47,083	258	443	582	5.5	288	432	666	6	288	436	661	6
Berhampore .....	41,973	142	401	354	3.4	172	416	413	4	171	430	398	4
Burdwan .....	63,539	498	966	517	7.8	562	976	576	8.8	615	972	635	9.5
Krishnagar .....	32,336	351	452	776	10.9	360	454	793	11.4	376	461	817	11.4
Malda .....	3,883	51	287	178	13.1	61	287	213	16.1	67	299	224	16.9
Midnapore .....	43,602	260	479	543	6	370	479	772	8.4	413	479	866	9.2

++ Population on the assumption of one per cent increase per year on 1941 Census figure.

2.2.

Basis of System Load Estimates

The above discussion will show that applying the ascertained results for areas already partly developed to other unelectrified and less affluent areas is uncertain unless the physical characteristics, the density of population, the habits and occupations of the people sufficiently agree. But it is believed that the average demand per head of population of the typical centres will afford some criterion as to the general consumption of electricity that may be expected and may be taken as representing the upper limits which may be obtained by the fifth year.

For none of the Indian undertakings, and in particular, for none of the six undertakings chosen as a model, have either comprehensive or sampling investigations of diversity and load factors for various classes of load been made. These factors will obviously be of a nature which reflects the social conditions peculiar to India and they cannot therefore be deduced from similar investigations undertaken elsewhere. If data of this description had been available, a possible method of approach to the problem could have been made by application of diversity factors to the estimated installed load to obtain the system maximum demand, deriving the energy consumption therefrom by means of load and efficiency factors. In the absence of such information/

information however, resort has been made to the a priori method in 2.3. below.

2.3. A Priori Calculation of Load

Surveys of the estimated population, number of permanent dwellings, number of shops both of permanent and smaller stall types, number of public buildings, cinema and possible street lighting requirements have been made as a basis for estimation.

Consideration must be given to the important part played by the cash income of the inhabitants of the area. Energy sales will necessarily be governed by the size of dwelling, but potential consumers are likely to be those in receipt of a cash income of (say) at least 100 rupees per month and who, accordingly, will be occupying the larger permanent dwellings. The capital cost of a simple domestic installation of eight lighting points, executed in V.I.R. protected by wood casing (the most common system employed in the Province) cannot be put below Rs.15/- per lighting point, a total cost of Rs.120/-, even taking into account the low cost of labour in India. Hence the occupiers of these larger premises will also be those who will request connection to the distribution network in the earlier years of development. The smaller and less-permanent houses and shops will follow at a later stage.

It/

It is of interest here to note that the average annual expenditure on kerosene for lighting purposes by the occupant of a permanent house is in the region of 60 rupees per annum, whilst those in smaller houses may expend up to 30 rupees per annum for this purpose. Kerosene for lighting is at present in very short supply, and consumers may well be expected to be willing to pay something over and above the cost of this form of lighting for a much better alternative service.

Table IV is annexed, which sets out, inter alia, the estimated average revenue per consumer from the six towns chosen as a model.

TABLE VI : REVENUE FROM SALES OF ENERGY IN CERTAIN  
TYPICAL TOWNS IN WEST BENGAL : 1945

Town.	Years of Operation.	Total Revenue from Energy Sales (Rupees)	Average Revenue per Unit Sold (Annas)	Total Annual Revenue per consumer (Rupees)
kura .....	8	70,372	3.90	171
hampore .....	13	50,998	4.75	133
dwan .....		154,032	4.0	188
shnagar .....	10	87,626	3.75	206
da .....	8	25,798	6.1	99
napore .....	13	108,454	4.2	243

The consumption expected from the various categories of load have been analysed, bearing in mind the relevant factors mentioned above. Estimated installed load and consumption habits are detailed in Table VII below. The power requirements in various small industries that may be expected are taken separately, so that an analysis can be made of their peak time responsibility on the total demand.

Pumping load for water works has been detailed separately from other power data, in view of the fact that special "Off Peak" rates may have to be offered for development.

A load estimate form designed for the purpose has been completed for each locality and for each year of forecast. A total of 50 such tables was required, and it has been deemed unnecessary to reproduce them individually and the results are shown in Table VIII and summarised in Table IX.

TABLE VII : FORECAST OF REQUIREMENTS OF THE DIFFERENT CLASSES OF LOADS

Class of Consumers	Installed Load (in kW.)			Period load in use	Year of connection to the Supply.
	Lighting	Fan	Others		
Large Domestic Dwellers.	1 kW	0.4 kW	Radio & Light domestic appliances 1 kW approx.	Ltg. 7-10 pm. all the year. Fan. 12- 2 pm. & 6-8 pm. from May to August. Radios & small domestic appliances 1 hr. each day.	Between 1st to 3rd year of operation.
Small Domestic	0.5 kW	0.1 kW	Few may have radio & domestic appliances.	Ltg. 7-10 pm. Radios and small domestic appliances 1 hr. each day.	4th and 5th year of operation.
Permanent Shops	1 kW	0.2 kW		Ltg. 6-8 pm. for 300 days. Fan. 12-8 pm. for May to August, excluding Sundays.	Between 1st to 3rd year of operation.
Small Shops	0.5 kW	-		Ltg. 7-10 pm.	Between 1st to 5th year of operation.
Industrial.	-	-	5 to 15 kW Induction Motors.	This load will be imposed during the cooler portion of the day from 8 am. - 12 noon, 4 - 6 pm.	do.
Cinema	2 kW	1 kW	5 kW Projector Load.	0.2 kW of lighting for 4 hrs 1.5 kW of lighting for 1 hr. 5 kW of Projector load for 4 hrs. 1 kW of Fan load for 4 hrs, 300 days.	Connection is likely between 1st and 3rd year in some towns.
Street Lighting	50 - 100 lamps of 60W.	-	-	7 pm. to 12 midnight all the year round.	This is likely to mature in one town during the 1st year of operation. Others may follow later.
Water Works.			15 to 30 h.p. Motors.	6 - 11 am.	This will vary according to the town but it is only to be expected in the later years of development.

2.4. Load Curve.

A model load curve for the system together with the constituent components are shown in Fig.11.

The characteristic peak of the system load may be expected to arise as a result of the extensive uniformity of consumption habits of the different classes of consumers. Of the component parts of the system demands, the industrial and water pumping loads are the only ones which will not contribute to the "system peak". The diversity between the other classes of consumers (domestic, commercial, cinema and public lighting) will be negligible, and furthermore, owing to the habits of the population concerned, the diversity between different consumers belonging to the same consumption category will also tend to be low. Some variation in the actual system maximum demand can be expected over the period of a year: the addition of fan loads during the hot weather season will be the principal cause of this feature. The graphical presentation of the 12 monthly deviations from moving average in Fig.10 serves to illustrate this tendency. Over the daily 24-hr. period, however, the incidence of maximum system load is to be expected, almost without exception, in the early evening hours, say between 7 and 9 p.m., as a result of the regular hours of darkness and/

FIG. No 11.

ESTIMATED LOAD CURVE & COMPONENTS OF THE DEMAND  
ON  
THE EAST CALCUTTA RURAL ELECTRIFICATION  
(5<sup>TH</sup> YEAR OF OPERATION)

INDUSTRIAL LOAD  
DOMESTIC LOAD  
COMERCIAL LOAD  
STREET LIGHTING  
COMBINED LOAD

KILOWATTS

700

500

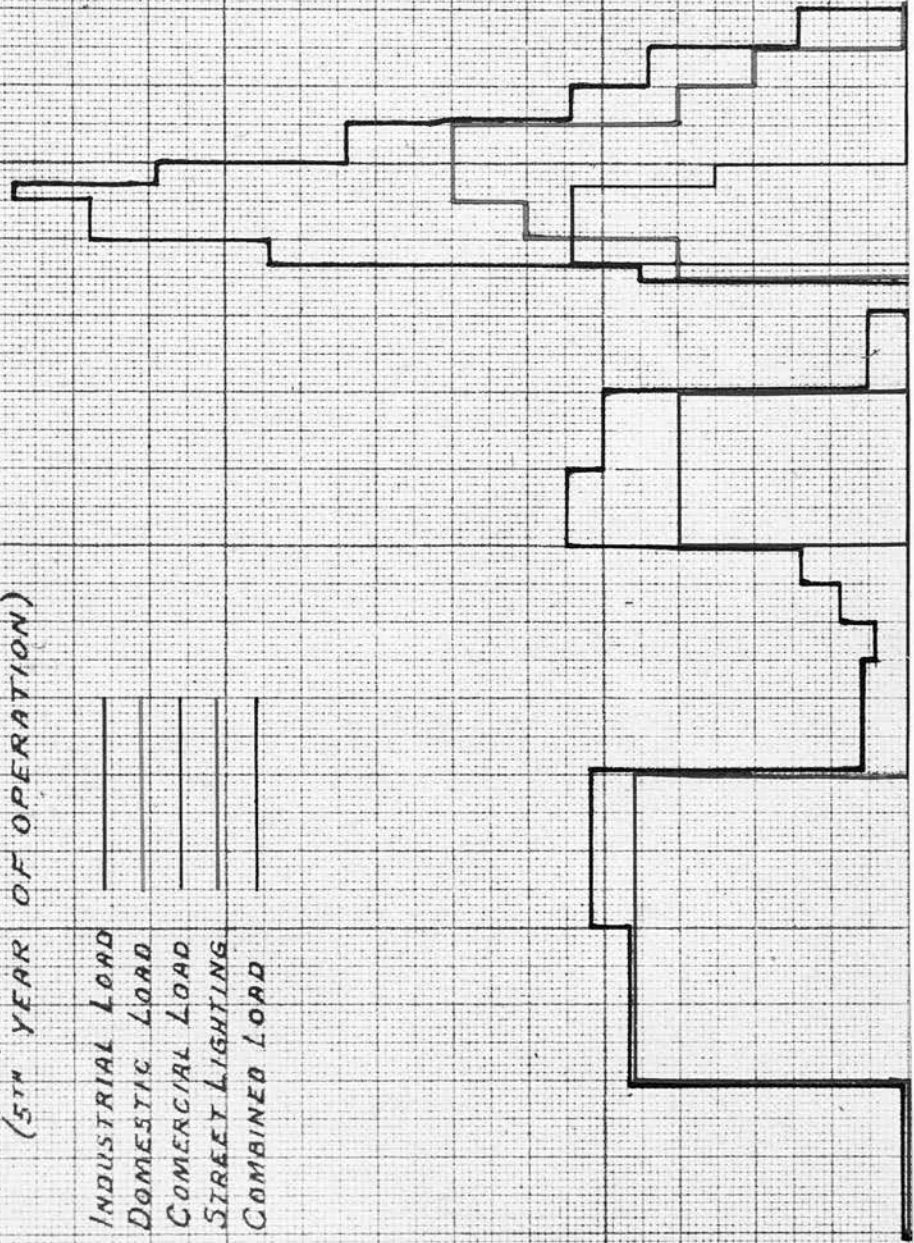
500

400

300

200

100



and the social habits of the population. There is also very much less fluctuation in the residential and commercial load groups: but should the industrial and manufacturing activities of the area be greatly accelerated, the effect on the system load may be to produce a peak earlier in the day.

From Tables VIII and IX mentioned above it appears that the domestic and commercial consumers (lighting and fan loads) are to account for 48% of the total energy sales, industrial power consumers (light rural industries) for 48%, and 4% for public lighting. The curves in Fig. 11 are so constructed that the areas bounded by them accord with the estimates of system maximum demands, load factors and energy sales.



TABLE IX LOAD ESTIMATE5 YEAR PERIOD

YEAR OF OPERATION	TOTAL NUMBER OF CONSUMERS	ESTIMATED SALE PER ANNUM TO CLASSES OF CONSUMERS					ESTIMATED LOSS ON UNITS + PURCHASED	ENERGY PURCHASED AT BULK SUPPLY POINT		
		DOMESTIC	COMMERCIAL	INDUSTRIAL	STREET LIGHTING	TOTAL		UNITS	K.W.	L.F. %
1st	750	138,700	165,400	109,000	7,300	420,400	18%	512,682	279	21
2nd	1,300	228,900	223,900	218,000	25,500	696,300	16%	828,928	420	22.5
3rd	1,700	269,100	247,400	362,300	40,200	919,000	15%	1,081,177	521	23.7
4th	2,000	301,700	263,600	495,000	43,900	1,104,200	14%	1,283,954	604	24.3
5th	2,250	327,100	285,000	611,400	55,000	1,278,500	12%	1,452,841	671	24.7

+ System Losses have been calculated for the different years of operation and are discussed in the next section.

2.5. Load Comparisons

Statistics for 1948 for the six selected towns (Table VI § 2.3.) covering the energy sales divided according to classifications above, are shown in Table X.

TABLE X COMPARISON OF LOAD

Consumer Category	Units sold in six selected towns		Estimated sale in the East Calcutta Scheme (5th year of operation)	
		% of total		% of total
Domestic & Commercial.	1,705,174	55	612,100	48
Industrial Power.	1,231,190	40	611,400	48
Public Lighting	144,238	5	55,000	4
TOTAL	3,080,602	100	1,278,500	100

Corresponding details for the area under consideration obtained from the load estimation tables are also shown for the fifth year of operation for comparison. It will be seen that from this view point the estimates accord closely with past experience.

Further details for the six typical towns and also estimate for the East Calcutta Rural Project are given in the table below.

TABLE XI SALES COMPARISON

	Units sold per consumer per annum.	Units sold per capita per annum.
Average for the six selected towns for 1945	627	8
Average for, the East Calcutta Project (Estimated 5th year of operation)	568	10

The estimate submitted above is believed to be conservative and takes no consideration of the measures the Government might adopt to accelerate the development. There is a good deal of potential domestic and rural demand which when the restrictions are removed will tend to new industrial developments and the demand is likely to increase. The new industrial centres might in the absence of control, shift as is usual towards Calcutta in order to gain proximity to markets. The Government may decide to impose measures to prevent this tendency and secure some degree of dispersion. Any such measure would exert a favourable effect on the financial standing of the proposed scheme.

PART II

SECTION B.

3. TECHNICAL DESIGN FEATURES OF NETWORK FOR  
EAST CALCUTTA RURAL PROJECT

3.1. General.

The technical scheme for the development of the East Calcutta Project (See map Fig. 12.) is based upon bulk supply at 33 kV from the Calcutta Electric Supply Corporation Ltd. at the Chord Road Substation. (Arrangements are being made for this substation to receive supplies for the North Calcutta Scheme now under construction). A supply is also obtainable at 6.6 kV from the substation of the Barrackpore Undertaking now being run by the Government of West Bengal after obtaining supplies in bulk from Calcutta Electric Supply Corporation Ltd.

3.2. Special Features.

In planning a scheme for electrification, it is necessary to consider the special local climatic and geographical conditions obtaining.

3.2.1. TERRAIN. The area is fairly flat, offering no geographical obstruction. The soil is arable land, moist for most of the year and giving no undue earthing difficulties. There are no river crossings except for monsoon flooding which may require more carefully constructed/

constructed tower footings. The area thus presents a straightforward problem involving no special constructional features and suitable for standard line equipment.

2.2.

TEMPERATURE. To estimate the normal variations of temperatures to be expected in the area, the following table has been compiled from records of the Meteorological Dept., Alipore (Calcutta).  
(Lat.  $22^{\circ} 32' N$ ; Long.  $88^{\circ} 20' E$ ; height, 20 ft.).

TABLE I : MAXIMUM AND MINIMUM SHADE TEMPERATURES, °F.

Months.	1941		1942		1943		1944		1945		1946		1947	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Jan.	84	49	84	51	88	52	89	50	86	47	87	47	83	50
Feb.	93	54	94	50	88	49	90	54	92	49	93	55	90	52
Mar.	106	63	101	64	101	60	97	63	100	57	102	62	100	63
Apr.	107	73	103	69	101	67	101	66	101	68	96	68	108	74
May.	102	72	108	74	100	73	105	72	100	72	101	69	103	73
June.	100	74	106	76	97	74	109	75	104	76	98	74	99	75
July.	95	75	95	77	95	76	95	76	94	78	93	76	95	78
Aug.	95	75	93	75	93	76	97	75	96	76	-	-	95	75
Sept.	96	77	93	76	95	77	95	75	94	76	95	75	96	76
Oct.	95	67	94	71	95	68	94	67	94	70	93	69	95	66
Nov.	90	67	89	61	92	59	92	55	89	57	88	59	92	59
Dec.	86	53	86	50	85	55	86	51	84	47	86	54	86	51

Approximate additions to above for sun temperatures, °F.

Jan., 55; Feb., 64; March, 63; April, 62; May, 66; June, 71;  
July, 71; Aug., 67; Sept., 66; Oct., 67; Nov., 62; Dec., 65.

The figures in Table I indicate that the normal range of shade/

# WEST BENGAL RURAL ELECTRIFICATION

## THE NORTH CALCUTTA TRANSMISSION SCHEME

THE LICENSED AREA OF SUPPLY OF THE  
CALCUTTA ELECTRIC SUPPLY CORP<sup>N</sup> LTD.

THE BARACKPORE ELECTRIC SUPPLY UNDERTAKING  
TAKEN OVER BY GOVERNMENT  
AREA COVERED BY THE PROPOSED EAST  
CALCUTTA PROJECT

- PROPOSED 66 KV TRANSMISSION LINE
- " 33KV " "
- " 11KV " "
- STEAM POWER STATION (EXISTING)
- ▲ DIESEL " "
- - - PROVINCIAL BOUNDARY
- ROAD METALLED
- - - UNMETALLED
- RAILWAY
- RIVER

SCALE 1" = 4 MILES

FIG. 12



FIG. 12

shade temperature variation is  $47 - 109^{\circ}\text{F.}$ , no temperature higher than  $109^{\circ}$  having been recorded during the last 10 years. The corresponding sun temperatures are  $47 + 55 = 102^{\circ}\text{F.}$  in January and  $109 + 71 = 180^{\circ}\text{F.}$  in June. Thermal ratings of transformers and feeder equipments need to be reduced considerably in view of these high ambient temperatures.

3.2.3. WIND. Table II gives the maximum wind velocities recorded at the Alipore Observatory for the years 1939 - 47.

The table indicates that the maximum wind velocities were recorded in the summer months for each of the ten years of record examined. Meteorological records also show that over the same period on only three days did the maximum velocity exceed 70 m.p.h. and that only for a few minutes. The normal wind velocity seldom exceeded 30 m.p.h.

TABLE II : MAXIMUM WIND VELOCITIES, m. p. h.

	1939	1940	1941	1942	1943	1944	1945	1946	1947
Jan.	28	21	45	20	22	27	18	24	30
Feb.	38	43	37	44	39	37	26	32	27
March.	33	53	34	36	46	51	29	38	35
April.	40	35	52	46	46	42	39	62	38
May.	74	60	48	50	44	46	36	80	48
June.	64	67	46	50	39	50	-	52	49
July.	35	69	43	50	40	34	-	44	40
Aug.	57	33	47	35	30	27	-	34	48
Sept.	39	41	37	30	38	25	-	36	32
Oct.	29	31	33	67	39	30	-	50	40
Nov.	28	20	22	34	20	20	28	22	22
Dec.	20	23	20	22	20	16	28	26	26

- = no record.

The effective wind pressure on a plane surface may be obtained from  $p = 0.0032 V^2$  where 'p' is the pressure in lb./sq. ft. exerted by a wind of velocity V m.p.h. In calculating pressure, only the projected area of the surface need be taken into account. For circular conductors the streamlining of the air flow permits 2/3 of the projected area to be used. For the maximum recorded velocity of 80 m.p.h., wind pressure is 20.5 lb./sq. ft. For a velocity of 30 m.p.h. the corresponding pressure is only 2.88 lb./sq. ft. It is to be noted that the worst wind loading condition does not occur at the time of minimum temperature, when the stress in the conductor is high, but is to be expected in the summer, when sudden squalls of short duration may occur. During the low-temperature period the wind loading is relatively light.

As tower costs are affected by sag, it is a matter for careful consideration whether conductors should be strung at maximum temperature to a definite tension limit or to a higher sag. This is discussed more fully later.

3.2.4. HUMIDITY AND RAINFALL. The humidity values in Calcutta recorded from 1943 onwards are given in Table III.

TABLE IIIA : MAXIMUM HUMIDITY, PER CENT.

Month	1943	1944	1945	1946	1947
January.	100	100	100	100	100
February.	100	100	99	100	100
March.	99	100	100	99	100
April.	99	100	99	100	99
May.	100	98	100	100	97
June.	100	99	100	98	100
July.	99	100	100	100	96
August.	98	100	100	x	99
September.	98	99	100	100	98
October.	100	99	100	100	99
November.	100	100	100	100	100
December.	100	100	100	100	100

TABLE IIIB : MAXIMUM RAINFALL IN 24-Hr. PERIOD, INCHES.

Month	1940	1941	1942	1943	1944	1945	1946	1947
January.	0.00	0.74	0.02	1.84	1.15	0.74	0.00	0.09
February.	0.13	0.00	0.12	1.26	0.25	0.31	0.56	0.29
March.	1.36	0.01	0.07	0.24	0.89	0.54	0.28	0.68
April.	0.06	0.34	0.79	1.53	0.55	0.84	0.61	0.36
May.	2.17	1.19	0.47	0.97	1.37	1.06	1.09	2.22
June.	1.68	4.06	1.53	2.68	3.73	3.45	1.83	1.72
July.	3.00	3.47	2.59	2.07	1.63	1.08	1.85	5.47
August.	2.07	4.53	1.65	3.56	6.48	1.05	2.74	4.09
September.	3.24	1.89	3.22	1.38	2.05	3.11	6.85	5.73
October.	1.44	4.38	4.54	0.64	2.46	4.24	3.26	1.06
November.	0.00	2.86	0.17	0.00	0.00	0.00	1.26	0.00
December.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.83

Table IIIA shows the humidity in the locality to be very high throughout the year. The heaviest rainfall (Table IIIB) during the monsoon may be as much as 6 inches in 24 hours. Special precautions are therefore necessary for protection of equipment against wet weather conditions. Moreover, sudden downpours during/

during the hot summer months will cause abrupt changes of temperature. The dangers due to variation of stress resulting therefrom are important in the case of high-voltage line insulators where, due to the cementing of parts and non-homogeneity of material, such thermal stressing is most likely to occur. Again, insulators must not flash over during heavy rain and high humidity. The insulators are also subject to the changes in line tension and to vibration, as a result of the rapid changes. The temperature-cycle test of alternate immersion in hot and cold water (B.S.S. 137:1941) is important for proving insulators in this case.

3.2.5. LIGHTNING. Lightning storms are more frequent during monsoon periods. Unfortunately no record is kept of lightning incidence at the Alipore Observatory, but the data given in Table IV is derived from the British Meteorological Office records.

TABLE IV : MONTHLY THUNDERSTORM AVERAGES, 1900 - 1926.

---

Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
0.04	0.55	2.2	4.8	6.1	2.9	0.63	0.63	0.93	0.22	Nil	Nil

---

3.3. Regulations.

Overhead-line design is generally governed by official Regulations, which lay down factors of safety, loading conditions, minimum ground clearances, and provisions relating to road crossings, telephone interference, etc.

3.3.1. EXISTING REGULATIONS. The design conditions specified for the Province of West Bengal are as follows :-

- (1) Ice loading is to be ignored.
- (2) The minimum and maximum temperatures specified are to be 50°F. and 130°F.
- (3) The wind is assumed to blow horizontally on the line conductors and to exert a pressure equivalent to 20 lb./sq. ft. calculated on 2/3rds of the projected area of the conductors.
- (4) Factors of Safety.
  - (i) 2, for conductors (under conditions of maximum loading and minimum temperature).
  - (ii) 2.5, for metal supports (wind assumed to exert a pressure equivalent to 20 lb./sq. ft. on  $1\frac{1}{2}$  times the area of one face of the support).
  - (iii) 3, for guard wires or bearer wires.
- (5) The minimum height of conductors is to be not less than 20 ft. from the ground at any point of the span at a temperature of 130°F.

The loading conditions in Bengal are not only less severe than in the U.K., but there is less difference between the loaded and unloaded/

unloaded conditions. The same minimum figures for safety factors as El.C.53 in the U.K. are, however, specified; this would appear to be unreasonable.

3.3.2.

PROPOSED ALTERATION OF REGULATIONS. The loading conditions adopted by the different Indian Provincial Governments has been criticised as irrational, and further consideration has been recommended with a view to reduction in line costs. (Coventry, Proc. I.E.E. 96 (II), 521 (1949).

In Britain also as the result of extensive experience of high-voltage overhead lines, suggested modifications of the present code of Overhead-Line Regulations El.C.53 (1947 Revised) have been published (See Crimmett, Proc. I.E.E. 96 (II), 673/699 (1949) to elicit criticism before the preparation of a final draft.

The object of the proposed amended regulations is to reduce the capital cost of overhead lines, to simplify construction, to reduce ground clearance and to improve appearance without affecting public safety.

Many of these suggestions will, no doubt, be suitable to Indian conditions, and if implemented will materially reduce the cost of line construction. As an example the following may be cited :-

(a)/

(a) Minimum Conductor Ground Clearance

This is 17 ft. for 11 and 33-kV lines, and 19 ft. for 66-kV lines, except at road crossings where the clearance is 19 ft. for 11-kV and 20 ft. for the higher-voltage lines.

(b) Earthing and Bonding

The new regulations permit non-earthed metal work on wood pole supports.

(c) Road Crossings

It will not be necessary to provide duplicate insulators, earth bars or arcing horns at road crossings. The construction will be similar to that for normal spans, subject to the use of insulators of the next higher rating to that recommended in Table 2 of E.S. 137: 1941 for the appropriate line voltage.

(d) Factors of Safety

There is a suggestion for dropping of the term "Factor of Safety" in the case of overhead lines. An empirical formula has been proposed for tensioning line conductors. Such tension is not to exceed 75% of the breaking load at 22°F. instead of 50% as hitherto.

3.4.

Transport and Communication

Rail communication in the East Calcutta Rural Area is not likely to be very convenient for line construction. There are, however, metalled and unmetalled roads 7 to 8 ft. wide and the proposed route of the h.v. lines will be run to be as near as possible to the roads so that the system can be easily reached by the Undertaking's own transport.

No reliable telephone communication exists at present and arrangements will have to be made with the Post Office Authorities for extension of such facilities, which are essential for the operation and maintenance of h.v. distribution. The Post Office Authorities may call for a capital contribution towards the necessary extensions, but this is likely to prove less costly than the running by the Supply Authority of its own private telephone system, erected on the transmission line supports, although that would have the advantage of exclusive availability.

3.5.

Labour

Plenty of unskilled labour is available and it is necessary to provide facilities for proper training, particularly for those men between the grades of Engineers and "mistries" (skilled mechanics). There are no schools in Bengal comparable with the trade/

trade schools in Britain for training the more intelligent and literate artisans from whom the foreman types must be drawn. In spite of the importance that staff training undoubtedly holds, it is felt that the experience gained in existing schemes can, if necessary, be drawn upon and expanded, so that the question need not be discussed further here. In any case the matter must eventually be of Government concern, for the progress of the country in almost every field of enterprise - whether technical or other - depends considerably on education and training.

3.6. Load Estimation

- 3.6.1. **LOADS AND CONSUMERS.** The Area to be supplied by the scheme is 600 square miles and the total estimated load is 1,500 kVA.

The load estimates were fully discussed in Part II, Section A, and are summarised in Table V which gives the probable loads at the eight supply points during the first 12 years. It appears that the estimated loads up to 5 years of operation at the eight places shown in the map are very small. In this connection it may be pointed out that once the public is aware that electricity will be made available, industry, the growth of which is difficult to forecast, may spring up in the district concerned. It is therefore necessary/

necessary to keep the scheme flexible, bearing in mind the possibility of ultimate rearrangement. In the first instance, however, it has been assumed that only the demands listed in the Table are to be met.

The geographical locations of the potential loads are shown in the map, Fig. 12, from which the maximum transmission distance involved appears to be about 50 miles from the bulk supply point .

Section A

Table IX (Part II) shows the estimated numbers of consumers during the 5-year development period.

TABLE V : LOAD ESTIMATES, kW.

Place	Y E A R					
	1st	2nd	3rd	4th	5th	12th
Barasat	40	70	85	100	115	300
Habra	30	50	65	75	90	200
Gobardanga	25	40	55	65	75	200
Bongaon	40	55	70	90	100	250
Baduria	15	20	25	30	35	100
Kolapola	5	10	10	10	15	50
Basirhat	50	80	100	120	140	300
Taki Hashnabad)	15	25	30	35	40	100
TOTAL ..	220	350	440	525	610	1500

(Section A)

3.6.2. LOAD FACTOR. This has been shown in Part II/to rise from 20% during the first year to about 24% by the end of the fifth year. The distribution cost per unit sold is lowest for the highest load factor. The most promising means of improving the load factor is by the extension of public services, such as water supply, water pumping and dewatering. For drainage purposes in low-lying ground and fen-land, electricity could be made available at off-peak periods at a cost much lower than with other methods of drainage.

The model load curve for the estimated supply during the fifth year is shown in Fig. 11 and this has been used in subsequent calculations.

### 3.7. Choice of System and Voltage

The successful operation of the system depends on the proper choice of voltage and system of supply. With regard to the voltage, too low a value will result in insufficient line capacity, unnecessarily heavy conductors, inadequate provision for future development and difficulty with voltage regulation. If on the other hand too high a voltage is selected, the scheme will be unnecessarily expensive, due to the extra cost of providing adequate high grade insulation.

#### 3.7.1./

3.7.1. SYSTEM. Inevitably all main transmission will be by 3-phase lines, but consideration has to be given to the comparative advantage of single phase lines as an alternative in the development of sparsely-populated areas where the load requirements are such that the minimum possible amount of capital expenditure is essential.

A single-phase system of distribution for spur lines has been operating in Dumfriesshire, Scotland, since 1933 (J. S. Pickles, J.I.E.E. 82, 333-386, (1938); and Pickles & Wills, Proc. I.E.E., 93 (II), 501 (1946)). Here supplies to remote villages, etc., are given by 11-kV spur lines, each village having its own transformer to feed a 2- or 3-wire, 230/460-V distribution network. Similar systems have been successfully installed elsewhere in Great Britain by the Yorkshire Electric Power Company and the South Wales Power Company. Not only is this system economical, but, in practice, it presents distinct advantages in that out-of-balance trouble can be avoided.

There are certain disadvantages, of course, with regard to motor loads with large starting current: again, single-phase motors cost more than three-phase motors and their starting characteristics are inferior. These drawbacks would be outweighed by the saving in the aggregate/

aggregate capital expenditure. In the E. Calcutta Rural Area, motors installed would usually be no more than 5-h.p. rating, which can be started without undue adverse effects on the network. Defects in starting characteristics may be overcome by loose-pulley starting.

3.7.2. VOLTAGE. For overhead line work it is now the generally accepted practice to use an 11-kV system for rural distribution. Such a system with 0.05-sq.in. equivalent copper conductors has a capacity of about 3,000 kVA calculated on a heating basis. With the distances involved in the present scheme such a conductor would have an excessive voltage drop; it is therefore considered desirable to set up feeder points, supplied at some higher voltage, from which 11-kV lines would radiate. This scheme would be flexible, and capable of extension to meet unexpected demands.

In order to make use of standard equipment, the only practicable choice of voltage for primary supply to the feeding points is 33 kV: this voltage is fortunately the value at which bulk supply is available at the Chord Road Substation.

### 3.8. Choice of Conductor

3.8.1. EQUIVALENT COPPER SECTION. The capacity of an overhead transmission line can be advantageously expressed in kW- or MW-miles per unit voltage/

voltage drop instead of in power rating alone, as the transmission distance is an essential factor.

Charts to determine the MW-mile capacities of 33- and 11-kV lines for 0.025 and 0.05 sq. in. equivalent copper have been constructed by Forrest's method (Elec. Review, June - September, 1945) see Figs. 13 - 16. The charts indicate that, for a 5% voltage drop and an 0.85 lagging power factor, the MW-mile ratings will be as follows :-

<u>Line Voltage kV.</u>	<u>Conductor sq.in.</u>	<u>MW-miles.</u>
33	0.05	43
33	0.025	26
11	0.05	5
11	0.025	2.8

In deciding on voltage and conductor size it is necessary to consider limitation by Statutory Regulations that require the voltage variation at any consumer's terminals not to exceed  $\pm 6\%$ . It is, therefore, the general practice for the purpose of network layout arbitrarily to divide the permissible variation between the h.v. mains, the local transformer and the l.v. distribution in the following manner :-

High-voltage mains	6%	) = 12%
Local transformer	2%	
l.v. distribution and services	4%	

11KV + 0.025 sq. in.

FIG. 13

MVAR - MILES.

LAG

LEAD

P.F.

0.7

0.8

0.85

0.9

0.95

0.98

MILES

15

0.98

0.95

20

VOLTAGE DROP - PER CENT.

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

H.D. (B.S. 125) COPPER CONDUCTOR FOR A FREQUENCY OF 50 CYCLES/SEC.

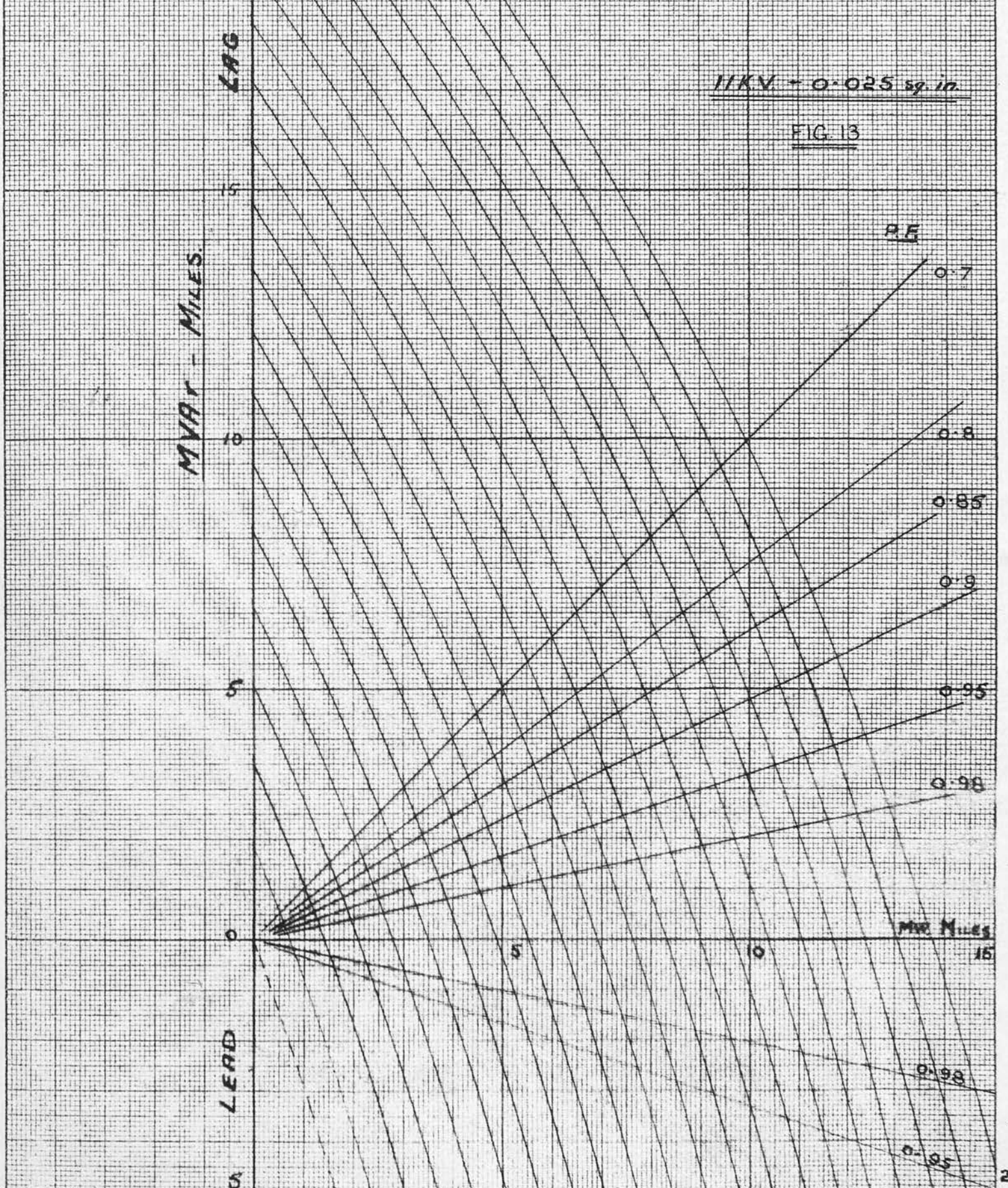
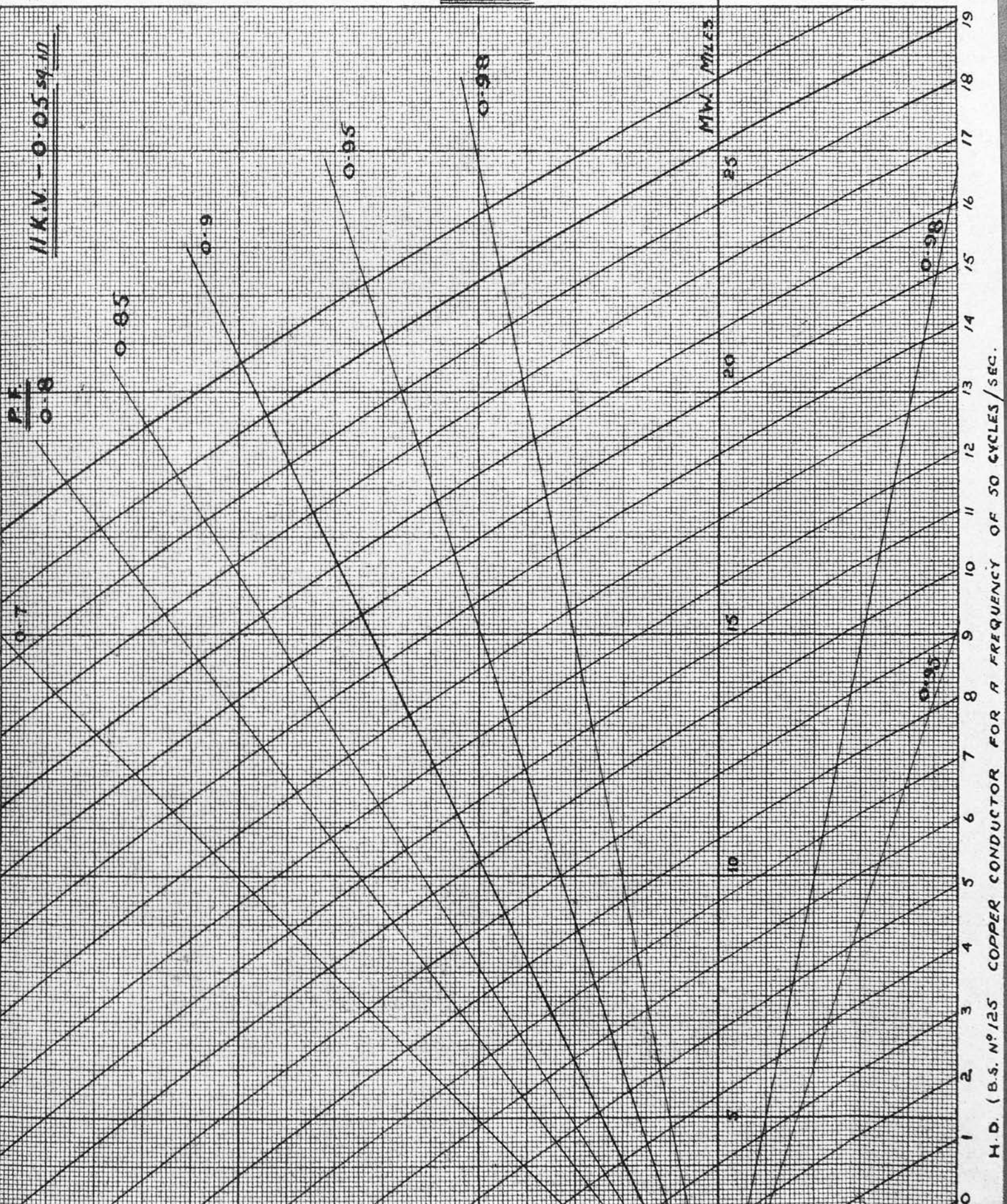


FIG. 14



11 K.V. - 0.05 sq. in.

PF  
0.8

0.7

0.85

0.9

0.95

0.98

MW  
10

15

20

5

10

0.85

0.98

M.D. (B.S. N° 125) COPPER CONDUCTOR FOR A FREQUENCY OF 50 CYCLES/SEC.

33 KV - 0.05 sq. in. P.F.

FIG. 16

0.7

LAG

50

00

MVAT - MILES

50

0

LEAD

50

MW - MILES

50

100

150

200

20

19

18

17

16

15

0.8

0.85

0.9

0.95

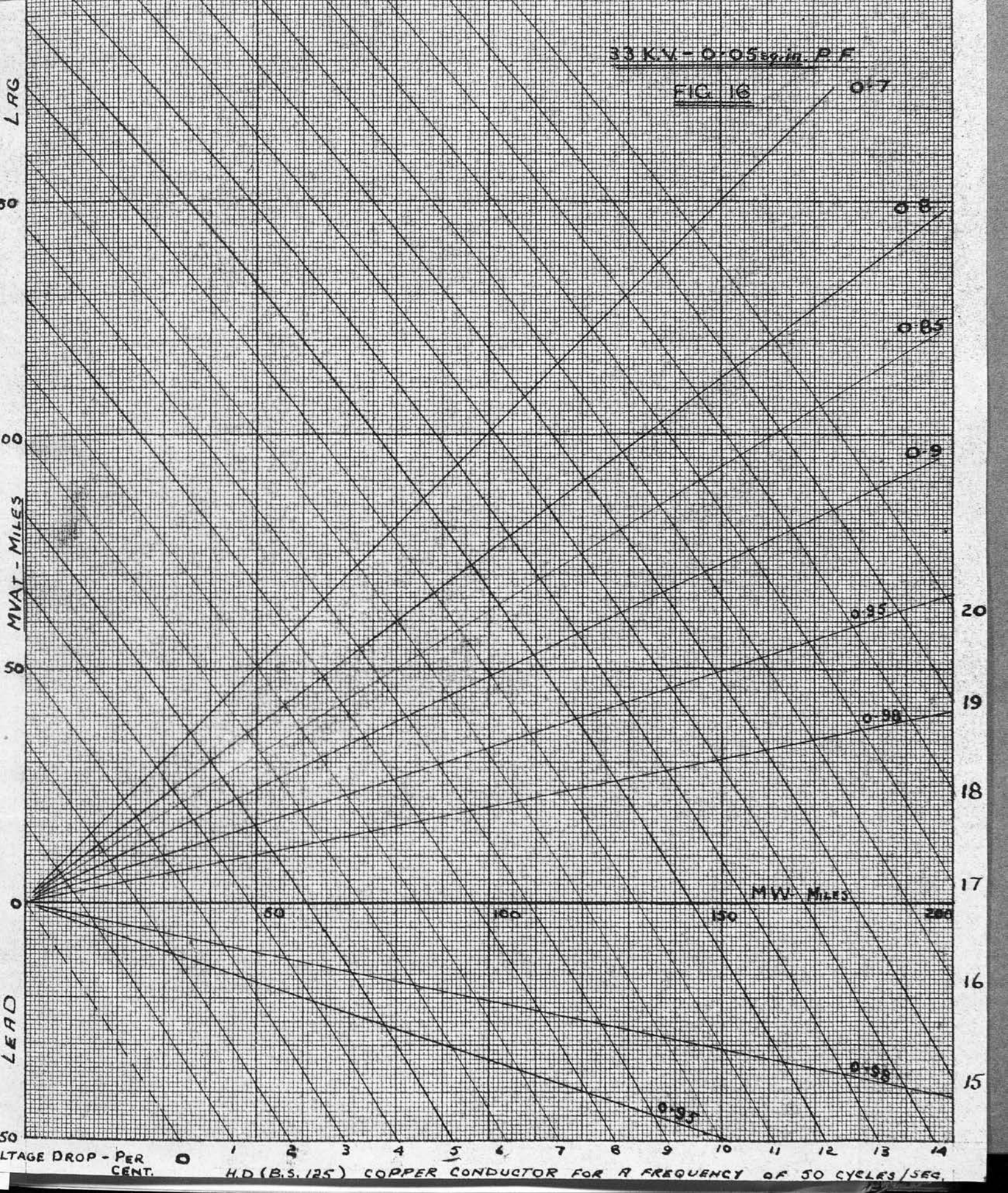
0.98

0.98

0.95

VOLTAGE DROP - PER CENT.

H.D. (B.S. 125) COPPER CONDUCTOR FOR A FREQUENCY OF 50 CYCLES/SEC.



Voltage variation can be compensated by induction or voltage regulation, or by tap-changing on transformers, and this, rather than load capacity, may control conductor size.

As the maximum load to be dealt with is only about 25 - 30 MW-miles, a combination of 33-kV and 11-kV lines with 0.05-sq.in. equivalent section is considered adequate. The 0.05-sq.in. equivalent area is the minimum size that could be used on 33-kV systems under mechanical limitations. Smaller sections demand greater sag, giving undue freedom of swing and vibration troubles; they may also introduce corona loss.

3.8.2. CONDUCTOR MATERIAL. Conductors for e.h.v. transmission lines may be hard-drawn copper, cadmium-copper or steel-cored aluminium.

Steel-cored aluminium is generally used with long-span steel-tower construction such as the British Grid where large powers have to be transmitted. The larger diameter and higher corona voltage make the construction there more economical. In the present case the large diameter of such a conductor is excessive for the load and would introduce high wind pressures.

In the present case the power to be dealt with is small and the most suitable standard size is found to be 0.05 sq. inch equivalent copper/

copper section. Cadmium-copper conductors show particular advantages as with these sections the breaking strength of cadmium-copper is greater than that of either copper or steel-cored aluminium. Moreover, for a given conductivity the overall diameter of a cadmium-copper conductor is less than that of any other high-tensile conductor and the loading on supports due to conductor windage is less. The sag for cadmium copper is also very much reduced. All the above will lead to an appreciable saving in support and foundation costs. A reduction of conductor spacing is also permissible.

TABLE VI : CONDUCTOR COMPARISON

Size Sq.in.	Ultimate Strength, lb.	Sag in ft. for 400-ft. span.	
		At 60°F.	At 122°F.
H-D Copper			
0.025	1518	8.8	10.5
0.05	2920	6.9	8.6
Cadmium-copper			
0.025	2630	3.8	5.4
0.05 equiv.	4670	3.8	5.5

Loading conditions assumed: No ice; wind pressure 16 lb/sq.ft.;  
factor of safety, 2.5 at 22°F.

Construction/

Construction therefore favours cadmium copper. Its 13% higher cost is offset by savings on poles and accessories. Fewer and shorter poles will be required and digging and erection costs will be reduced.

3.9. Layout of Supply System

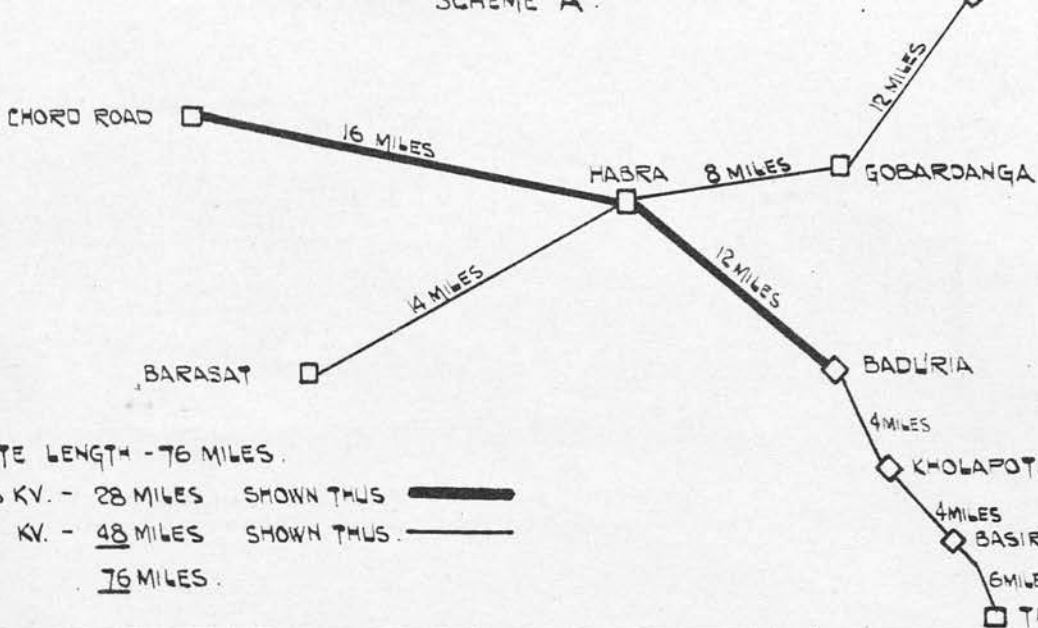
3.9.1. GENERAL REQUIREMENTS. The h.v. overhead-line system, a prerequisite on financial grounds, is routed in accordance with the potential load points. But in choosing from the several possible layouts there are other factors - such as flexibility of operation, continuity of supply, alternative feed and maintenance facilities - to be given due weight.

A ring main is operationally preferable. Limitation of capital expenditure may not permit such a scheme at the early stage, but the provision of an eventual ring in the later years of development should be easily possible. Another guiding principle for rural distribution is simplicity of layout and design in view of the lack of trained staff.

3.9.2. ALTERNATIVE LAYOUTS. Several schemes of supply for the eight load centres have been considered. These are shown in Fig. 17 together with their route length of 33- and 11-kV line.

To arrive at a prima facie decision on the relative merits of/

SCHEME A



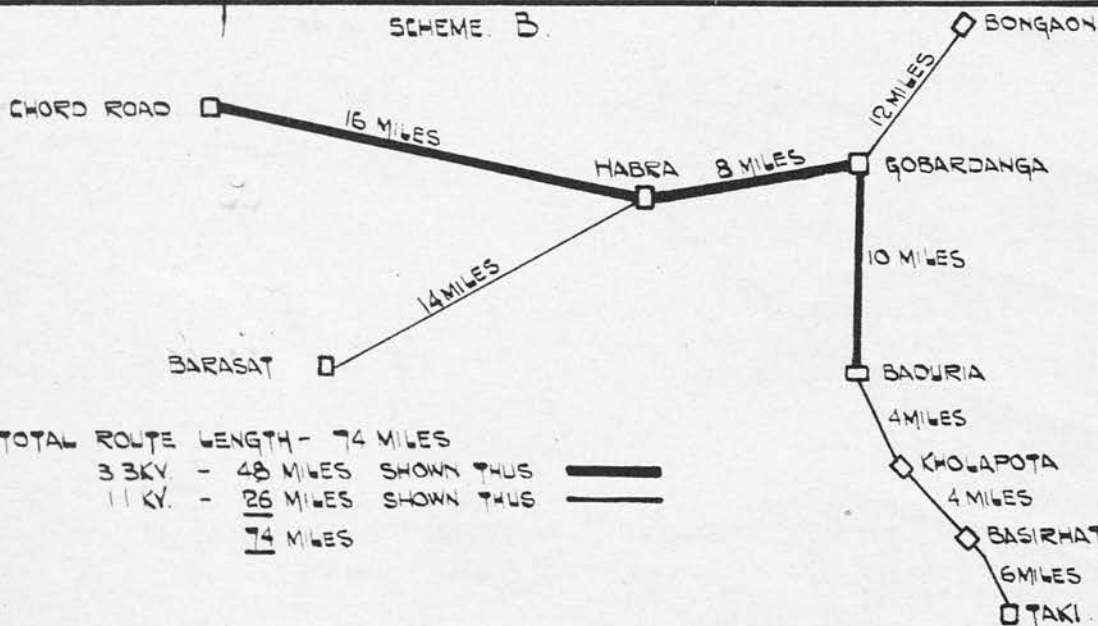
TOTAL ROUTE LENGTH - 76 MILES.

33 KV. - 28 MILES SHOWN THUS **————**

11 KV. - 48 MILES SHOWN THUS **————**

76 MILES.

SCHEME B



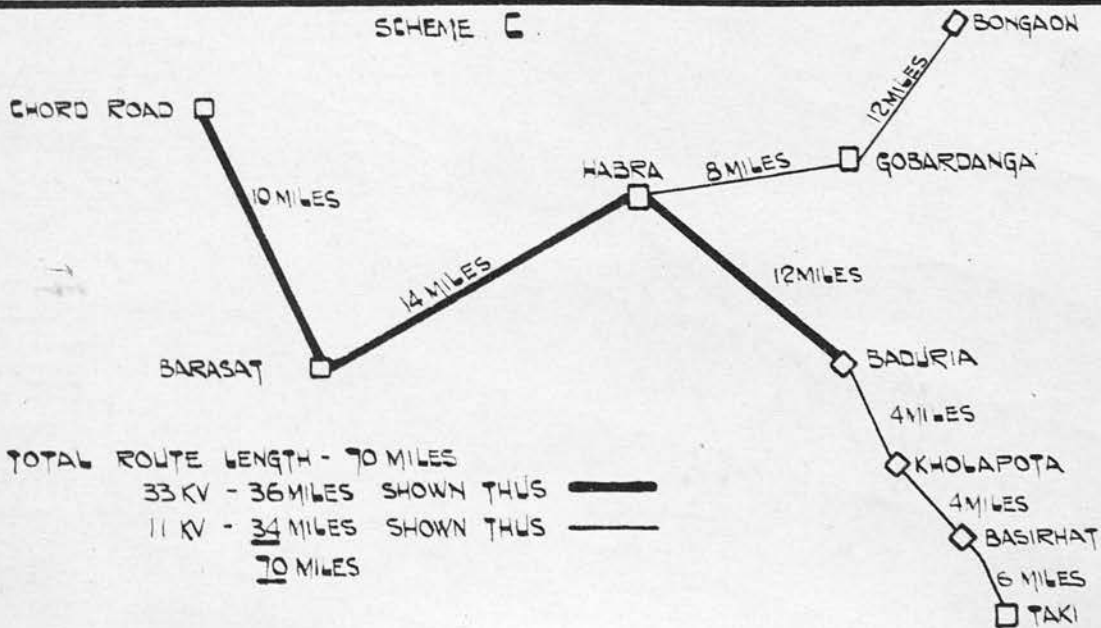
TOTAL ROUTE LENGTH - 74 MILES

33KV. - 48 MILES SHOWN THUS **————**

11 KV. - 26 MILES SHOWN THUS **————**

74 MILES

SCHEME C



TOTAL ROUTE LENGTH - 70 MILES

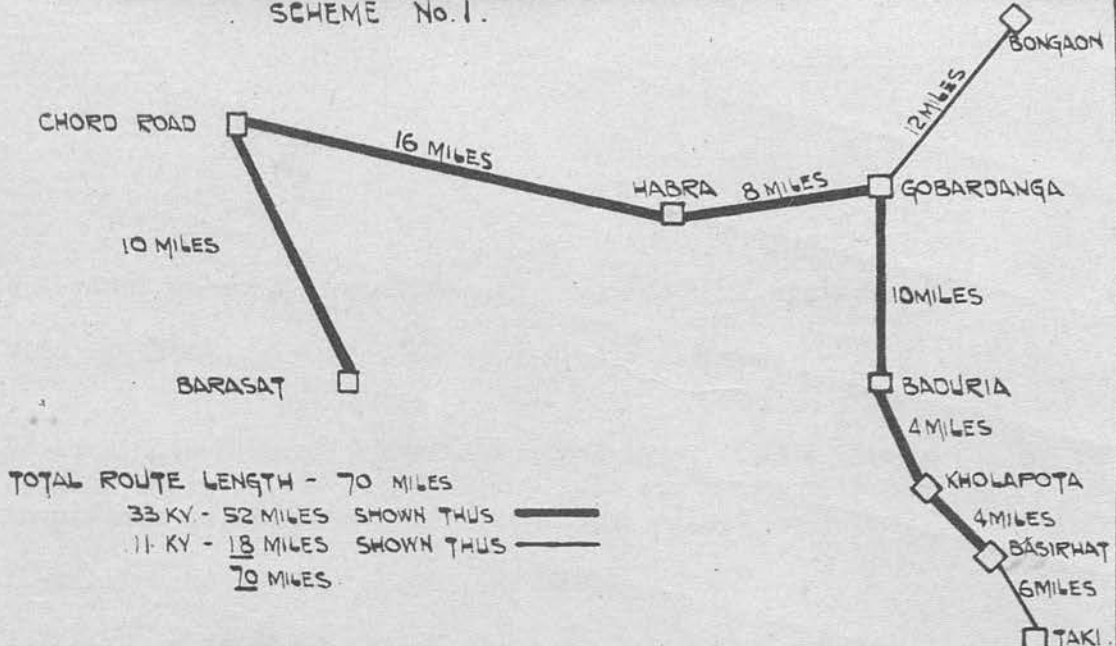
33KV - 36 MILES SHOWN THUS **————**

11 KV - 34 MILES SHOWN THUS **————**

70 MILES

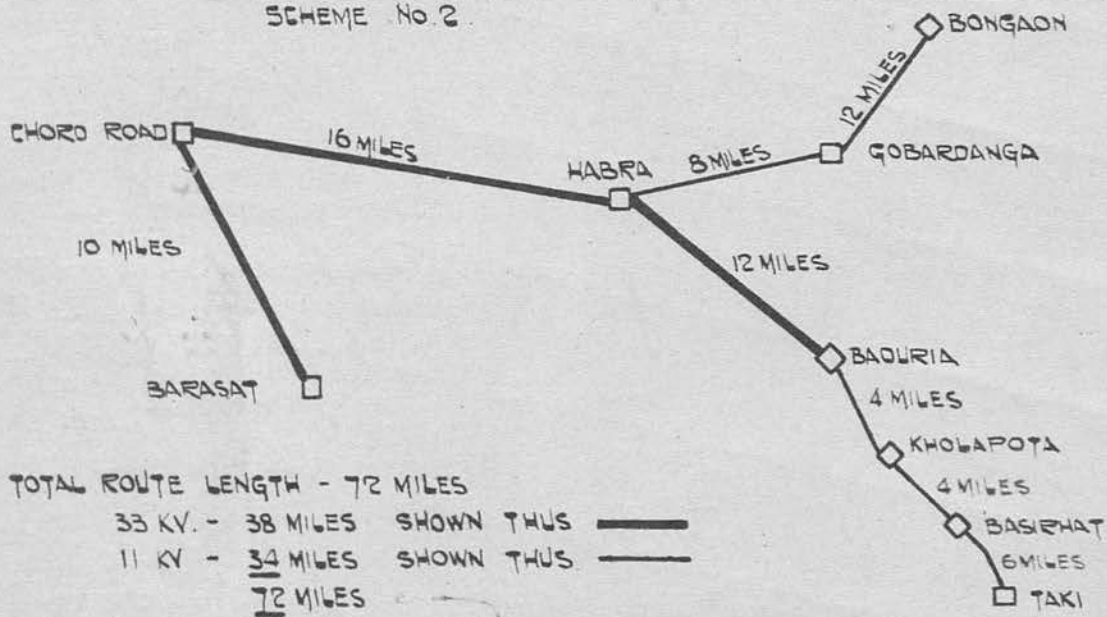
(D)

SCHEME No. 1.



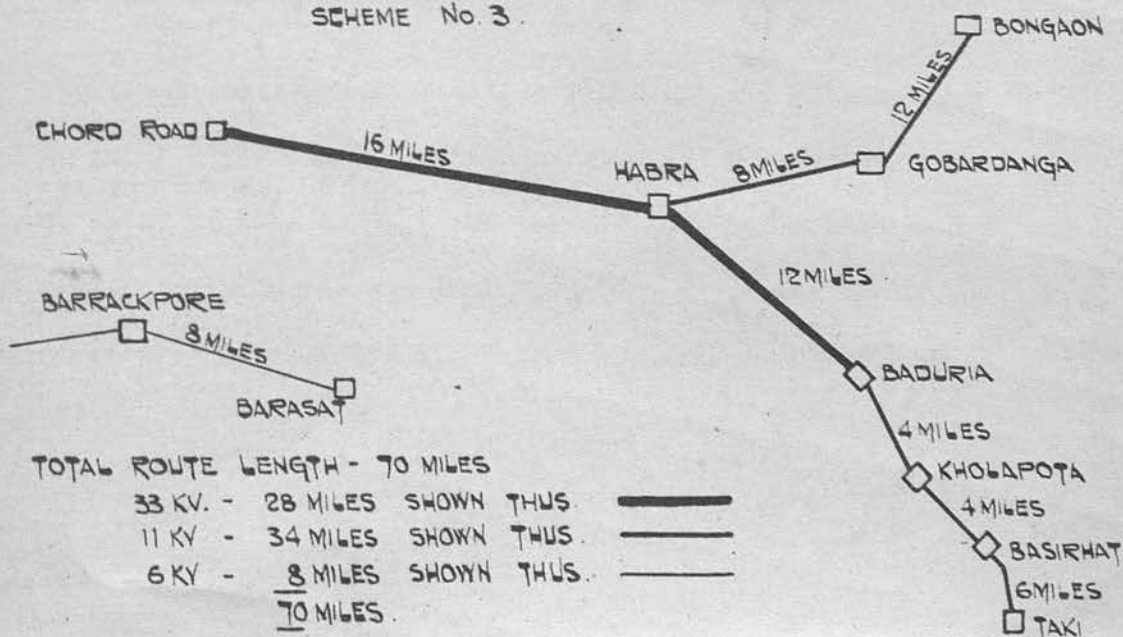
(E)

SCHEME No. 2.



(F)

SCHEME No. 3.



of the several schemes, a preliminary comparison of costs has been made by using the following approximate figures:

- (1) 33-kV single-circuit 3-phase overhead line, 0.05 sq.in. cadmium copper, 7/12 S.W.G. galvanised earthwire with pin insulators on steel towers; £2,000 per mile.
- (2) 11-kV line as above; £1,400 per mile.
- (3) 33/11-kV substation:

Land	£ 35
Building	200
33-kV pull-down fuse isolating switch.	150
11-kV 150-MVA switch, isolators and protection	700
33/11-kV 250-kVA outdoor transformer.	800
Cabling, connections etc.	<u>100</u>
	<u>£1,985</u>

- (4) 11-kV 100-kVA outdoor substation with transformer and h. v. and l. v. switchgear: £500.

The total costs (rough-estimated) for all six schemes show that no great difference is likely to be found between any of schemes A, B, C, D, E or F. But schemes D, E and F lend themselves much more readily to the eventual formation of a ring and offer promise of greater flexibility. They are therefore examined in greater/

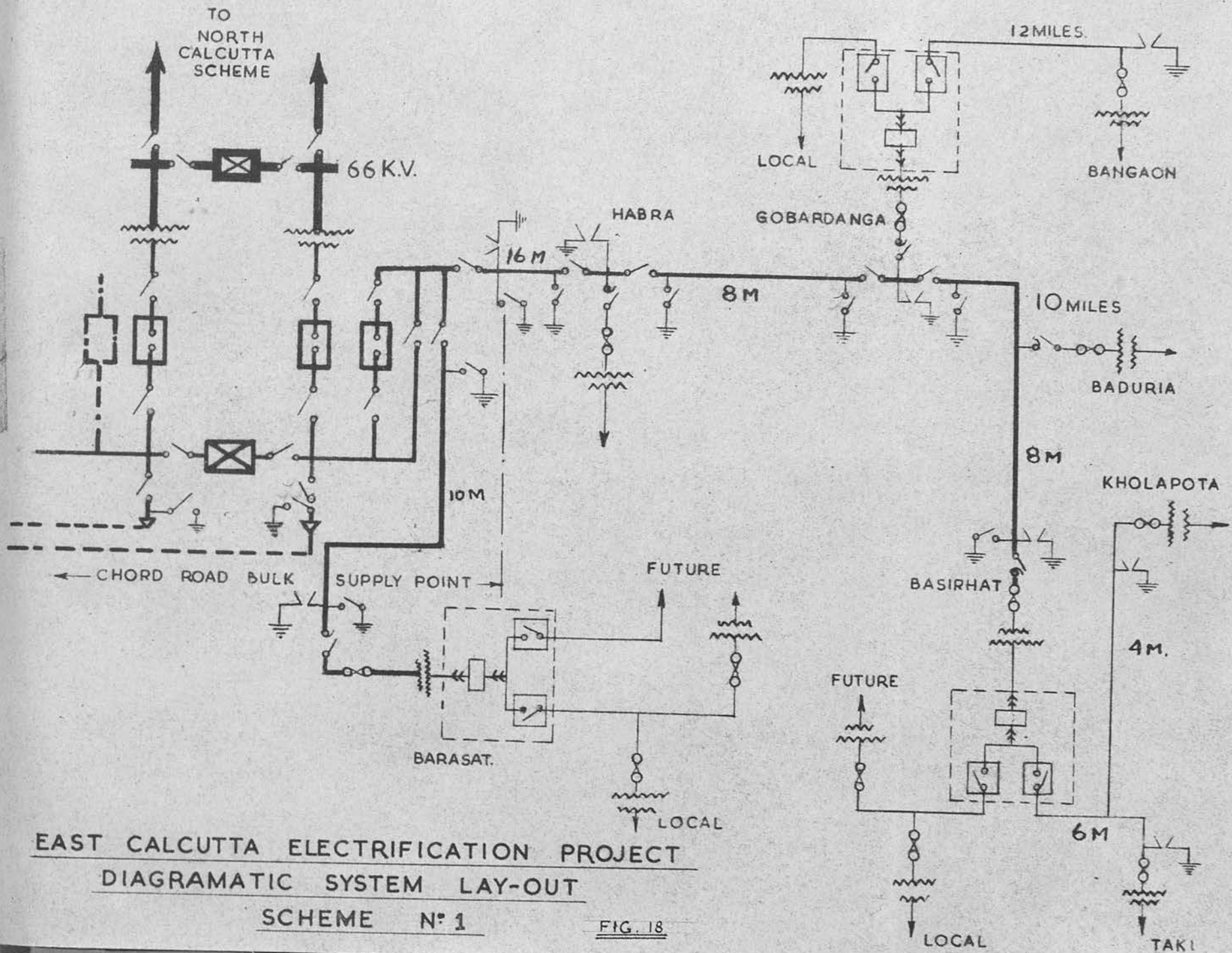
greater detail. These schemes will be designated Schemes 1, 2 and 3.

3.9.3. SCHEME 1 (Fig. 18). This is typical of a scheme suitable for a highly progressive area likely to develop rapidly.

Bulk supply from Chord Road station is transmitted by a single-circuit 33-kV line to Habra, Gobardanga and thence to Basirhat via Baduria and Kolapola. At Gobardanga and Basirhat, voltage will be stepped down to 11-kV for local distribution and also for feeding Bongaon from Gobardanga and Taki and Hashnabad from Basirhat. Bongaon is 12 miles from Gobardanga and Taki 6 miles from Basirhat. These places would therefore be fed by extension of 11-kV lines from Gobardanga and Basirhat respectively.

A separate 33-kV line is proposed from Chord Road to Barasat for feeding this place by stepping down from 33-kV to 11-kV and then to 0.4-kV. A 33-kV ring main could be completed by a line between Barasat and Basirhat through other centres of load which may develop in course of time. The ring, although not feasible at present, has been considered as a probable future addition.

Basirhat is the most important load centre and is expected to develop quickly. Its supply direct from Barasat by a line via/



EAST CALCUTTA ELECTRIFICATION PROJECT  
 DIAGRAMATIC SYSTEM LAY-OUT

SCHEME N° 1

FIG. 18

66 K.V. OVERHEAD TRANSMISSION LINE SHOWN THUS

33 K.V. " " " " "

11 K.V. " " " " "

CABLE U.G. " " " "

FUTURE EXTENSION " " " "

FUSE ..

LIGHTNING ARRESTER

T.P. HORNGAP ISOLATING SWITCH GANG OPERATED

(SUITABLE FOR BREAKING THE MAGNETISING CURRENT OF TRANSFORMER)

T.P. AIR BREAK ISOLATING SWITCH GANG OPERATED

EARTHING SWITCH

TRANSFORMER

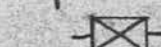
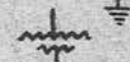
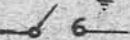
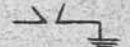
BUS COUPLER

OIL CIRCUIT BREAKER DRAW OUT TYPE

" " " NON " " "

T.P. BUS SECTION ISOLATING SWITCH GANG OPERATED

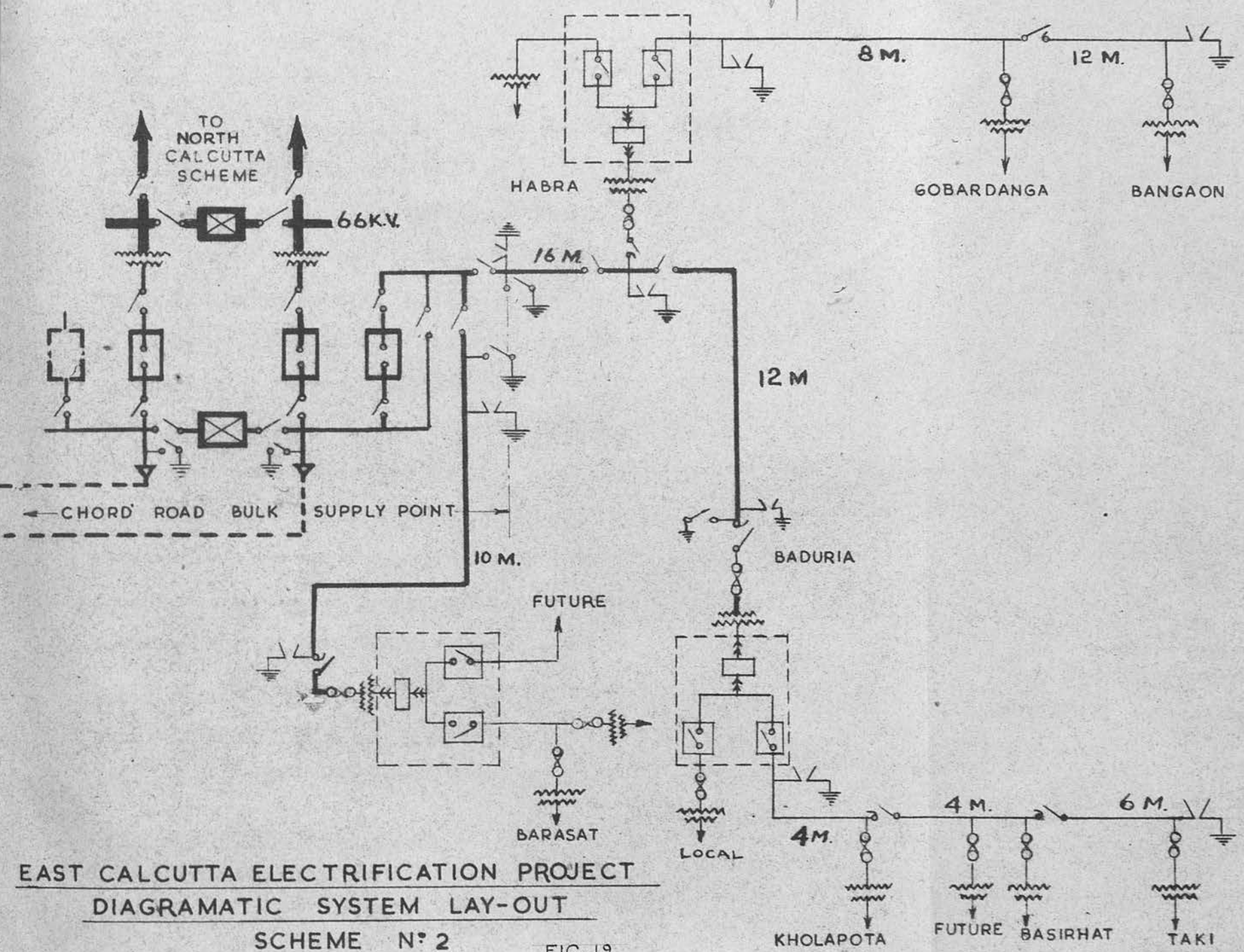
SINGLE BREAK OIL IMMERSED ISOLATING SWITCH



via Deganga and Brachapa was considered, but as these places do not at present show any prospective load, it has been deemed more economic to feed Basirhat as already indicated. Similarly, it is less expensive to feed Bongaon from Gobardanga than from Habra. The layout further shows that the line has been made to zig-zag through the area. This has an additional advantage in that a duplicate supply will be available to all substations if the line becomes part of a ring main.

3.9.4. SCHEME 2 (Fig. 19). This proposal is put forward on the assumption that there is no possibility of the individual loads increasing indefinitely or of the spur lines being extended over the Pakistan border. It has therefore been considered unnecessary to extend the higher transmission voltage to remoter places in view of the higher costs of switchgear, transformers and overhead lines. The scheme is therefore based on a minimum mileage of 33-kV lines.

Two single-circuit 33-kV lines radiate from Chord Road to supply feeding points at Barasat and Habra and Baduria. All supplies in this scheme are provided by 33/11-kV transformation. A 33-kV ring can be formed at a later date by inter-connecting Barasat and Baduria. This would strengthen the existing 11-kV system in a simple manner. At present main radial feeders are adopted.



**EAST CALCUTTA ELECTRIFICATION PROJECT**  
**DIAGRAMATIC SYSTEM LAY-OUT**

**SCHEME N° 2**

**FIG. 19**

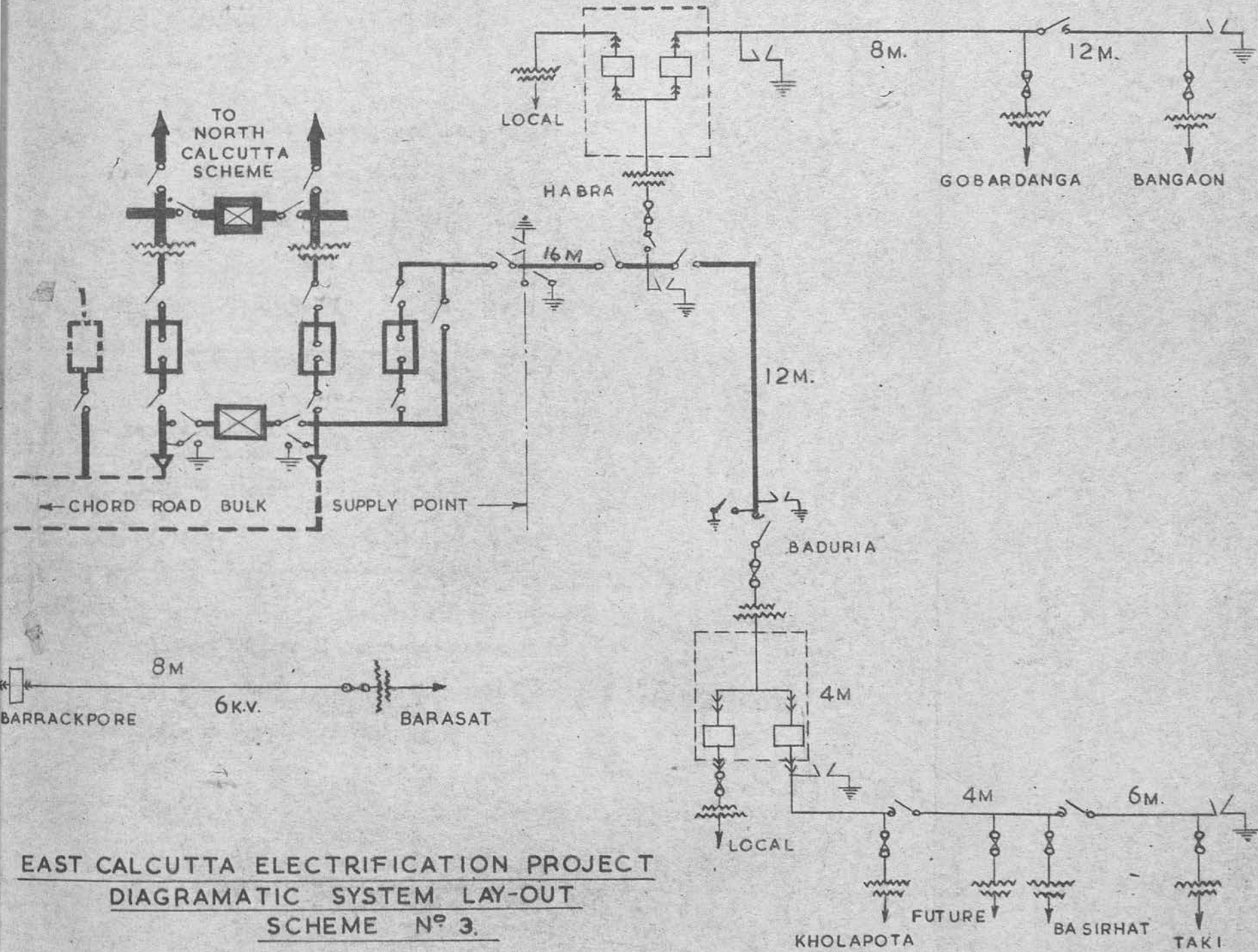
3.9.5. SCHEME 3 (Fig. 20). This is the same as Scheme 2 except that Barasat in the first instance would be fed from Barrackpore at 6-kV, saving a costly 33-kV tapping and shortening the total 33-kV mileage. The line from Barrackpore to Barasat, although initially operated at 6-kV, would be insulated for 11-kV. It has been borne in mind that in the event of the ultimate requirements of the area increasing sufficiently, a 33-kV tie-line may be provided between Chord Road and Barasat and this scheme would then reduce itself to Scheme 2. An additional advantage is that the requirements of the Barrackpore undertakings could be fed from the same Government Grid, thereby improving load factor and maximum demand on the system at Chord Road. Appreciating the necessity for keeping the initial cost to a minimum, the proposal outlined under this scheme deserves special consideration. Moreover, this scheme would provide supplies to Barasat independently of the rest of the scheme.

3.10. Comparison of Schemes 1, 2 and 3

All three schemes have the disadvantage that a prolonged interruption of supply to consumers might occur under line-fault conditions until such time as a ring main can be constructed. This contingency must be risked. The adoption of the principle detailed under Scheme 3 will make one part of the area independent of the other, a partial mitigation.

The/

FIG. 20.



The estimated capital costs of the scheme based on the current prices ruling in Britain are given in Appendix 1 and the totals are given below in Table VII.

TABLE VII : COMPARISON OF CAPITAL COSTS

---

	Scheme 1.	Scheme 2.	Scheme 3.
Detailed Estimated Costs	£163,000	£154,000	£142,000

---

Scheme 3 shows the greatest economy in capital expenditure and has relatively more operating reliability. It is recommended that this be adopted for the East Calcutta Rural Area project.

Adopted Scheme

REGULATION. Fig.16 shows the megawatt-miles that can be delivered for various voltage drops and power factors by a 33-kV 3-phase single-circuit 0.05 sq.in. conductor line. Similar curves are also shown for 11-kV 3-phase single-circuit 0.05-sq.in. and 0.025-sq.in. conductor lines. The voltage drops in the various branches with the maximum system load of 1500 kW for the adopted scheme III with 0.05-sq.in. equivalent copper conductors have been calculated and are given in Table VIII.

TABLE VIII : VOLTAGE REGULATION PER CENT. FOR ULTIMATE LOAD 1500 kVA

Station	Regulation %
Taki	6.8
Basirhat	6.2
Kolapota	4.6
Baduria	2.8
Bongaon	8.7
Gobardanga	5.7
Habra	2.1
Barasat	7.9

As all maximum loads are taken to occur simultaneously, the fore-going calculations over-estimate the figures likely to be obtained within the first ten to twelve years of operation when the scheme will be working up to the load shown. Transformer voltage/

voltage regulation will have to be taken into account in addition, but the above regulation figures would appear to be reasonable. It is therefore proposed to use 0.05-sq.in. (equivalent) Cd.-copper conductors for both the 33-kV and 11-kV lines.

4.2. LOSSES. The annual energy loss in the transmission system has been worked out with the anticipated loads for the first five years of operation and is given in Table IX. The details of the calculation are given in Appendix II.

TABLE IX : ANNUAL TRANSMISSION LOSS, kWh.

Year of Operation	1st	2nd	3rd	4th	5th
Annual Line $I^2R$ loss at specified L.F.	1,000	2,400	4,300	6,400	8,400
Transformer $I^2R$ loss on specified L.F.	2,230	5,320	7,600	8,660	11,335
Transformer Core Loss	75,700	75,700	82,400	92,440	92,440
Meter Loss	1,150	1,950	2,550	3,000	3,380
Total Annual Loss up to the supply points	80,080	85,370	96,850	110,500	115,475
Output per annum on specified L.F.	420,400	696,300	919,000	1,104,200	1,278,500
Input per annum	500,480	781,670	1,015,850	1,214,700	1,393,975
Loss as % of input	16%	11%	9.5%	9%	8.3%

Table IX gives the losses as a percentage of the input to the

main/

main transformer for the specified average load factor of 24 per cent. for the first five years of operation. In addition to the above, l.v. distribution line losses and miscellaneous other losses have to be considered. These are mainly  $I^2R$  losses in the system and when multiplied by the equivalent load loss factor, will not be appreciable.

The Table further shows that core losses of the transmission and distribution transformers constitute about 80% of the total. The importance of minimising the core loss of rural transformers is at once apparent. The proper selection of a transformer size for an individual load is important.

#### 4.3. Supports and Span Lengths

4.3.1. WOOD POLES. A large measure of standardisation has been achieved for overhead-line construction up to 33-kV. The present practice for 11-kV lines with light conductors up to and including 0.05 sq.in. copper or copper-equivalent is based on the E.R.A. design covered by B.S.1320:1946. In this document the use of wood poles with unearthed steel fittings has been advocated except at terminations or on poles fitted with transformers, mechanically-operated switchgear, cables and like apparatus. At such poles all steelwork must be bonded and earthed and stays left uninsulated. Spans of length/

length 250 ft. to 350 ft. are recommended.

The construction for lines at 33-kV may also comprise wood poles with horizontal conductors on single cross-arms, the metal structure being unearthened and without earth wires. In these "unearthed" types of construction the high impulse strength of a wood pole in series with the line insulator is utilised against earth faults and lightning troubles.

For the East Calcutta Rural Project the use of local wood poles for h.v. lines forming a permanent transmission system would not be desirable at present as the proper creosoting process required by B.S. 513 is not available. The suitability of this type of support has not been thoroughly established for Indian climatic and soil conditions, but there is clearly a need for some research into this problem.

4.3.2. REINFORCED CONCRETE SUPPORTS. These would be suitable if they could be locally manufactured by the centrifugally-spun method. They are, however, much heavier than wood, and transport difficulties would be great on narrow roads.

4.3.3. STEEL SUPPORTS. The use of steel is generally confined to heavy transmission work. Such supports may be tubular or lattice towers, the lattice being of broad or narrow base construction. Lines using such/

such supports would be a little more expensive. The following note compares concrete and steel poles:

Advantages

Disadvantages

GALVANISED LATTICE STEEL POLES

Relatively light. Easy to transport and handle.

Require large quantity of steel. Require careful inspection against corrosion damage.

REINFORCED CONCRETE POLES

Require limited amount of steel. Proof against climatic conditions.

Relatively heavy, more difficult to transport. Need special gear for erection and careful handling.

The cost per mile of 33-kV line with 0.05-sq.in. cadmium copper conductor on narrow-base steel towers is approximately £2,100, against £1,975 for concrete. Concrete poles have been used in Britain only when timber has not been available. The expansion coefficients for concrete and its steel reinforcement differ, and so far no sufficiently extended experience is available for forecasting useful life or possible tendency to disintegrate.

4.3.4. RECOMMENDATION. Bengal is not a producer of concrete poles, but it has important steel works. Assuming that local industry is prepared/



prepared to undertake the production of transmission-line hardware, and having regard to the serious effect of a failure of supports, the use of steel poles is recommended for both the 33- and 11-kV line construction.

High individual footing resistances may be encountered, so that it is considered advisable to provide earth wires on all lines. Installed above the line conductors with proper regard for coverage, they tend to mitigate the effect of lightning, as well as providing a good earth leakage path.

Fig. 21 shows a typical support for 11-kV line construction. Similar construction can also be used for the 33-kV line, and Fig. 22 gives details of such a support. Pole fittings could be standardised and the same construction used throughout, with reduced cost and a more convenient stock. Conductor spacing and ease of fixing the fittings have been duly considered in the selection of this arrangement. The slanting construction of the arms reduces the bird trouble. Provision has been made for an earth wire to be strung on the top of supports.

The economic span length for a 33-kV steel-tower line has been estimated/

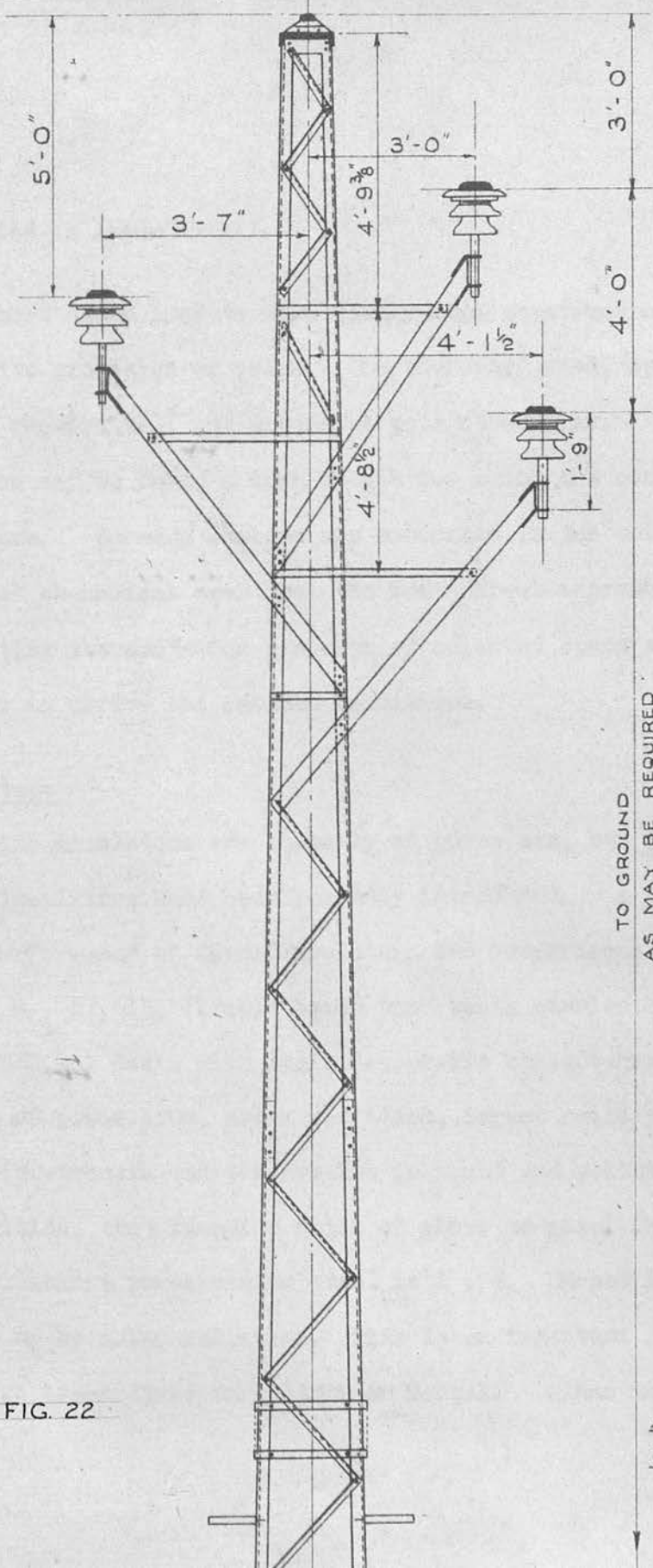


FIG. 22

TO GROUND  
AS MAY BE REQUIRED

TYPICAL TOWER  
ARRANGEMENT FOR  
33 kV. OVERHEAD LINE

estimated in Appendix III.

Short spans lead to more costly line construction because of the excessive provision of poles. On the other hand, spans of great length require tall and expensive pole structures. Between these extremes may be found a span length for which the cost per mile is a minimum. So many factors are concerned in the calculation of the most economical span that the most direct approach is by estimating the costs for a number of selected spans and using the figures to derive the optimum conditions.

#### Insulators

4.4. Line insulators are commonly of porcelain, but toughened glass insulators have been recently introduced. A paper on "The Performance of Glass Insulators and Comparisons with Porcelain" (J.I.E.E., 87,615, (1940)) based upon tests carried out by B.E.A.I.R.A. (ref. U/T.16) deals with their favourable characteristics in the effect of power arcs, solar radiation, impact resistance, impulse electric strength and performance in humid and polluted atmosphere. In addition, the expansion ratio of glass to steel is in the order of  $1 : 1\frac{1}{2}$ , whilst porcelain to steel is  $1 : 6$ . Hence less stress will be set up by solar radiation. This is an important factor in view of the high temperature variations in Bengal. Glass insulators cost more/

more than porcelain and it has to be considered whether the advantages gained by their use outweigh the somewhat greater material cost.

Pin-type insulators (either of porcelain or of glass) on normal supports, and cap-and-pin disc type on straining supports, are normally usable at 33 and 11-kV.

#### 4.5. Transformers

Because of the low load factor of supply in rural areas, the cost of energy loss in transformers is considerable.

There are three variables to be considered, the core loss, the  $I^2R$  loss and the costs. In the selection of transformers for rural distribution, therefore, not only should the number and size be reduced to the minimum, but the actual value of the core loss should be considered economically in relation to the cost price of the transformer. In the specification for outdoor and rural transformers issued by the Overhead Line Association it has been left to the purchaser to compare the offers on the basis of annual cost of the transformer when in use, summing the capital charges (i.e., interest and depreciation) and the annual value of the transformer losses, based on the energy tariff in force.

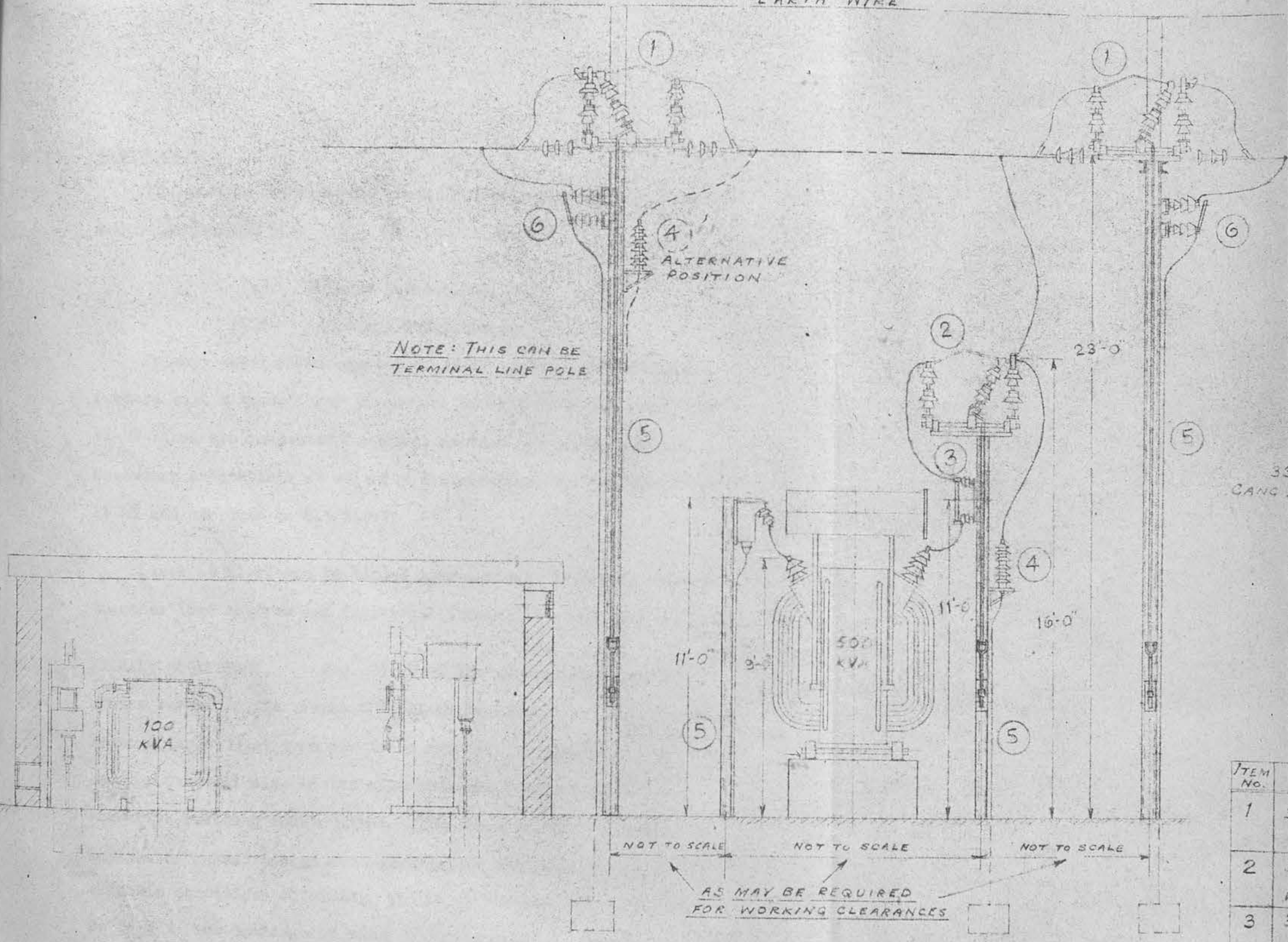
The/

The alternative equivalent method is to compare the capitalised cost, i.e., the sum of the initial cost price and the capitalised value of the core and  $I^2R$  loss.

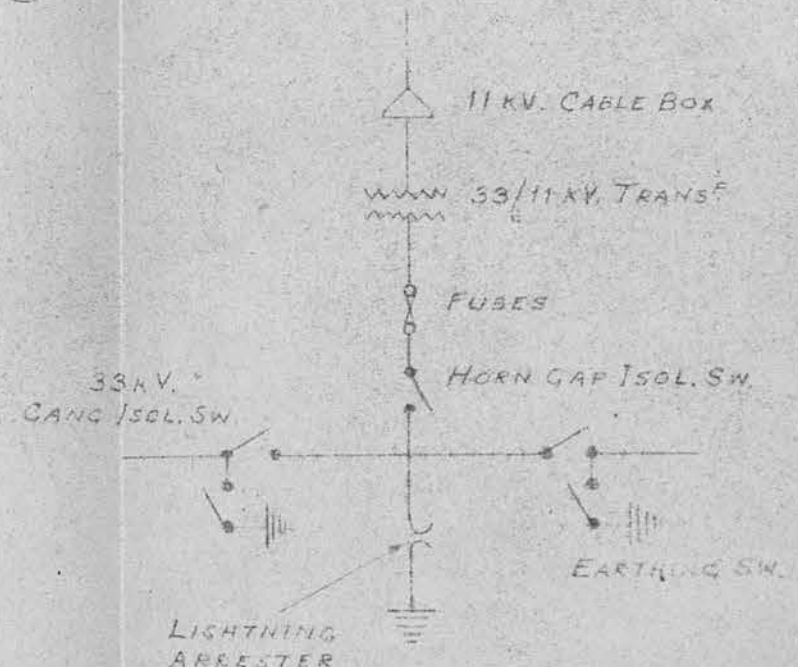
On account of the high ambient temperatures reached in the area, the normal transformer rating (B.S.171-1936) must be reduced to avoid maximum oil temperatures exceeding  $90^{\circ}\text{C}$ . The rating is therefore based on an oil temperature-rise of  $35^{\circ}\text{C}$ .

For the present scheme it is proposed to use standard 500-kVA, 33/11-kV, delta/star transformers of the outdoor type for the two 33-kV stations at Habra and Baduria. The normal rating of these transformers will be reduced by  $12\frac{1}{2}\%$ . The transformers would be provided with porcelain bushings on the 33-kV side and arranged for 11-kV cable connection. For earthing the 11-kV network the neutral would be brought out to a porcelain bushing, allowing the use of either a direct earth or an arc-suppression coil. These transformers would be arranged for off-load tap changing. Conservators and silica-gel breathers would be provided. The drying agent would require frequent inspection on account of the high humidity conditions ruling. Spare charges of silica gel would be kept locally and used in rotation after drying.

Smaller outdoor-type 11-kV transformers, even of less than 50 kVA rating, would also have breathers and conservators.



NOTE: THIS CAN BE TERMINAL LINE POLE



SINGLE LINE KEY DIAGRAM

ITEM No.	DESCRIPTION	No. OFF
1	33 KV. T.P. SINGLE BREAK ROCKER SW.	2
2	33KV. T.P. SINGLE BREAK ROCKERSW. WITH ARCING HORNS.	1
3	33KV. S.P. FUSE ISOLATORS WITH H.R.C. LIQUID FUSES.	3
4	33KV. S.P. STATION TYPE LIGHTNING ARRESTERS.	3
5	STEEL SUPPORTING STRUCTURE	4
6	EARTHING SWITCH	2

PROPOSED LAYOUT OF PRIMARY 33/11 KV. SUB-STATION

FOR THE EAST CALCUTTA PROJECT

FIG. 23  
SCALE 1/4" = 1 FOOT

4.6.

### Substations

The general arrangements chosen for substations are classified under the following :-

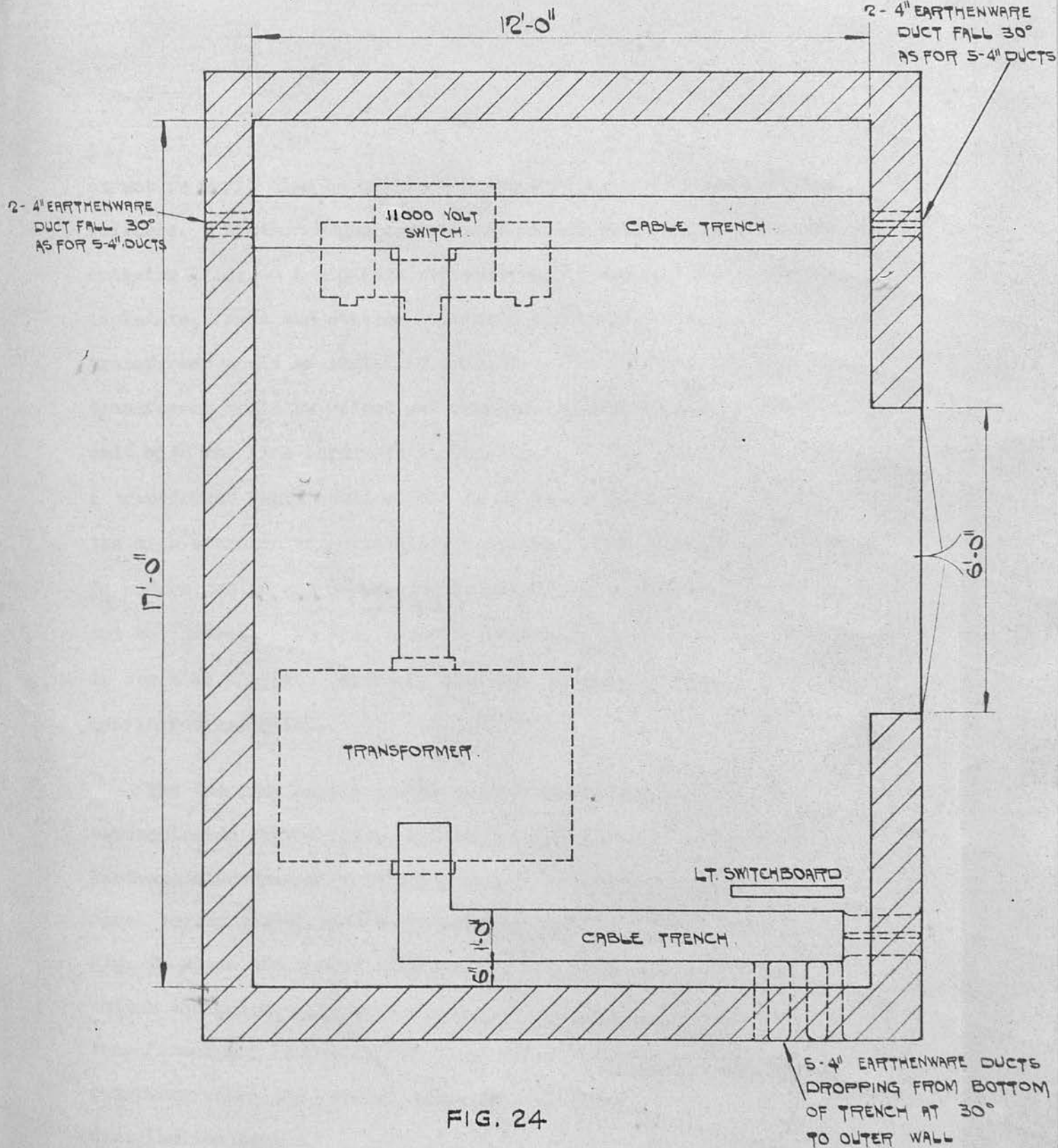
- (i) Primary Substations;
- (ii) Secondary Substations.

Primary substations consist of 33-kV incoming and outgoing feeders with a tee-off for an outdoor 500-kVA 33/11-kV transformer. 11-kV lines are connected for rural centres and local supplies. Secondary substations at suitable distribution centres receive at 11 kV and stepdown to 415/240 V.

Lines at 11-kV can be tapped inexpensively to afford supplies to other load centres and individual industrial consumers.

4.6.1. PRIMARY SUBSTATION. Fig. 23 shows the arrangements and the system layout of the proposed 33/11-kV substations. For economic reasons, an outdoor type has to be adopted, as the large clearances and the over-all size of the apparatus would otherwise involve excessive building construction. The whole of the equipment must be of robust design and construction to withstand the climatic conditions obtaining, and in particular, attention must be paid to the drainage of water from the site.

The outdoor stations could be composed of a steel frame structure (if necessary) for taking the incoming main. This structure/



GROUND PLAN ARRANGEMENT FOR HOUSING THE  
 11 KV. SWITCH EQUIPMENT TOGETHER WITH  
 A 11/0.4. TRANSFORMER.

SCALE · 3/8" = 1 FOOT

structure would also be utilised to support isolating and earthing switches. Another support similarly fitted would be used for the outgoing lines. A separate structure would support the transformer isolators, fuses and station lightning arresters. Only one transformer would be installed outdoor. The platform for the transformer would be raised and designed to support a 1000-kVA unit with the line terminals at least 9 ft. above ground level. A transformer fault would result in an interruption of supply but the high standard of reliability associated with transformers, due to modern design and manufacturing processes, is a factor which should not be ignored. It has, however, been decided to hold one transformer in stock as a spare: stand-by facility at each substation is not considered essential.

The incoming supply to the outdoor transformer is controlled by tetrachloride liquid fuses, and the 11-kV outgoing supply by metalclad hand-operated drawout switchgear housed in a brick building located close to the transformer to reduce the cost of land and cabling. Fig. 24 shows the ground plan arrangement for housing the 11-kV switch equipment. Provision is made for accommodating also a transformer for 11000/415/240 V. to afford l.v. supplies to local consumers where the primary substation is suitably placed as a distribution centre.

6.2. SECONDARY SUBSTATIONS. These will be constructed either (i) indoor or (ii) outdoor, depending on circumstances.

Indoor Type. A standard design is desirable. The substation site may be 24 ft. x 30 ft. in plan, the building surrounded by 3 ft. path with 6 ft. path leading from the entrance.

The site would be fenced all round and have double metal paling gate of total width 7 ft.

The substation would consist of a brick building sufficient in size to accommodate the following :-

11-kV Switchgear: one incoming feeder switch equipment.

Transformer: one 100-kVA, 11,000/415/240 V. unit with 5% tapplings.

L.V. Distribution: one 300-A 3-pole airbreak switch-fuse on the incoming side from the transformer and set of l.v. distribution fuse gear to suit the number of circuits supplied from the substation. Earthing stud should be provided in frame adjacent to neutral busbar and connected to the main earth of the substation by removable copper links 2" x  $\frac{1}{8}$ ".

Little overall saving in capital cost can be gained by the use of outdoor transformers for Indian conditions when the load is of the order of 100-200 kVA. With indoor stations the building construction costs will have to be incurred but the costs/

STANDARD INDOOR SUBSTATION  
FOR EAST CALCUTTA RURAL  
ELECTRIFICATION PROJECT

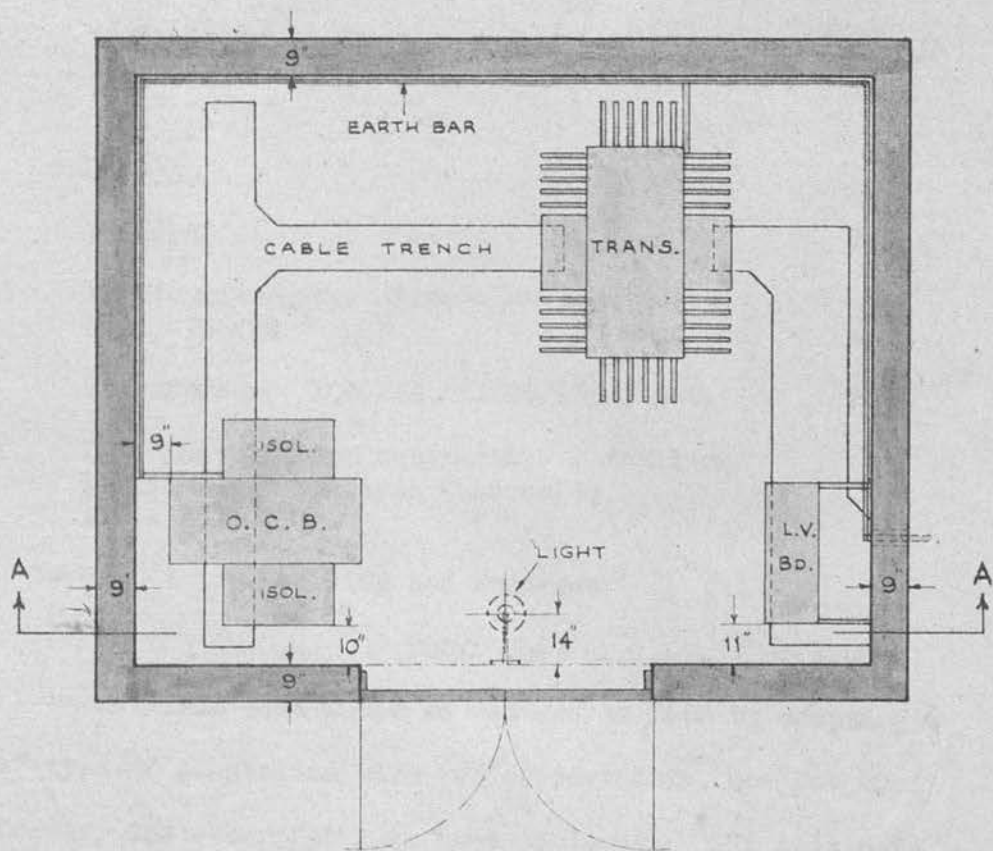
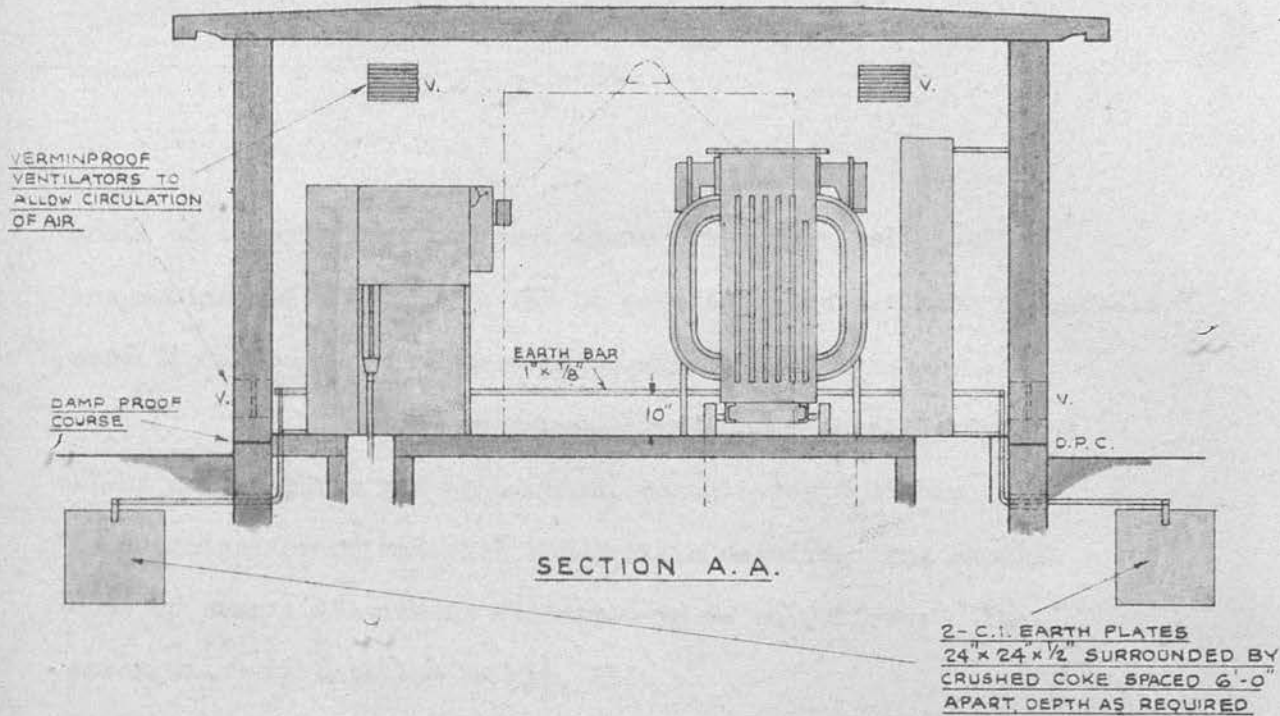


FIG. 25

**STANDARD INDOOR SUB-STATION  
FOR EAST CALCUTTA RURAL  
ELECTRIFICATION PROJECT**

SCALE: 1/4" = ONE FOOT

DATE: 30 DEC 1949

costs of transformers and switchgear are rather less, whilst inspection and maintenance can be carried out under more favourable conditions and there is protection against the weather.

The same design outlined under (4.6.1.) for the 11-kV switch-house may be adopted, as this would enable standardisation of material and certain details. The capital cost of such a station is estimated to be as follows: the arrangement is detailed in Fig. 25.

	<u>Item</u>	<u>Cost, £.</u>
(i)	Land	30
(ii)	Building	200
(iii)	11-kV Switchgear: iron-clad draw-out type, 75 MVA	400
(iv)	Transformer: 100-kVA, 11000/415/240-V.	250
(v)	L.V. Distribution equipment: 1 tailless link unit, 3 tailless fuse units, £10 + £30	40
(vi)	H.v. & l.v. cabling and sundries.	<u>80</u>
	Total Cost .....	<u>£ 1,000</u>

This cost would be reduced to £600 by adopting a "kiosk" type of substation with two compartments, one for the transformer, the other for l.v. fuse equipment. In this case the transformer would be protected by tetrachloride fuses on the adjacent terminal pole.

At/

At the initial stage it is possible to meet all the load in an area by installing one transformer only at the substation. This practice may have to be modified as the load grows by erecting outdoor stations at the probable load centres as this would avoid the running of heavy section l.v. overhead conductors and avoid excessive voltage regulation.

#### Outdoor Station

When catering for supplies of 25 - 50 kVA it will be economical to adopt outdoor-type stations. A simple standard construction for transformer capacities up to 50 kVA is illustrated in Fig. 26 and h.v. tappings with switchgear and transformer can be taken from intermediate, section or terminal poles. The design shows both constructions. Connections will be taken directly from the line to a link fuse, and thence to the transformer. If it is impracticable or undesirable to mount a transformer of a larger size upon a pole-supported platform, the transformer may be installed on the ground and fenced. Such a method of installation necessitates armoured cable and iron-clad terminal sealing boxes on the transformer and would be necessarily more costly.

As an alternative, the "kiosk" type described above might be adopted with little difference in cost and with the advantage of protection from direct sunlight.

INTERMEDIATE  
POLE

TERMINAL POLE

EARTH WIRE

EARTH WIRE

OVERALL HEIGHT AS REQ'D

6'-0"

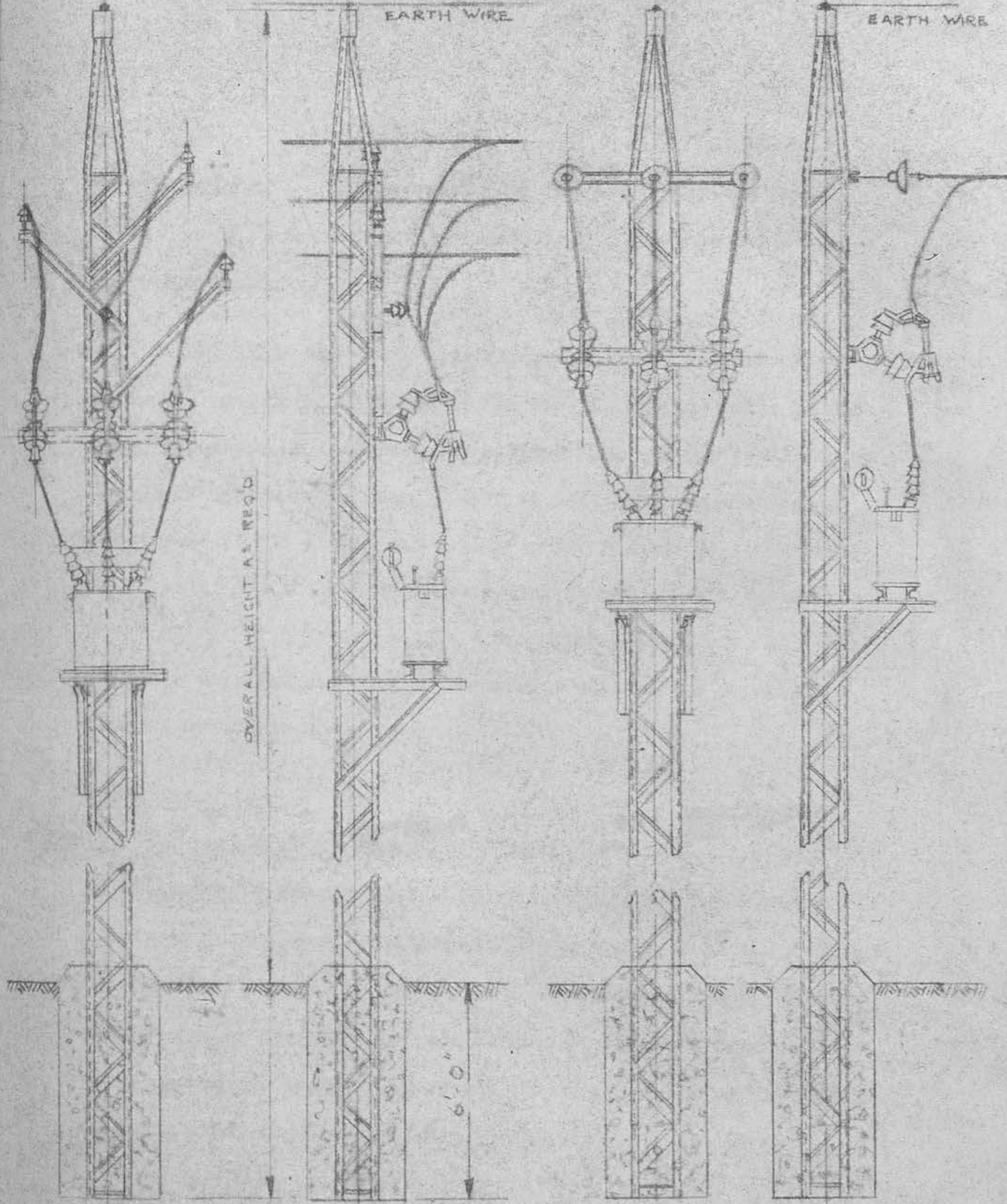


FIG. N° 26  
TYPICAL TOWER ARRANGEMENT - 11KV

4.6.3. SWITCH RATINGS. The current under the worst possible fault conditions will determine the selection of a suitable switch rupturing capacity.

Calculations have been made (Appendix IV) in respect of the maximum short circuit MVA and it has been found that owing to the large impedance of the line, the maximum fault energy available on the 33-kV system falls from 750 MVA at the receiving station to about 50 - 75 MVA at the other 33-kV primary stations. On the 11-kV side, the small transformers limit short circuit values to 7 - 8 MVA. With regard to the transformers, therefore, switches would be provided with plain overcurrent with series tripping shunted by a time-limit fuse.

#### 4.7. Protective Gear

The choice of protection of a rural distribution system is limited by economic factors. Overhead system faults may originate in abnormal conditions within or external to the system. The former are common to all types of electrical circuits, whether underground or overhead, but the latter are peculiar to circuits above ground particularly by reason of atmospheric conditions such as rain, wind, fog and lightning.

4.7.1. EXTERNAL CAUSES. Earth faults on overhead lines are most common, but are often of a temporary nature and may clear themselves quickly. However, /

However, should the earth fault be sustained, severe damage may be caused due to burning of conductors or failure of insulators. Adequate protection is necessary not only to prevent damage to lines but also to safeguard against the interruption of supplies.

There are two alternatives by which amelioration of the effects of transient earth faults can be effected: (1) by adopting the "unearthed" system and isolating the neutrals of transformers; and (2) by including an arc-suppression coil between the neutral terminal of the transformer (on the supply side) and earth. This coil, if perfectly tuned, reduces the fault current to a value corresponding to a small resistive component and the network continues to supply without interruption. There are, however, disadvantages in the use of the arc-suppression coil.

These are :-

- (a) when an earth fault exists, the earth point of the system shifts to the position of the earth fault and the voltage of the healthy conductors rises to full line voltage to earth.
- (b) A higher standard of network insulation is needed to avoid normal suppressions developing into multi-phase faults.

The use of arc-suppression coils originated in Germany. In America the star points of most networks are directly earthed.

In/

In Sweden and Holland the star points of transformers are directly earthed or earthed through arc-suppression coils. The earthing of the neutral point is the general practice in Britain, although recently, in a few cases, arc-suppression coils have been installed. From an economic aspect, the use of the arc-suppression coil is determined by the importance of maintaining the supply uninterrupted.

In the present case, the method of earthing the 33-kV system is determined by the practice adopted by the Calcutta Electric Supply Corporation. Their system is earthed at Mulazore Station so that the use of arc-suppression coils on the 33-kV system is not permissible. For the 11-kV sections of the network the charging current is only of the order of 1 - 2 A, and arc-suppression coils are hardly justifiable in view of the cost involved and the small section and charging fault current to be dealt with. On the other hand, it is considered quite safe with such a small charging current to have the neutral of the system unearthed if legally permissible. An all-insulated system is allowed in Europe but not in Britain or India. Permission to use a fully unearthed system may therefore not be easily obtained. Provision is therefore made for solidly earthing the system, but providing an isolating link so that the neutral can be isolated should occasion arise. This will enable future inclusion of a Petersen Coil when continuity of supply/

supply becomes a matter of more importance. Faults caused by lightning may be due to the breakdown of insulation under increased voltage stress at a point of reflection of a steep-fronted voltage surge, or due to the development of a power arc following a flashover. Lightning is a source of trouble which can never be wholly guarded against if economy is of importance. Direct strokes are chiefly responsible for lightning faults. It has been held that the provision of an earth wire strung above the line conductors, to intercept the strokes rather than to reduce induced voltages, coupled with efficient earthing constitutes a major protection against lightning. In Britain, experience has indicated that on a low-voltage line an earth wire is no advantage unless a very low resistance earth can be obtained at every pole or tower position along the line.

4.7.2. INTERNAL CAUSES. The balanced system of protection employing pilot wires - apart from its cost - is considered unnecessary in the present project. As an alternative it is proposed to control the supply at Chord Road by an outdoor-type oil circuit-breaker equipped with overload and earth leakage protection by definite minimum inverse-time-delay relays. Supplies will be taken from this breaker direct to the primary substations at Habra and Baduria.

Protection/

Protection at the 33/11-kV primary substations would consist of tetrachloride fuses on the 33-kV side of the transformer. The 11-kV side would be connected solidly to a common busbar from which would be fed (1) the local 11/0.4-kV transformer protected by oil switch-fuse, and (2) the out-going 11-kV feeder protected by oil circuit-breaker with overload and earth leakage direct-acting trips with time-limit fuses. The 33-kV tetrachloride liquid fuses would be set high, and suitable values of time-limit fuses chosen to ensure that faults on the 11-kV side only affect the tripping of the 11-kV supply.

The tetrachloride fuses would operate for short circuits in the windings only of the 33/11-kV transformers, and in addition to the above mentioned discrimination will be chosen to give discrimination with the protection at the source of the 33-kV supply.

Discrimination with fuses is sometimes considered impracticable, but properly designed fuses have proved successful in certain rural areas in Britain.

Secondary substations scheduled include both indoor and outdoor types, the former where the transformer rating is 100 kVA and/

and over. This allows for a 100% increase in rating over the original scheme without other alteration, since pole-mounted transformers up to 100 kVA have - at any rate in Britain - proved quite satisfactory, though the transformer pole might require to be reinforced e.g. by upright steel channels bolted together through it. The steel channel would also provide support for the transformer bracket.

Transformers at outdoor secondary substations would generally be protected by plug-in rewirable tetrachloride fuses mounted on the poles at the tee-off position; an air-break isolator also being provided at this position to break the main line on the remote side of the transformer tee-off.

Secondary type indoor substations at the more important sites would incorporate oil-immersed switch-fuse protection for the transformer and oil circuit-breaker with simple overload and earth-leakage protection for the outgoing 11-kV feeder. Also at the substation, on the incoming side, air-break isolators mounted on the terminal pole will prove useful for maintenance work.

On the 400-V side of the local pole-mounted transformers adequate/

adequate protection would be obtained by the use of suitable l.v. line fuses of the plug-in type. In the indoor substations with larger transformers (generally with two or more feeders) an l.v. panel with cable tailless units, having quick-break links on the incoming and rewirable strip fuses on the outgoing side, is a suitable provision.

4.8.

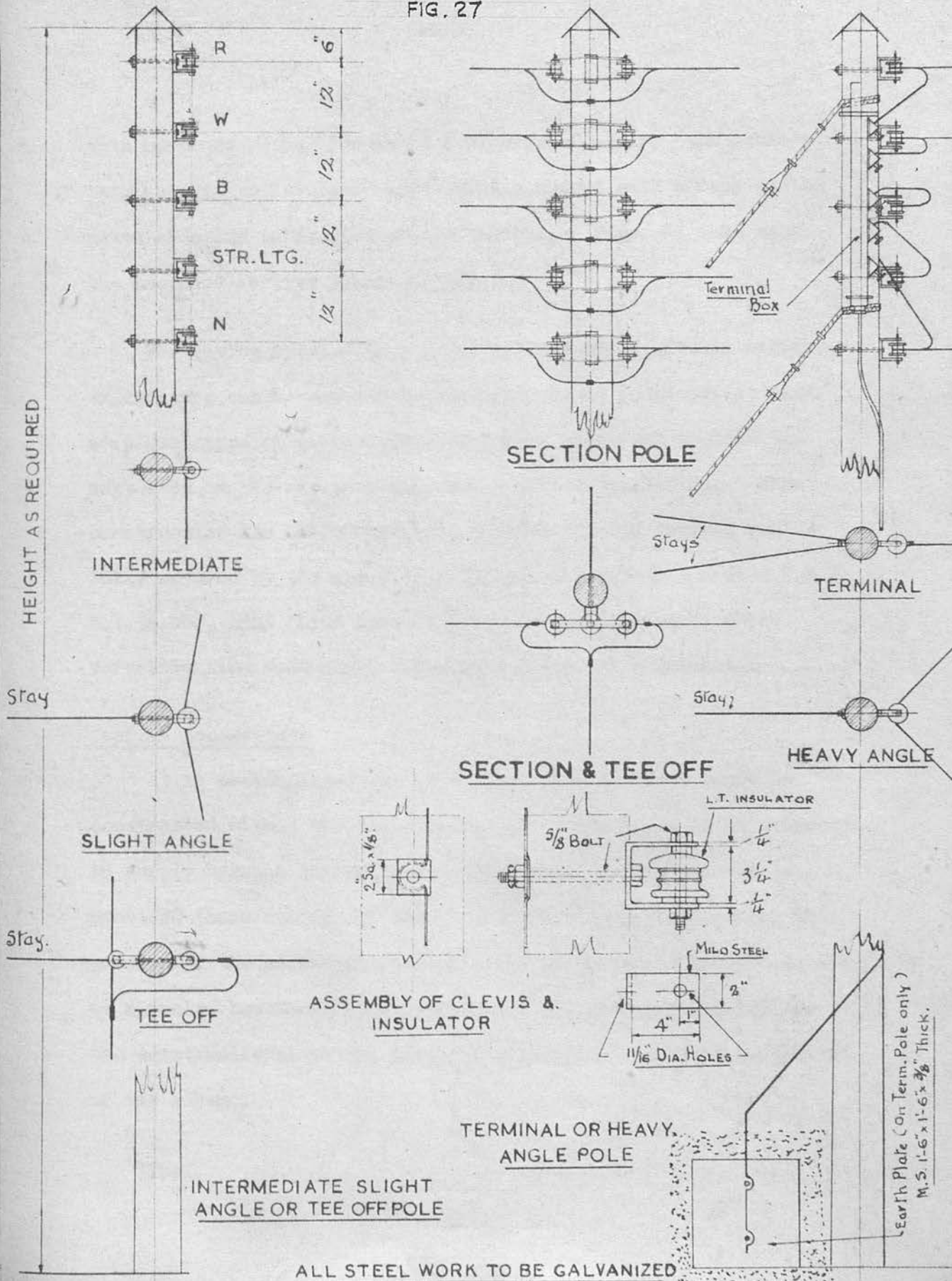
Low-Voltage Distribution and Services

The l.v. distribution networks would be composed on overhead "Sal" wood poles, the conductors being supported on shackle insulators fixed to the pole by a galvanised clevis (or D-iron) and through-bolts. All steelwork would be bonded. The same type of clevis would be used throughout for terminal, angle, section and intermediate poles, and all poles drilled at standard 12-in. spacing for 5 conductors, including a switch wire for street lighting. This simplifies and cheapens erection and service connections.

The overhead house service would have either two V.C.J. conductors or an insulated line wire and a bare neutral. The service wires would be made off on the house wall with the same type of clevis and insulators as for the distributor lines, but modified to suit wall mounting. The lead-in wires between the house service bracket and the meter board would comprise twin/

# LT OVERHEAD DISTRIBUTION DETAILS FOR EAST CALCUTTA RURAL PROJECT

FIG. 27



twin compound-rubber-insulated weatherproof cable; the cable would terminate in an insulated type service cutout with a fuse on the phase side and solid link on the neutral. Figs. 27 & 28 show the proposed service arrangements.

For giving service to a group of consumers, greatly reduced expenditure can be secured by the under-eaves construction with a special type of paper-insulated cable, taped and braided and supported on two-way porcelain wall-mounted insulators. This construction has been found very satisfactory in Britain and is fully covered by the new revised proposed Regulation 4 Proc.I.E.E. Vol. 96.686, 1949 "Line Conductors to be inaccessible", which refers to line conductors other than those fully insulated .....

4.9.

#### Capital Expenditure

It is contemplated that the whole of the scheme could be constructed within two "constructional" years. As it is proposed to supply Barasat initially from Barrackpore, supply could be provided there during the second constructional year, making this portion of the scheme revenue-earning thereafter. For the scheme as a whole, however, the first operational year will follow the two constructional years, i.e. the third year after the initiation of the scheme.

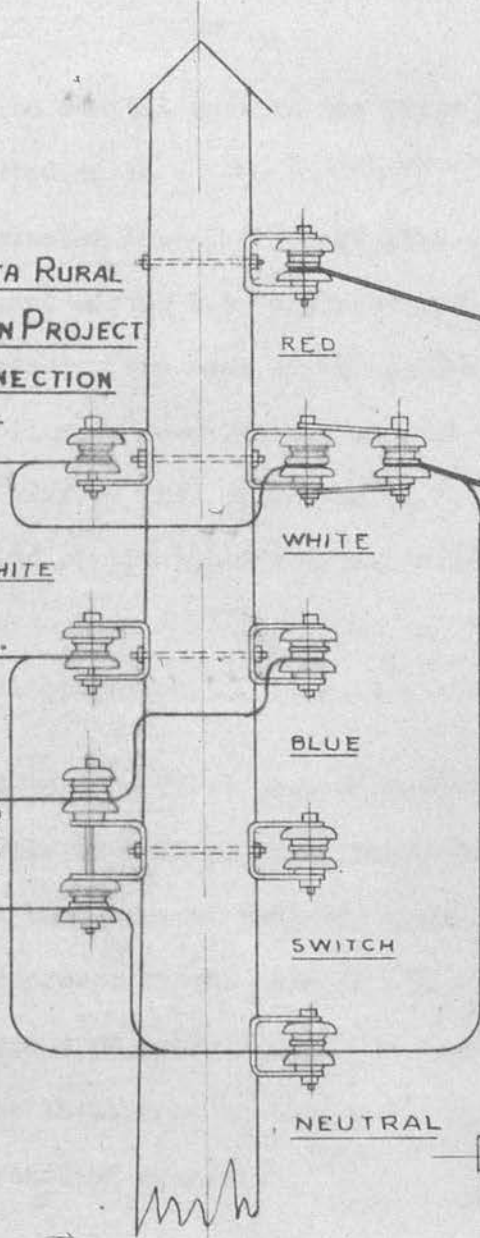
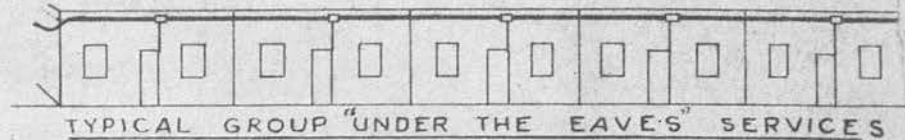
The/

FIG. 28

**EAST CALCUTTA RURAL  
ELECTRIFICATION PROJECT  
SERVICE CONNECTION  
AND DETAILS.**

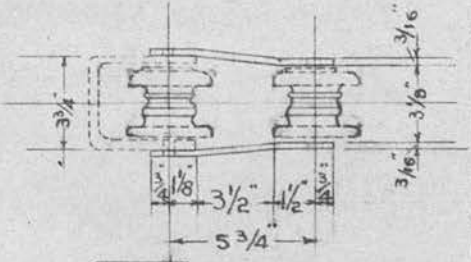
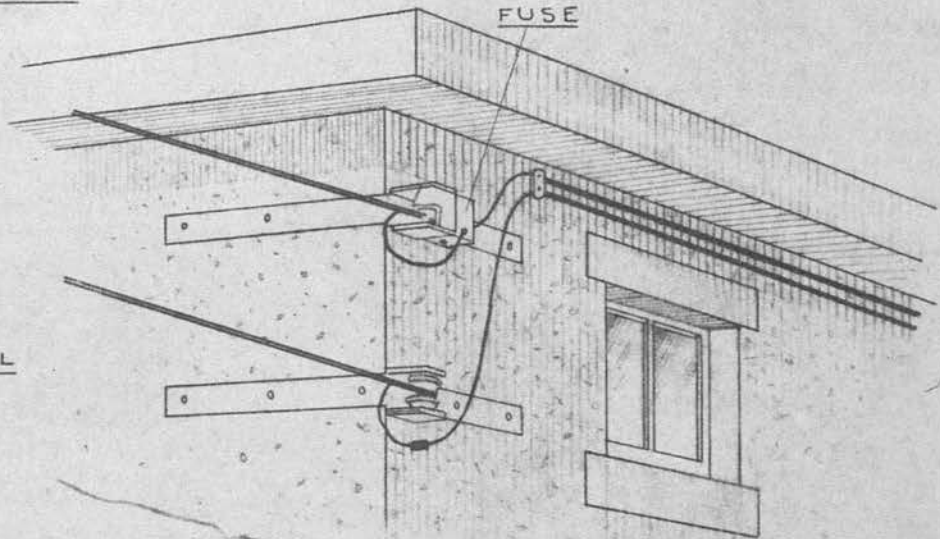
SERVICE OFF WHITE  
PHASE

ALTERNATIVE METHOD  
SHOWING SERVICE  
OFF BLUE PHASE

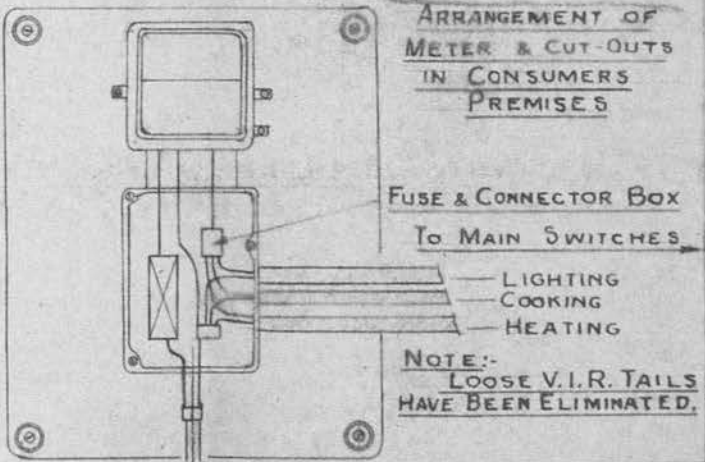


PHASE WIRE

NEUTRAL

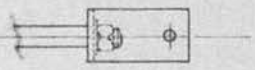


ARRANGEMENT OF  
METER & CUT-OUTS  
IN CONSUMERS  
PREMISES



NOTE:-  
LOOSE V.I.R. TAILS  
HAVE BEEN ELIMINATED.

ARRANGEMENT OF SERVICE TEE OFF



The capital cost in the first constructional year is estimated to be Rs. 1,098,000 this includes 33-kV transmission lines, the 6-kV line and substation for Barasat, and that part of the l.v. distribution lines and services pertaining to Barasat. The rest of the scheme would be constructed during the following year and the capital cost up to the beginning of the first year of full operation (i.e. the third year from the sanction of the scheme) is estimated to be Rs. 2,624,000 rising to Rs. 2,900,000 at the end of the fifth year of full operation.

After the first year of operation, the only capital expenditure contemplated will be that incurred in connecting new consumers. It has been assumed that the expenditure on l.v. distribution will increase at the rate of 10% per annum during the first five years of operation. The capital budget shown below caters for the total cost of l.v. works up to and including the first five years of operation.

	Equipments	
7.	Transformers	1,30,000
8.	Distribution Lines: 32 miles of l.v. 3-phase overhead distribution lines, on wood poles, 150-ft. spans, with provision for staying at angle positions, @ Rs. 13,500 per mile.	76,000
9.	l.v. Switchgear	4,32,000
10.	Services	15,000
11./		2,20,000

TABLE X : E. CALCUTTA RURAL AREA.

SUMMARY OF ESTIMATED CAPITAL COST TO FIFTH OPERATING YEAR		Rs.
11.		1,00,000
12.	Transport	25,000
13.	Office Equipment	10,000
1.	<u>Land</u>	15,000
2.	<u>Buildings for Service Centres, Substations and Workshops, Repair Depot.</u>	50,000
3.	<u>33-kV Transmission:</u> 28 miles of 33-kV, single-circuit, 3-phase, overhead line with 0.05 sq.in. (equiv.) cadmium-copper conductors, 7/12 s.w.g. galvanised-steel earth conductor and 33-kV pin insulators, on narrow-base steel towers @ Rs. 26,000 per mile.	7,28,000
4.	<u>11-kV Transmission:</u> 34 miles of 11-kV single-circuit, 3-phase, overhead line with 0.05 sq.in. (equiv.) cadmium-copper conductors and 7/12 s.w.g. galvanised-steel earth conductor on steel towers @ Rs.19,500 per mile.	6,63,000
5.	<u>6-kV Transmission:</u> 8 miles of 6/11-kV. single-circuit, 3-phase, overhead line with 0.05 sq.in. (equiv.) cadmium-copper conductors and 7/12 s.w.g. galvanised-steel earth conductor on steel towers, @ Rs.19,500 per mile.	1,56,000
6.	<u>Switchgear &amp; Substation Equipments</u>	1,30,000
7.	<u>Transformers</u>	76,000
8.	<u>Distribution Lines:</u> 32 miles of l.v. 3-phase overhead distribution lines, on wood poles, 150-ft. spans, with provision for staying at angle positions, @ Rs.13,500 per mile.	4,32,000
9.	<u>L.v. Switchgear</u>	16,000
10.	<u>Services</u>	2,20,000
11./		

	Rs.
11. <u>Meters</u>	1,00,000
12. <u>Transport</u>	25,000
13. <u>Office Equipment</u>	10,000
14. <u>Miscellaneous:</u> Measuring instruments, meter-testing equipments and small tools.	15,000
	<hr/>
	26,36,000
Contingencies - 10%	<u>2,64,000</u>
	<u>29,00,000</u>

At present exchange rates (Jan. 1950), this sum is equivalent approximately to £ 217,500.

APPENDIX 1

SCHEME NO 1

ESTIMATED COSTS

ITEM	SITE	DESCRIPTION	£	£
1	Chord Road	1-33-kV switch equipment 750 MVA with overload and earth leakage protection.	£ 4,200	
		5-sets of 33-kV ganged isolators @ £80	400	
		2-sets of 33-kV lightning arresters @ £150	300	
		6-single pole line earthing switches @ £20 each	120	
		5 Structures @ £50	250	
		2 Terminal towers @ £200	400	
		Foundation	400	
		Connections etc.	150	£ 6,220
2	33-kV line	52 miles 0.05-sq.in. equivalent cadmium-copper, 33-kV single circuit line on steel towers with aerial earth conductor @ £2000 per mile	104,000	104,000
3	11-kV line	12 miles 0.05-sq.in. equivalent cadmium-copper, 11-kV single circuit line on steel poles with aerial earth conductor @ £1400 per mile.	16,800	
		10 miles 0.025-sq.in. equivalent cadmium-copper, 11-kV single circuit on steel poles with aerial earth conductor @ £1000 per mile.	10,000	
		2-sets of 11-kV ganged Isolators @ £35	70	
		4-sets of 11-kV lightning arresters @ £30 per set	120	
		Connections etc.	100	27,090
		CARRY FORWARD.		£ 137,310

ITEM	SITE	DESCRIPTION	£	£
		BROUGHT FORWARD		137,310
4	Barasat	1-set 33-kV Pulldown Fuse isolating switch with arcing horn	150	
		1-set of 33-kV lightning arresters	150	
		1-250-kVA 33/11-kV outdoor Transformer	800	
		3-single pole earthing switches @ £20	60	
		1-11-kV switch equipment 100 MVA, with protection	650	
		2-11-kV oil immersed isolators		
		1-substation building	200	
		11-kV cabling into substation Transformer, foundation, etc.	100	
		Earthing & Sundries	45	2,180
5	Basirhat	Similar to Barasat except that the transformer is of 400-kVA, 33/11-kV instead of 250-kVA.	1,380 + 1,000	2,380
6	Habra (designed for future 33/11-kV modification)	2-sets of 33-kV ganged isolators.	160	
		6-single pole earthing switches.	120	
		1-set 33-kV Pulldown Fuse Isolator	150	
		1-100-kVA, 33/.4-kV Transformer.	520	
		1-set of co-ordinating gaps for lightning protection	10	
		Mounting for transformer	50	1,010
		CARRY FORWARD.	£	142,880

ITEM	SITE	DESCRIPTION	£	£
		BROUGHT FORWARD.		142,880
7	Gobardanga	Similar to Barasat with the addition of 2-sets of 33-kV ganged Isolators 3-single pole earthing switches	2,180 160 60	2,400
8	Baduria	1-set 33-kV Pulldown switch fuse 1-50-kVA, 33/0.4-kV transformer 1-set co-ordinating gaps for lightning protection Mounting for transformer.	150 450 10 10	620
9	11/0.4-kV Transformers	4-100-kVA, 3-phase 11/.4-kV @ £250 5-50-kVA, 3-phase 11/0.4-kV transformers @ £180 1-25-kVA, 3-phase 11/.4-kV transformers 10-11-kV fuse Isolator @ £25 L.T. fuses, metal boxes connections etc. @ £10	1,000 900 130 250 100	2,380
10	Low-Tension Service & Meters.	32-miles L.T. Overhead Lines 2250 Services & Meters Contingencies, add 10%  <u>Note:</u> Land, L.T. Distribution Mains and Services have been excluded.		148,280 14,828
				<u>163,108</u>

SAY £163,000

SCHEME NO 2

Estimate of Cost

130,145

ITEM	SITE	DESCRIPTION	£	£
1	Chord Road	1-33-kV switch equipment 750 MVA with overload and earth leakage protection  5-sets of 33-kV ganged isolators  2-sets of 33-kV lightning arresters  6-Single pole line earthing switches  5 Structures @ £50 2 Terminal towers @ £200  Foundations etc. and Connections etc.	4,200  400  300  120  250 400  400 150	£ 6,220
2	33-kV Line	38 miles, 0.05-sq.in. cadmium copper, 33-kV single circuit O.H. line on steel tower with aerial earth conductor @ £2000 per mile.	76,000	76,000
3	11-kV Line	34 miles, 0.05-sq.in. cadmium copper, 11-kV single circuit O.H. line on steel pole with aerial conductor @ £1400 per mile  4-sets of 11-kV lightning arresters @ £30 per set.  3-sets of 11-kV ganged isolators @ £35 Connections etc.	47,600  120  105 100	47,925
		CARRY FORWARD		£ 130,145

ITEM	SITE	DESCRIPTION	£	£
		BROUGHT FORWARD		130,145
4	Barasat	1-set of 33-kV Pulldown fuse isolating switch with arcing horn	150	
		1-set of 33-kV lightning arrester	150	
		1-250-kVA, 33/11-kV outdoor transformer.	800	
		3-single pole earthing switches	60	
		(1-11-kV switch equipment 100MVA ) ( with protection )	650	
		(2-11-kV oil immersed isolators )		
		1-substation building	200	
		Transformer foundations	25	
		11-kV cabling into substation	100	
		Earthing and sundries	45	2,180
5	Baduria	Similar to Barasat except that 1-500-kVA, 33/11-kV outdoor transformer	1,380	
			1,150	2,530
6	Habra	Similar to above plus 2 sets of 33-kV ganged line selection switches.	2,530	
		3 single pole earthing switches @ £20	160	
			60	2,750
7	11/.4-kV Transformers.	5-100-kVA, 11/.4/230 volts transformers @ £250.	1,250	
		4-50-kVA, 3-phase 11/.4/230 V transformers @ £180	720	
		1-25-kVA, 3-phase 11/.4/230V transformers.	130	
		10-11/.4-kV fuse isolators mounted on line structure @ £25.	250	
		L.T. fuses, metal boxes and connections etc @ £12.	100	2,450
		CARRY FORWARD		£140,055

ITEM	SITE	DESCRIPTION	£	£
		BROUGHT FORWARD		£140,055
8	Low Tension	32 miles of L.T. overhead lines 2250 service connections at Meters etc.  <u>Note:</u> Land, L.T. Distribution Mains and Services have been excluded.		
		Contingency		£ 140,055
		Add 10% on Item		14,005
				<u>£ 154,060</u>
	33-kV Line	28 miles, 0.05 sq.-in. equivalent cable copper, 33-kV single circuit O.H. towers with <u>SAY £154,000</u> aerial earth conductor @ £2,000 per mile		36,000
	11-kV Lines	34 miles, 0.05-sq.-in. equivalent cable copper, 11-kV single circuit O.H. line on steel towers with aerial earth conductor @ £1,400 per mile  4-sets of 11-kV lightning arresters @ £30 each set  4-sets 11-kV line section switches @ £25 Connections etc.	47,600  120  100 100	47,820
		BROUGHT FORWARD		£102,820

SCHEME NO 3

Estimate of Cost

ITEM	SITE	DESCRIPTION OF PROPOSED WORKS	£	£
1	Chord Road 6-kV Lines	1-33-kV switch equipment 750 MVA, with overload and earth leakage protection  4-sets 33-kV ganged isolators @ £80  1-set 33-kV lightning arresters @ £50 each set  3-single pole line earthing switches @ £20 each  4 Structures @ £50 2 Terminal towers @ £200 Foundations Erections, connections etc.	4,200  320  150  60  200 400 400 150	5,880
2	33-kV Line	28 miles, 0.05 sq.-in. equivalent cadmium copper, 33-kV single circuit O.H. line on steel towers with aerial earth conductor @ £2,000 per mile		56,000
3	11-kV Line	34 miles, 0.05-sq.in. equivalent cadmium copper, 11-kV single circuit O.H. line on steel towers with aerial earth conductor @ £1,400 per mile  4-sets of 11-kV lightning arresters @ £30 each set  3-sets 11-kV line section switches @ £35 Connections etc.	47,600  120  105 100	47,925
		CARRY FORWARD.		£ 109,805

ITEM	SITE	DESCRIPTION OF PROPOSED WORK	£	£
		BROUGHT FORWARD		£ 109,805
4	Habra 6-kV Line	Similar to above plus 8 miles, 0.05-sq.in. equivalent cadmium copper 6-kV O.H. line insulated for 11-kV single circuit on steel towers with aerial conductor @ £1400	11,200	
		1-set 6-kV Lightning Arrester	30	11,230
5	Barasat 6.6-kV 100-kVA	1-set 11-kV Pullout type fuse Isolators 1 x 100-kVA transformer 6/.4-kV L.V. switch and fusegear	25 250 50	325
6	Barrackpore	Reinforcement of Barrackpore substation and provision for a 6/11-kV Drawout type O.C.B. fitted with O/L & E/L protection Earthing, cabling, connections etc.	500 100	600
7	Baduria 110 kV Tension Distri- bution	1-set 33-kV Pulldown fuse isolating switch with arcing horn 1-set 33-kV Lightning Arresters 1-500-kVA Outdoor transformer with off load tap changing gear 33/11-kV. 3-single pole earthing switches 1-11-kV Switch Equipment, 100 MVA } with protection } 2-11-kV oil immersed isolators } 1 - Substation Building Transformer Foundation 11-kV Cabling, earthing and sundries	150 150 1,150 60 650 200 25 150	2,535
		CARRY FORWARD		£124,495

ITEM	SITE	DESCRIPTION OF PROPOSED WORK	£	£
		BROUGHT FORWARD		124,495
8	Habra	Similar to above plus	2,535	
		2-sets 33-kV ganged isolators mounted on adjacent line structure.	160	
		3-single pole earth switches	60	2,755
9	Trans-formers	4 x 100-kVA, 3-phase Transformers 11/.4-kV @ £250	1,000	
		4 x 50-kVA 3-phase Transformers 11/.4-kV @ £180	720	
		1 x 25-kVA 3-phase Transformer 11/.4 -kV @ £130	130	
		8 sets 11-kV fuse isolators mounted on line structure @ £25	200	
		L.T. fuses metal box, Connections, etc. @ £12.	100	2,150
10	Low Tension Distribution	32 miles of L.T. overhead lines		129,400
		2250 Services and meters.		
		<u>Note:</u> Land, L.T. Distribution Mains and Services have been excluded.		
				129,400
Add 10%				12,940
Grand Total				<u>142,340</u>

SAY £142,000

COMPARISON OF THE PRELIMINARY  
ESTIMATED COSTS

Schemes	No. 1	No. 2	No. 3
Estimated Cost	£163,000	£154,000	£142,000

NOTE: Detailed estimate of the Capital Costs of the equipments with reference to the cost level in India has been rendered very difficult. The above estimate is based on the present day ruling prices in Britain and it has been assumed that the higher labour costs in England may be counterbalanced by the equipment cost in India.

Freight and duty will, however, have to be added on the above.

With 0.05-sq. in. copper-equivalent conductors at 11 KV the loss per mile is 0.0072  $q^2$  watts, and this gives a line loss per mile of 7.2 KW for a load of 1000 KVA. For the same conductor and 33 KV the loss is 0.0008  $q^2$  watts per mile, or 0.8 KW per mile for 1000 KVA.

A P P E N D I X II

SYSTEM LOSSES

The system losses comprise (a) line loss, (b) transformer loss, (c) distribution loss and (d) meter and miscellaneous losses.

Line Loss

This will be small until the load has grown to a value approaching that for which the system is designed, after which re-enforcement or restringing become necessary.

Let

q = substation load, kVA;

V = line voltage, kV;

l = transmission route-length, miles;

a = conductor section, sq. in.;

Then the  $I^2R$  line loss in watts is

$$P_r = 0.0437 \sum \frac{l q^2}{a V^2}$$

for copper conductors.

With 0.05-sq.in. copper-equivalent conductors at 11 kV the loss per mile is  $0.0072 q^2$  watts, and this gives a line loss per mile of 7.2 kW for a load of 1000 kVA. For the same conductor and 33 kV the loss is  $0.0008 q^2$  watts per mile, or 0.8 kW per mile for 1000 kVA.

Applying/

Applying these figures for the estimated peak-load conditions (from Table V), the combined loss in 33- and 11-kV line networks as a percentage of the relevant peak load is:

Year of operation	1	2	3	4	5	.....	12
percentage peak line loss	2.5	3.9	4.9	5.7	6.4	.....	15.5

The total annual energy loss is obtained from the average line power loss; the latter is in turn derived from the product of the peak power loss with the annual "loss load-factor" (which differs, of course, from the load factor appropriate to the load itself). The loss load-factor has a value depending on the load/time curve and not solely on the load factors because the same load factor - or ratio (average/peak) - is given by widely differing load/time curves, whose (load)<sup>2</sup>/time curves (on which the loss load-factor depends) are bound to be different. Thus the loss load-factor  $K_l$  cannot be derived with accuracy without a knowledge of the load/time curve. It can, however, be estimated by aid of empirical expressions such as

$$K_l = 0.2 K_p + 0.8 K_p^2$$

where  $K_p$  is the load factor.

In/

In the present case, taking  $K_f = 0.24$ , then

$$K_l = 0.2 \cdot 0.24 + 0.8 \cdot 0.24^2 = 0.09$$

This figure agrees with that derived by assessing the losses from the square of the predicted load curve given in Part II, Section A.

The annual line loss in kWh as a percentage of the annual load kVAh is then as below:

Year of operation	1	2	3	4	5	.....	12
Percentage annual line loss	0.2	0.3	0.4	0.5	0.6	.....	1.4

#### Transformer Losses

The following Table lists the core and full-load  $I^2R$  losses of the transformers on the system. The two main 33/11-kV, 500-kVA transformers respectively at Habra and Baduria feed seven 11/0.4-kV subsidiary transformers of various ratings. In the first year the estimated peak load of this group is 190 kVA. The separate supply at 6 kV to the 6/0.4-kV, 100-kVA transformer at Barasat deals with an estimated maximum demand of 40 kVA.

$$8760 [4.75 + 0.09 + 13.6 (190/1000)^2]$$

$$45,300 \text{ (core)} + 390 \text{ (I}^2\text{R) kWh}$$

Similarly for the remaining transformers, the losses are:

Voltage kV	Rating kVA	Losses, kW		No. of Units	Total Losses, kW	
		Core	$I^2R$		Core	$I^2R$
33/11	500	2.48	6.8	2	4.96	13.60
11/0.4	25	0.24	0.70	1	0.24	0.70
	50	0.38	1.18	4	1.52	4.72
	100	0.64	2.0	2	1.28	4.00
					3.04	9.42
6/0.4	100	0.64	2.0	1	0.64	2.0

Figures calculated by...

The  $I^2R$  losses vary as the square of the load, and it is legitimate to assume for them the same loss load-factor of 0.09 already obtained for the transmission lines.

For the two main transformers the loss in the first year (maximum demand 190 kVA) will be

$$8760 [4.96 + 0.09 \cdot 13.6 (190/1000)^2]$$

$$= 43,500 \text{ (core)} + 390 \text{ (I}^2\text{R)} \text{ kWh.}$$

Similarly for the subsidiary transformers, whose rating totals  $25 + 4.50 + 2.100 = 425$  kVA:

$$8760 \left[ 3.04 + 0.09 \cdot 9.42 \left( \frac{190}{425} \right)^2 \right]$$
$$= 26,600 \text{ (core) } + 1,450 \text{ (I}^2\text{R) kWh}$$

For the Barasat transformer, peak load 50 kVA and rating 100 kVA, the annual energy loss is

$$8760 \left[ 0.64 + 0.09 \cdot 2.0 \left( \frac{50}{100} \right)^2 \right]$$
$$= 5,600 \text{ (core) } + 390 \text{ (I}^2\text{R) kWh}$$

The total transformer energy loss for the first year is thus  $75,700 + 2,230 = 77,930$  kWh. The preponderance of core loss is notable, but unavoidable.

Figures calculated for other years are tabulated in Table IX, (Part II, 4.1.).

APPENDIX III

OVERHEAD-LINE DESIGN AND ECONOMIC SPAN-LENGTH.

III.1. Specified Working Conditions

Maximum wind pressure: on conductors, 20 lb/sq.ft. on  $\frac{2}{3}$  projected area; on supports, 20 lb/sq.ft. on  $\frac{1}{2}$  times surface area (lattice pole), on projected area (tubular pole).

Temperature range,  $50 - 130^{\circ}\text{F.} = 80^{\circ}\text{F.}$

Factors of safety (minimum): on conductors, 2; on supports,  $2\frac{1}{2}$ .

Clearance: 20 ft. from ground.

III.2. Design for Specification

Conductor: stranded cd-cu, 0.0588 sq.in. (3/0.147"),  
ultimate strength 4670 lb., weight 690 lb/1000 yd.

Supports: narrow-based steel lattice or tubular, height  
39 - 43 ft., working load 1100 lb, crippling load  
2750 lb.

Cross arms: wish-bone type, channel section, insulator  
pins spaced 4 ft. 6 in. between phases.

Earth wire: stranded galvanised iron wire, 7/14 S.W.G.,  
weight 360 lb/1000 yd.

III.3.

Procedure

The height, and therefore the cost, of the supports is a function of the sag and span length. The conductor sag is greatest at maximum temperature with maximum wind pressure. The economic span is estimated by calculating the sag, support height and cost for selected spans between 250 and 600 ft. This range is well below the span limit imposed by the working loads on the insulator pins, which are rated for 400 and 800 lb. With a wind pressure of 0.38 lb/ft. run these give span limits respectively of

$$400/0.38 = 1050 \text{ ft.}, \text{ and } 800/0.38 = 2100 \text{ ft.}$$

Thus insulator strength does not impose a limit within the proposed range of span lengths.

The calculations of cost for a chosen span are made for tubular steel poles, details of which are given in Fig. 29.

MANUFACTURER'S DETAILS  
OF TUBULAR POLES

£37

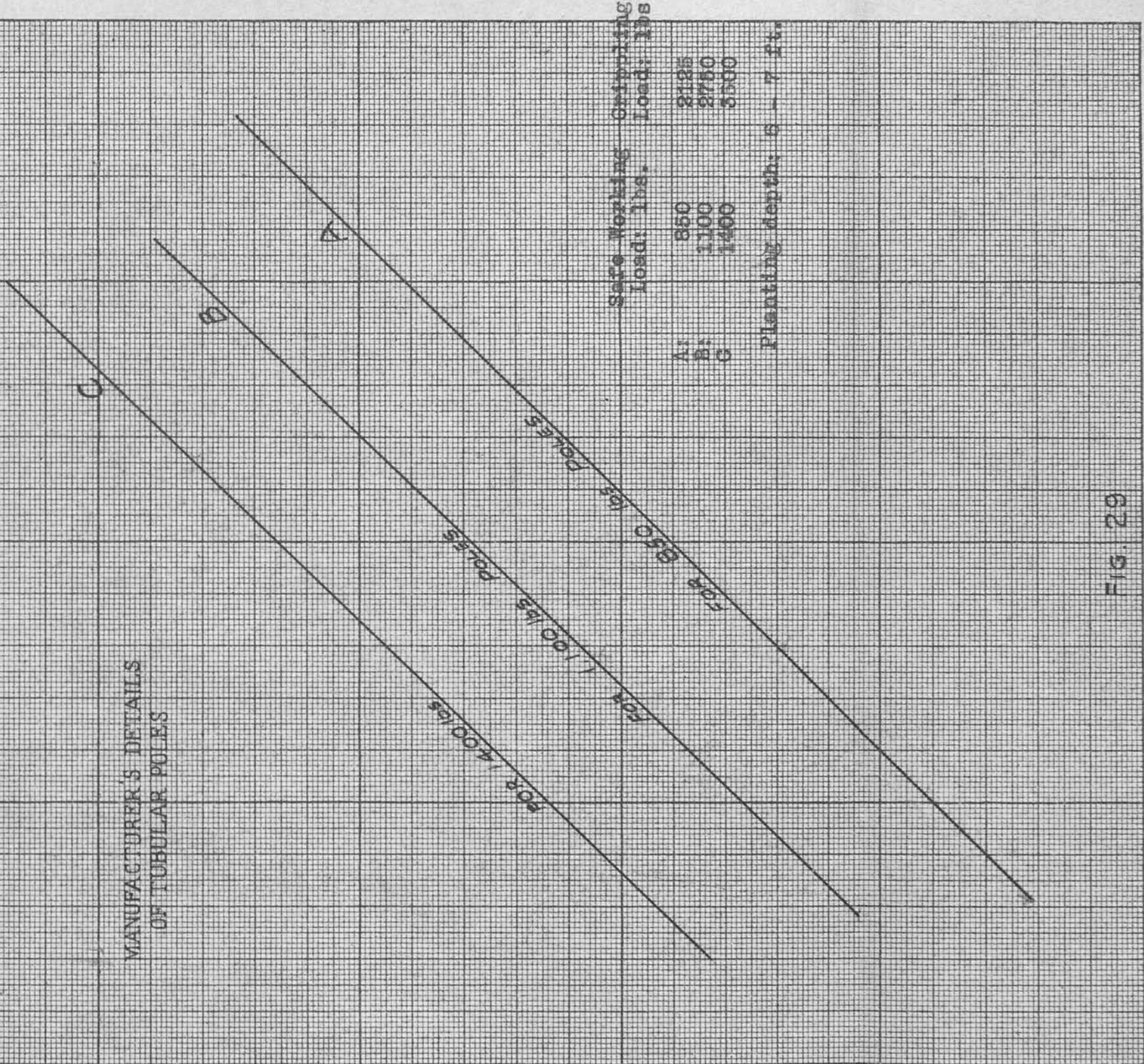
£30

£25

£20

£15

COST PER POLE



FOR 1,400 lbs POLES  
FOR 1,100 lbs POLES  
FOR 850 lbs POLES

Safe Working Load: lbs  
Crippling Load: lbs

Planting depths: 6 - 7 ft.

FIG. 29

30

35

40

45

50

POLE LENGTH IN FEET

III.4. Calculation for 400-ft. span

III.4.1. TENSION AND SAG.

Conductor diameter = 0.34 in., area, A = 0.0588 sq. in.  
 conductor weight/ft., W = 0.23 lb/ft.

Wind load =  $(0.34/12)(2/3)20 = 0.378$  lb/ft.

Resultant load  $W = \sqrt{(0.23^2 + 0.378^2)} = 0.443$  lb/ft.

Maximum tension (f. of S = 2),  $T_0 = 4670/2 = 2335$  lb.

Modulus of elasticity, E =  $18 \cdot 10^6$  lb/sq. in.

Coeff. of linear expansion,  $\alpha = 9.22 \cdot 10^{-6}$  in/ $^{\circ}$ F.

The tension T for the high-temperature wind-loaded condition is

$$T^3 + T^2 \left[ \frac{EA\alpha t}{6} + \frac{W^2 l^2 EA}{6 T_0^2} - T_0 \right] = \frac{W^2 l^2 EA}{6}$$

where t is the maximum working temperature-rise

(1)  $EA\alpha t = 18 \cdot 10^6 \cdot 9.22 \cdot 10^{-6} \cdot 0.0588 \cdot 80 = 781.$

(2)  $\frac{W^2 l^2 EA}{6 T_0^2} = \frac{(0.23)^2 \cdot (200)^2 \cdot 0.0588 \cdot 18 \cdot 10^6}{6 (2335)^2}$

= 68.

(3)  $\frac{W^2 l^2 EA}{6} = \frac{(0.443)^2 \cdot (200)^2 \cdot 0.0588 \cdot 18 \cdot 10^6}{6}$

=  $1385 \cdot 10^6$

Hence  $T^3 + T^2 (781 + 68 - 2335) = 1385 \cdot 10^6$

giving T = 1880 lb.

sag, at 130°F with wind load, in plane of conductor,

$$wL^2/2T = 0.443 \cdot 200^2/2 \cdot 1880 = 4.7 \text{ ft.}$$

### III.4.2. POLE HEIGHT.

This will be ground clearance + twice conductor clearance + sag,  $H = 20 + 2 \cdot 4.5 + 4.7 = 33.7 \text{ ft.}$  above ground.

The length of buried portion would be 6 ft., making a total pole-length of 39.7 ft., i.e. 40 ft.

### III.4.3. WIND LOADINGS.

(a) On pole surface. Pole height  $H = 34 \text{ ft.}$ , diameter  $D = 1.17 \text{ ft.}$

wind pressure, 20 lb/sq.ft.

Bending moment

$$20 DH \cdot \frac{1}{2}H = 13500 \text{ lb.-ft.}$$

Load acting at 1 ft. from top of pole

$$= 13500/33 = 410 \text{ lb.}$$

(b) On conductor surface. Conductor diameter  $d = 0.34 \text{ in.}$

wind pressure, 20 lb/sq.ft. on 2/3rds projected area.

Total pressure in 400-ft. span:-

$$\text{For conductors,} = 400 \cdot 0.34 \cdot 20 \cdot \frac{2}{3} \cdot 12 = 150 \text{ lb.}$$

$$\text{For earth wire,} = 400 \cdot 0.192 \cdot 20 \cdot \frac{2}{3} \cdot 12 = 85 \text{ lb.}$$

Bending moment at pole base produced by above

$$= 150 \cdot 25 + 2 \cdot 150 \cdot 29.5 + 85 \cdot 33$$

$$= 15,500 \text{ lb-ft.}$$

Wind load at 1 ft. from top of pole

$$= 15,500/33 = 470 \text{ lb.}$$

(c) Total Wind Load at 1 ft. from top of pole

$$= 410 + 470 = 880 \text{ lb.}$$

III. 4. 4. COMPARISON.

Results obtained for several selected spans are given in the Table below.

COMPARISON OF POLE COSTS PER MILE

Span, ft.	250	300	350	400	450	500	550	600
Tension at 130°F with wind load, lb.	1710	1770	1820	1880	1930	1990	2050	2100
Sag as above, ft.	2.0	2.8	3.7	4.7	5.8	6.9	8.2	9.5
Pole height, ft.	37	38	39	40	41	42	43	44.5
Wind load on pole, lb.	370	385	400	410	420	430	445	455
Wind load on conductor, lb.	290	350	410	470	535	595	660	720
Total transverse load on pole, lb.	660	735	810	880	955	1025	1105	1175
Cost of pole, £	21.0	22.0	23.0	27.8	28.8	29.9	31.0	36.0
Poles per mile	21.1	17.6	15.1	13.2	11.7	10.6	9.6	8.8
Total cost of poles per mile, £	443	388	348	378	337	317	298	318

Factor of safety for conductors, 2; at 50°F. without wind and at 130°F. with wind.

III.5.

Economic Span Length.

It would thus appear that a span length of 550 ft. would give the most satisfactory line, with a pole cost of £298 per mile.

III.6.

Insulators.

Either the 400 or 800 lb. insulators are adequate for normal load conditions. With broken conditions, however, the pull on the insulator may reach full conductor tension, i.e. 2335 lb. A 400-lb. insulator would almost certainly fracture under these conditions but an 800-lb unit, although it would be overstrained, would probably not break as the movement due to strain would relieve the tension.

Impedance Values.

Impedances have been calculated with an angle value and as percentages on 100-KVA base. Percentage values are used in calculating symmetrical fault conditions, but the values are more convenient for asymmetrical faults.

The short circuit flow at each end is 750 MVA. The generator neutral at Malajore is solidly earthed. The equivalent impedance of the generating plant on a 100-KVA base is

$$100,000 \times 100 / 750,000 = 13.33 = 0.16 \text{ pu at 11-kV}$$

For 0.05-sq.in. (equiv.) conductors the impedance per mile, line to neutral, is

$$0.89 + j0.63 = 1.08 \text{ ohms} = 9.2 \text{ pu}$$

The resistance per mile of 35-KV lines on a base of 100-KVA is 0.16 pu.

APPENDIX IV

SYSTEM SHORT-CIRCUIT CALCULATIONS

7.1. Layout.

The system layout is shown schematically in Fig. 30. Although Barasat is proposed to be supplied at 6-kV from Barrackpore, in view of its ultimate change-over, it is shown connected to the Chord Road substation for an estimation of the magnitude of possible fault current. A 0.05-sq.in. (equiv.) conductor is used throughout.

7.2. Impedance Values.

Impedances have been calculated both as ohmic values and as percentages on 100-MVA base. Percentage values are used in calculating asymmetrical fault conditions, but the ohmic values are more convenient for symmetrical faults.

The short circuit flow at Chord Road is 750 MVA. The generator neutral at Mulajore is solidly earthed. The equivalent reactance of the generating plant on a 100-MVA base is

$$100,000 \cdot 100/750,000 = 13.3\% = 0.16 \text{ ohm at } 11\text{-kV.}$$

For 0.05-sq.in. (equiv.) conductors the impedance per mile, line-to-neutral, is

$$0.88 + j0.63 = 1.08 \text{ ohms} = 9.9\%.$$

The resistance per mile of 33-kV lines on a basis of 11-kV is 0.12 ohm.

# SYSTEM LAYOUT FOR THE EAST CALCUTTA RURAL PROJECT

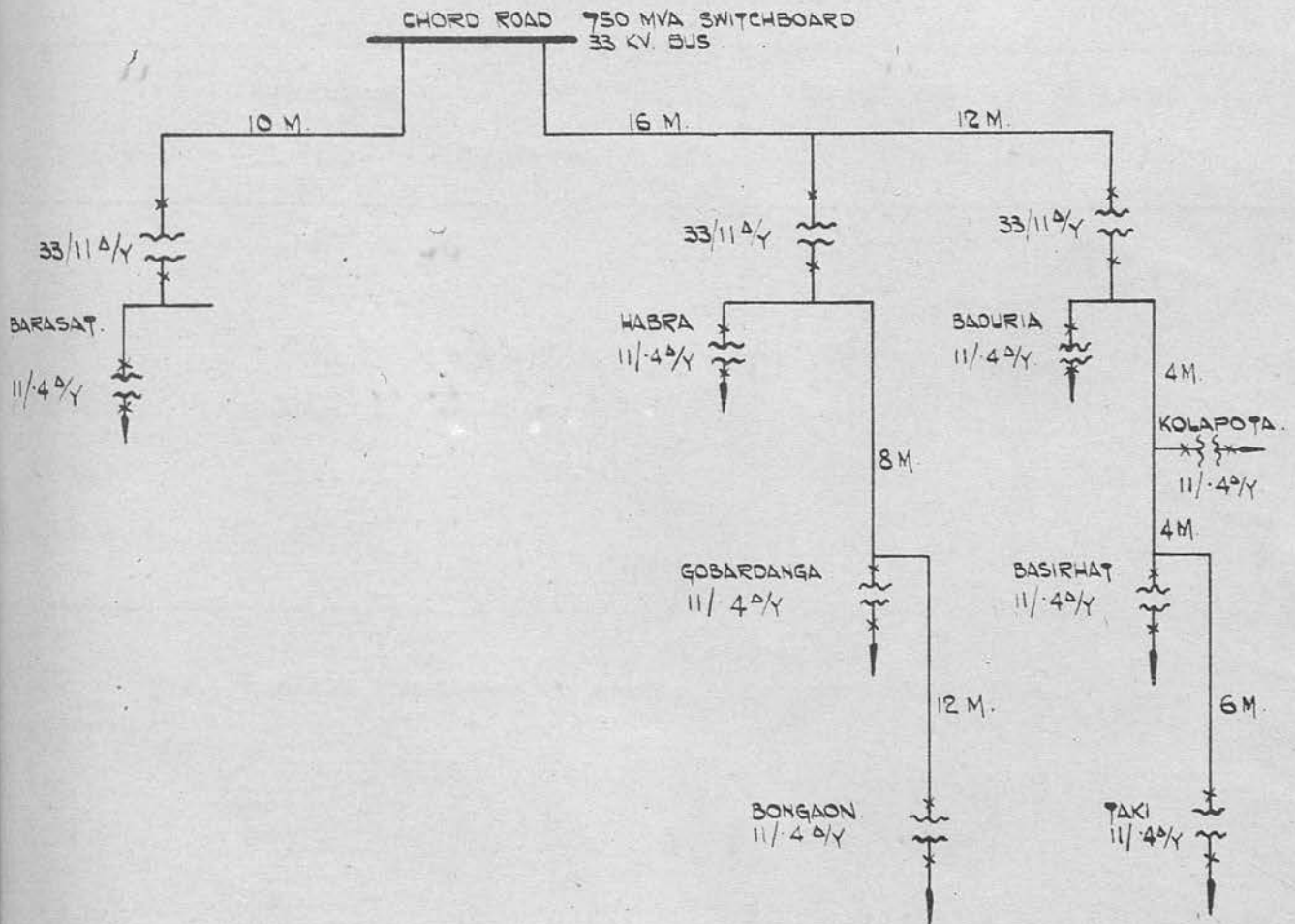


FIG. 30.

The transformer impedances as percentages on 100-MVA base and as ohmic values at 11-kV are as follows :-

Transformer Impedances.

Rates kV	Transformer		On 100 MVA	At 11-kV
	Rating kVA	Impedance %	%	ohms
33/11	500	5.5	1100	13.3
33/11	250	5.2	2080	25.2
11/0.4	100	4.4	4400	53.2
11/0.4	50	4.7	9400	113.7
11/0.4	25	3.7	14800	179.1

Fig. 31 shows the schematic system layout with these figures.

IV.3. Symmetrical Faults

From the impedance diagram, the total calculated impedances to the various substations are as given in columns 2, 5 and 8 of table below. The corresponding short-circuit MVA and current are given in the succeeding columns.

SYMMETRICAL SHORT-CIRCUIT CURRENTS

Station	33-kV Side			11-kV Side			L. V. Side.		
	Z%	MVA	Amps	Z%	MVA	Amps	Z%	MVA	Amps.
Barasat	112	90	1,580	21.92	4.5	237	6,592	1.5	2,165
Habra	171	58	1,020	12.71	7.8	410	5,671	1.7	2,453
Baduria	290	34	600	13.90	7.2	378	10,790	0.9	1,300
Gobardanga				13.50	7.4	389	5,750	1.7	2,453
Bengaon				14.69	6.8	358	5,869	1.7	2,453
Kolapota				14.30	7.0	368	16,230	0.6	866
Basirhat				14.70	6.8	358	5,870	1.7	2,453
Taki & Hashnabad.				15.30	6.5	342	10,930	0.9	1,300

IV.4. Asymmetrical Faults

The method of symmetrical components, in which the unbalanced currents and voltages are resolved into positive-, negative- and zero-phase-sequence components, is applied.

IV.4.1. IMPEDANCES. The impedance  $Z_+$  of a system to positive-phase-sequence currents is as already given in Fig. 31.

The impedance  $Z_-$  to negative-sequence currents is the same as for p.p.s. currents for lines and transformers but somewhat less/

less for generators. In the present case, the generator impedance is a small proportion of the total, so that negligible error will be introduced by assuming  $Z_- = Z_+$ .

The impedance of overhead lines to zero-sequence currents is difficult to assess since the current follows an indeterminate path through the earth. Reliance must therefore be placed on tests taken on similar lines. These indicate that the impedance to zero-sequence currents approximates to  $3\frac{1}{2}$  times the p.p.s. impedance.

The impedance of transformer to Z.p.s. currents is the same as to p.p.s., provided that a Z.p.s. current path is available on both primary and secondary sides.

In the present scheme all transformers are connected delta/star with star point solidly earthed. Zero-sequence currents originating from a fault on the secondary side will flow in the secondary winding of the transformer and through the star point, corresponding currents circulating in the primary delta but not flowing in the primary lines.

The impedance diagram for impedance to Z.p.s. currents is thus as shown in Fig. 32.

III.4.2. FAULT CURRENTS. The current  $I_{scp}$  due to a phase fault is  $\sqrt{3}E/(Z_+ + Z_-)$ . In the present case  $Z_- = Z_+$ , so that

$$I_{scp} = \frac{\sqrt{3}}{2} \cdot \frac{E}{Z_+} = \frac{\sqrt{3}}{2} I_{sc}$$

where  $I_{sc}$  is the symmetrical 3-phase fault current.

The phase fault currents at the various substations are thus 87% of the symmetrical fault currents shown in the previous table.

The current due to an earth fault is

$$I_{sce} = \frac{3E}{Z_+ + Z_- + Z_0} = \frac{3E}{2Z_+ + Z_0}$$

For a double earth fault the current will be

$$I'_{scd} = -1\frac{1}{2}EZ_+/\delta - j\frac{1}{2}\sqrt{3}E(Z_+ + 2Z_0)/\delta$$

in the line, and

$$I''_{scd} = -3EZ_+/\delta$$

to earth, where

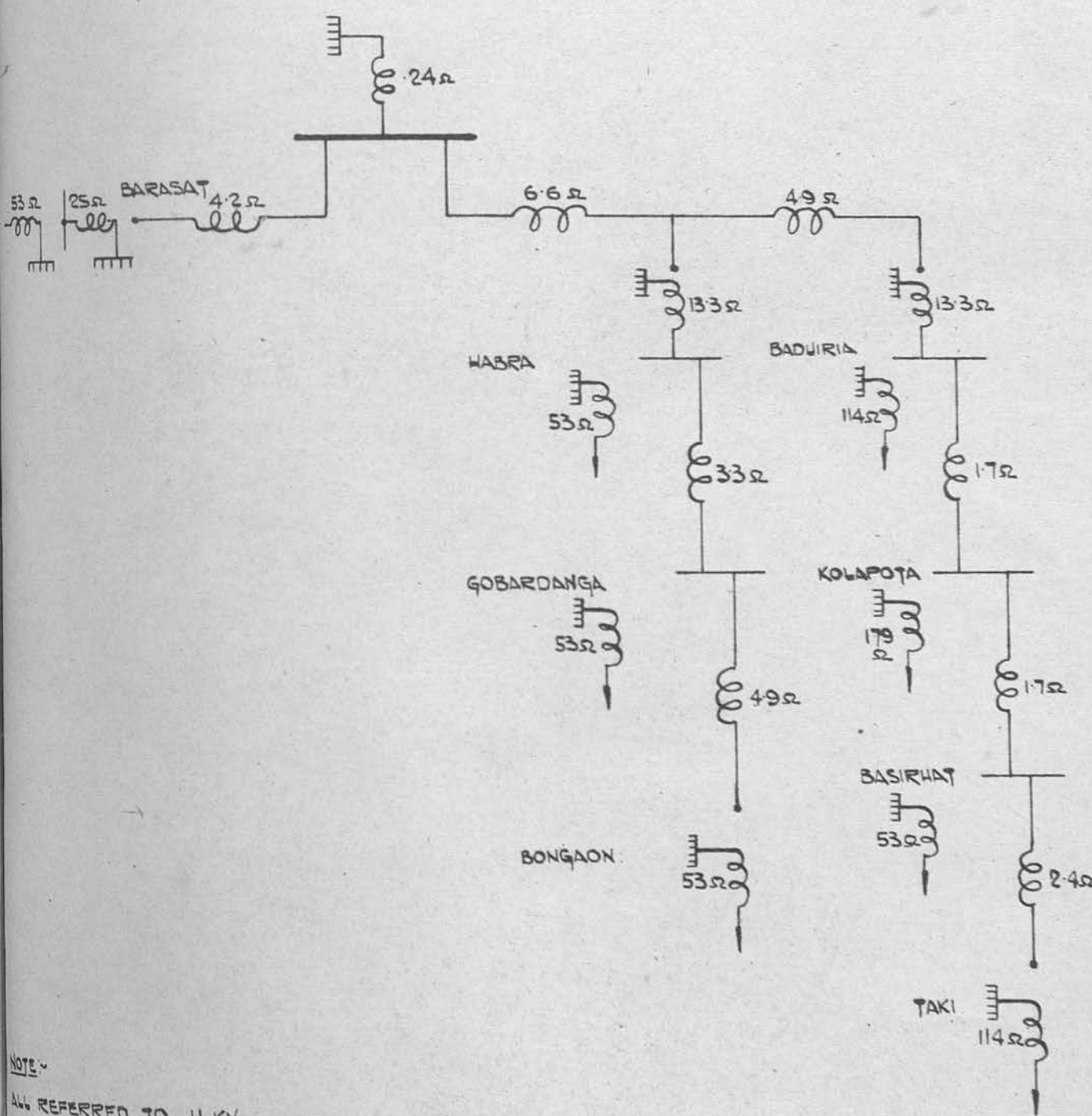
$$\delta = Z_+Z_- + Z_-Z_0 + Z_0Z_+$$

The application of the formulae for phase and single earth faults on the network yields the results tabulated below:

CURRENTS DUE TO FAULTS ON 33-kV NETWORK

Places.	Positive Sequence Impedance (ohms)	Zero Sequence Impedance (ohms)	Earth fault Current Amps	Phase fault current Amps	Symmetrical 3-phase fault Amps
Barasat	1.36	4.4	875	1,370	1,580
Habra	2.06	6.84	580	884	1,020
Baduria	3.46	11.74	340	520	600

# ZERO - SEQUENCE IMPEDANCES.



NOTE -  
ALL REFERRED TO 11 KV.

FIG 32

CURRENTS DUE TO FAULTS ON 11-kV NETWORK

Place	Positive sequence impedance ohms.	Zero Sequence Impedance ohms.	Current on 11-kV side			Current on 33-kV side		
			Earth fault Amps	Phase Fault Amps	3-phase Fault Amps	Earth Fault Amps	Phase Fault Amps	3-phase Fault Amps
Barasat	26.5	25.2	240	205	237	47	68	79
Habra	15.4	13.3	430	355	410	83	118	137
Baduria	16.8	13.3	410	327	378	79	109	126
Gobardanga	16.3	16.6	387	337	389	74	112	130
Bongaon	17.7	21.5	335	310	358	64	103	119
Kolapota	17.2	15.0	385	318	368	74	106	123
Basirhat	17.7	16.7	365	310	358	70	103	119
Taki & Hashnabad	18.4	19.1	341	296	342	65	98	114

PART II

SECTION C

5. FINANCIAL ASPECTS AND CHARGE RATES

The annual cost of supply in the Area under discussion can be divided into (1) the cost of energy, and (2) the costs associated with distribution and administration. Energy is to be purchased in bulk from the Calcutta Electricity Supply Corporation and the rates offered by the Corporation are set out below, together with a detailed analysis of the annual working expenses associated with distribution and management.

Tariff formulation is most readily achieved by following the conventional method of dividing working expenditure between fixed and running costs, a method applicable wherever fixed costs are large relative to variable costs. Accordingly, although energy is supplied by the Calcutta Electricity Corporation Ltd. at flat rates varying according to load factor and maximum demand, its cost has been divided into fixed and variable components. Distribution and local working expenditure has been similarly treated.

5.1. Cost of Energy Purchased

Energy will be purchased from the Calcutta Electricity Supply Corporation Ltd., at their generating voltage of 33-kV together with the/

the supply required for the North Calcutta Scheme. As it is proposed to supply Barasat from Barrackpore at the early stage, a partial supply for this scheme will have to be obtained from the Supply Corporation along with the Barrackpore supply at a slightly higher cost until agreement is made with the Company for aggregating the supply demands at the two places, in order to take advantage of any better load factor which may result.

Schedule 1 shows the rate chargeable by the Supply Corporation for energy in bulk based on the estimated combined demand and load factor of the North and East Calcutta projects. This rate has been applied for the calculation of the cost of the whole energy supply to this project and the estimated cost of electricity for the first five years of operation is shown in Schedule 2.

It will be seen that the rate amounts to an overall figure of 0.530 anna per unit delivered at 85% system power factor with coal at Rs. 23 per ton.

Revenue Costs on generation are divided into the fixed and running components by use of the formula in S.R.O. 1015, issued by the Electricity Commissioners in accordance with the British Electricity (Supply) Act, 1926. The same principle has also been embodied in the Ninth Schedule of the New Indian Electricity (Supply) Act of 1948.

As the precise apportioning of the expenditure for supply into (—) 'fixed' and 'running' components is not known, the system load factor may be used to split up the purchase price into the two principal parts and obtain the two-part basis of the tariff offered by the bulk licensee.

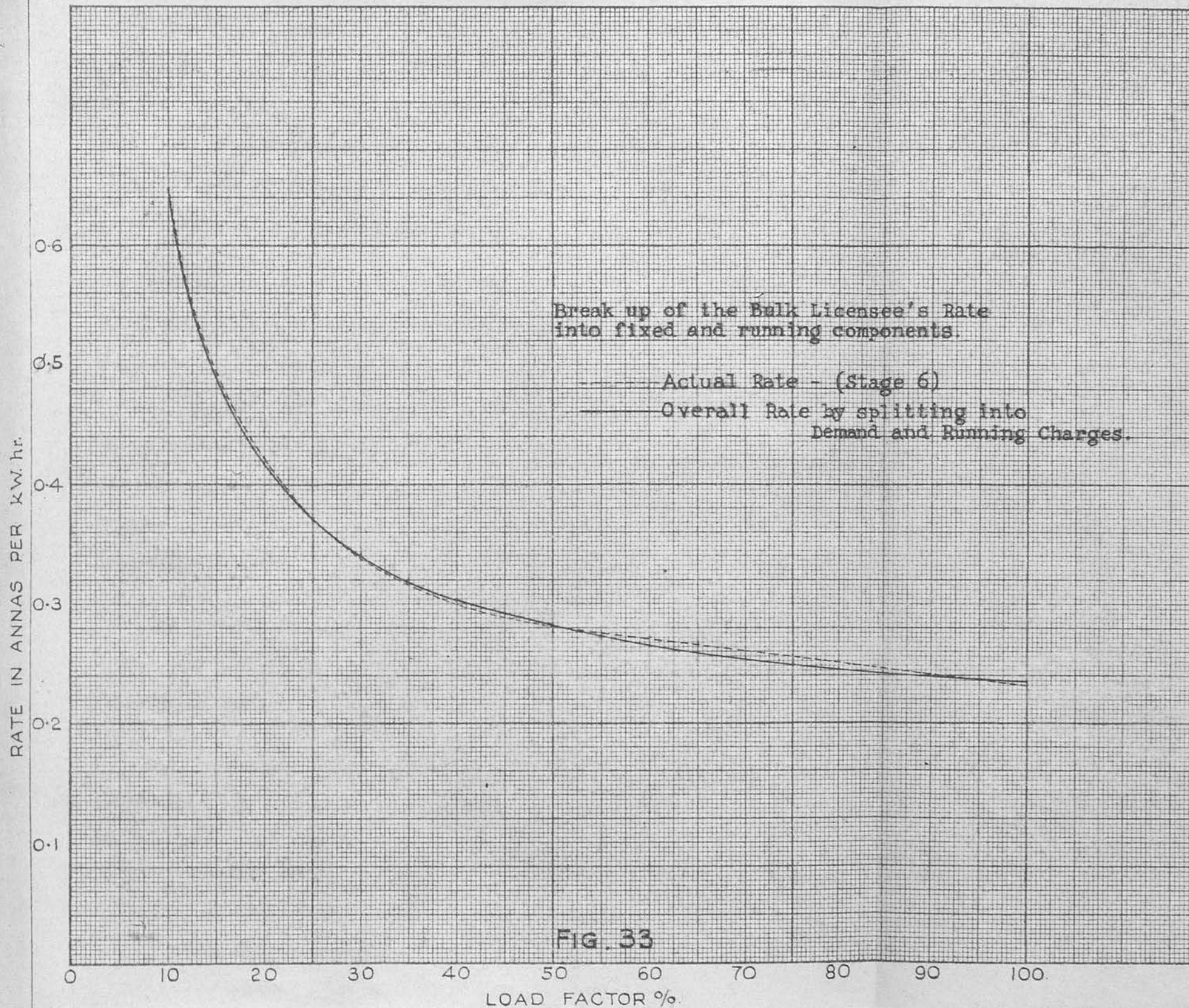
At a system load factor of the order of 47%, the principal component of the total cost of production is the energy cost. Its size is fairly consistent throughout the group of larger undertakings, and ranges from 65% to 79%.

In the case of the bulk licensee in question, it is believed that the cost component of the order of 65% for the 'energy', leaving 35% for the 'fixed' or standing charges, would represent a fair assessment.

At the system L.F. of 45% of the total basic rate of 0.292 anna (Stage 6) per kWh, the running cost allocation would, therefore, be 0.19 anna per kWh, and the fixed charge allocation would be 0.102 anna per kWh.

Rs. 25 per kW per annum at 45% system L.F. gives 0.102 per kWh.

The cost of energy at the receiving station at Chord Road may, therefore/



therefore, be expressed as Rs.25 per kW per annum of Maximum Demand, plus 0.19 anna per kWh with fuel delivered at Rs. 7/8 per ton: this is substantiated by the graph in Fig. 33.

The present price of coal is Rs. 23 per ton, the adjustment being 0.007 anna per kWh for every 8 annas variation in the cost of coal above the basic price of Rs. 7/8/- per ton. In accordance with the formula in S.R.O. 1015 quoted above, part (approximately 20%) of this increase in the cost of fuel would be allocated as fixed cost; but for purpose of convenience, the whole of the increase has been treated as belonging to running costs. The final result is not materially affected.

The system P.F. is assumed to be 85%. Power-factor surcharge is 0.0025 anna per kWh for every 1% by which the average monthly P.F. falls below 95%.

The charges for energy supply to this project, excluding transmission and distribution expenses are as follows :-

Demand Charge	-	Rs. 25/kW/Annum
Running Charge	-	0.19 anna
Fuel Surcharge	-	0.217 "
Power Factor Adjustment	-	<u>0.025 "</u>
		0.432 anna per kWh.

Allowing/

5.3. Revenue Account Expenditure

The probable expenditure is, for the sake of convenience in analysis, and in conformity with the Electricity Supply Act (India) 1948 shown under the following headings :-

(A) Annual Capital Charges

These comprise interest on the invested capital and sinking fund charges to provide for replacement of the capital assets, as set out in the programme of expenditure detailed in Schedule 3.

(B) Annual Operational Expenditure

This includes :-

- (1) The district administration expenditure.
- (2) Expenditure on repairs and maintenance.

(C) Management Expenditure

Headquarters administration expenditure. The Headquarters administration will be provided by the Electricity Development Organisation of the West Bengal Government, situated in Calcutta. An agreed proportion of its expenses will be chargeable to this scheme.

5.3.1. ANNUAL CAPITAL CHARGES

In order to calculate the annual charges for interest and depreciation on the plant and equipment, the interest charge has been taken/

Allowing for a system loss of 12% in the fifth year, the above cost at the consumer's terminal becomes as follows :-

Demand Charge - Rs. 28.4/kW/Annum

plus

Running Charge - 0.491 anna per kWh.

with coal at Rs. 23 per ton at 85% system P.F.

i.e., the cost of supply for the project can, therefore, be expressed as a demand charge of Rs. 28.4 or Rs.29 per kW per annum plus a running charge of 0.491 anna per kWh for a substantial load at 85% system power factor.

### Estimation of the Annual Working Expenditure

In order to compute this expenditure, the total capital expenditure in the first two years of construction and the succeeding first five years of operation, has been calculated, so providing the annual provision required for interest and depreciation.

The progress of capital works and the relevant expenditure is shown in Schedule 3. It will be noticed that capital expenditure incurred in any one year has for purposes of convenience been deemed to fall due for interest and depreciation during the next succeeding year. Pursuant to the provisions of the Electricity Supply India Act (1948), the interest falling due in the second year of construction (i.e. on capital expenditure incurred in the first year of construction) has been capitalised.

3. Revenue Account Expenditure

The probable expenditure is, for the sake of convenience in analysis, and in conformity with the Electricity Supply Act (India) 1948 shown under the following headings :-

(A) Annual Capital Charges

These comprise interest on the invested capital and sinking fund charges to provide for replacement of the capital assets, as set out in the programme of expenditure detailed in Schedule 3.

(B) Annual Operational Expenditure

This includes :-

- (1) The district administration expenditure.
- (2) Expenditure on repairs and maintenance.

(C) Management Expenditure

Headquarters administration expenditure. The Headquarters administration will be provided by the Electricity Development Organisation of the West Bengal Government, situated in Calcutta. An agreed proportion of its expenses will be chargeable to this scheme.

5.3.1. ANNUAL CAPITAL CHARGES

In order to calculate the annual charges for interest and depreciation on the plant and equipment, the interest charge has been taken/

taken at 3.5% on the first cost in accordance with the provisions of the Electricity Supply Act, India (1948). The annual allowance necessary to cover depreciation has been based on the life prescribed in the same legislation and has been calculated for each item separately on the sinking fund method at 4% compound interest. Detailed calculations for the 5 years of actual operation are shown in Schedule 4.

The Charges for the fifth year would be as follows :-

1. Interest on Capital investment @ 3.5% on Rs. 29,00,000	Rs. 1,01,500
2. Depreciation on sinking fund basis at 4% interest. +	<u>63,752</u>
	<u>1,65,252</u>

3.2. ANNUAL OPERATIONAL EXPENDITURE

(i) Local Administration Expenses

To administer this scheme, it is proposed to divide the area into two districts. Each district is to be operated by a District Manager under the administrative control of the Headquarters of the Electricity Development Organisation. Details of the staff requirements and cost of their services for the two districts are given in Schedule 5. Due regard has been paid to the types of labour available in India.

+ The Indian Act specifies 4% per annum compound interest rate, which is  $1\frac{1}{2}\%$  above the present Bank rate.

Besides the above there will be required certain additional staff in the Headquarters to prepare consumers' accounts, store records and to deal with general administration. These are of the nature of management expenses and are shown separately.

(2) Expenditure on running and maintaining transport is allocated to a transport expense account (Schedule 6) which is in turn charged to the main heads of expenditure in the proportion of 60% capital account (erection of services and local distribution work), 10% local management and 30% to repairs and maintenance.

Expenditure (other than on salaries and wages) is estimated below for the first year of operation.

	Rs. per annum
Transport	696
Cleaning and Lighting	130
Telephone Charges	<u>400</u>
	<u>1226</u>

The total annual cost of local administration is therefore estimated to be :-

Salaries and Wages	Rs. 28100
Other expenses	<u>1226</u>
Total .....	<u>29326</u>

This/

This total represents 1.2% approximately of the capital employed in the scheme. The expenses are assumed to increase by 5% per annum to cover increases of salaries and wages and other expenditure.

(ii) Repairs and Maintenance Expenditure

Repairs and maintenance of the system have been estimated as hereunder.

It will be seen that this represents an annual charge of 0.9% of the capital involved and should include the following items of expenditure :-

Repairs and maintenance to Buildings.

Repairs and maintenance of h.v. transmission lines, l.v. distribution and services.

Repairs and maintenance of transformers and switchgear.

Repairs and maintenance of meters and instruments.

Repairs to plant and tools including small replacement.

Salaries and wages have been estimated and are shown

in Schedule 5.

Other expenditure under this heading is estimated as follows :-

	Rs.
1. Transport.	2090
2. Inspection of 33-kV and 11-kV Line.	2000
3. Small replacements, services and l.v. distribution.	3000
4. Replacements of small tools.	200
5. Meter parts.	100
6. Repairs and maintenance of buildings.	<u>260</u>
	<u>7650</u>

The total annual cost of repairs and maintenance is therefore estimated to be :-

Salaries and wages	Rs. 14,600
Other expenditure	<u>7,650</u>
	<u>22,250</u>

These expenses are also assumed to increase by 5% annually to cover the cost of salaries and wages increases and other expenditure.

Total Annual Cost of Operation

(1) Local Administration	Rs. 29,326
(2) Repairs and Maintenance	<u>22,250</u>
	51,576

increasing at the rate of 5% per annum.

3.3. MANAGEMENT.

Provision for general management and proportion of the head-office supervision has been made as hereunder.

Items of management expenses are as follows :-

- (i) Head office supervision -  
Part salary of the Chief Electrical Engineer, Distribution Engineer, Commercial Officer and Accountant.
- (ii) General establishment charges.
- (iii) Advertising and demonstration.
- (iv) Transport and travelling expenses.
- (v) Insurance.
- (vi) Rents, rates, taxes, wayleaves etc.

Estimates of the cost of Management, Salaries and Wages are shown in Schedule 7.

Other Expenditure

General establishment charges	300
Printing and stationery	1300
Advertising	1300
Transport and travelling expenses	500
Telephone charges	100
Insurance	4000
Wayleaves and rents	<u>500</u>
	<u>8000</u>

The/

The total annual cost of head-office management is therefore estimated at :-

Salaries and wages	Rs. 21,100
Other expenditure	Rs. <u>8,000</u>
Total .....	Rs. <u>29,100</u>

3.4,  
SUMMARY

The capital charges and costs in the foregoing paragraphs, expressed as a percentage of the capital invested, are as follows :-

<u>Item</u>	<u>% on capital</u>
Interest	3.5
Depreciation	2.2
Operation	1.2
Repairs and Maintenance.	0.9
Management.	<u>1.2</u>
Total %	<u>9.0</u>

6. T A R I F F S.

1.  
Basis of Formulation of a Tariff Structure

The total cost of supplying electricity can, for convenience of analysis, be allocated under two main headings, viz., a fixed annual charge (the major element) and a running cost per unit. The former is incurred irrespective of the total output of energy for the particular installed/

installed capacity, while the latter varies directly with the energy. Thus, once the preliminary expenditure is met, the additional cost per unit of electricity is comparatively small. Electricity supply, as with other public utilities, is characterised by heavy fixed charges arising from generating plant, transmission and distribution lines and, accordingly, charges to consumers are based on their "peak responsibility" - the extent to which individual consumers contribute to peak period demand. This "peak responsibility" has been estimated for the main categories of consumer and is referred to in the section that follows. \*

Once the fixed and running costs have been ascertained, a total cost curve can be constructed to provide the total cost per kWh at varying load factors. In this manner the prices which should theoretically be charged to the various classes can be obtained. A two-part tariff is normally the best method of applying the charge but this is considered unsuitable for the comparatively undeveloped territory under discussion, and a simple block rate is to be preferred.

Costs will actually vary according to the length of transmission line involved, but for reasons of general policy it is not considered desirable to differentiate between districts in the matter of charges.

\* Because the estimated load curve has a clearly-defined evening peak, the "peak responsibility" basis has been adopted. As the project develops a more scientific approach to cost analysis may become possible.

The total capital investment required for the project up to the end of the fourth year of operation (applicable to the following year) amounts to Rs. 2,900,000. Of this Rs. 2,032,000 represents expenditure on h.v. mains and equipments, and Rs. 868,000 on l.v. distribution, services and meters.

Of the total expenditure on h.v. mains and equipments, a portion represents capital spent on the system parts of which are in excess of the present needs. Owing to technical requirements referred to elsewhere, this is of considerable importance and it may be several years before the main transmission lines and substations are loaded to maximum capacity. Considerable increments of load can, therefore, be met in the later years with comparatively small increase in cost.

Where, however, capital is mainly spent on distribution lines which normally come into operation practically within the year in which the capital is spent, the difference between total capital and the capital in operation is not so great.

It is proposed that the capital charges on the headworks and such portions as are not capable of being used immediately, are to be capitalised or held in suspense, so that the interest and sinking fund contributions payable are spread forward over the life of the equipment. The argument here is that the excess capacity over present requirements is in/

in the nature of development expenditure which is best recouped during the period in which it is actually in use.

Adequate provisions appear to have been included in the Indian Electricity (Supply) Act, 1948, to ensure that some portion at least of any profits from the sale of energy are passed on to the consumers, as will be evident from the following extracts from the Sixth Schedule of the Act, 1948.

"The licensee shall so adjust his rates for the sale of electricity by periodical revision that his clear profit in any year shall not as far as possible exceed the amount of reasonable return". The "reasonable return" having been specified as 5 per centum on the "Capital base".

The "Capital base" may be defined in general terms as "the value of that portion of an undertaking's property used and useful in rendering service and upon which value the undertaking is entitled to a reasonable return". Under the London Electricity Act (No. 2) of 1925, an attempt was made to limit profits and rates by somewhat similar means and more recently the system has been employed by the Federal Power Commission in the U.S.A. The "Capital base", as defined in the Indian Act, is in principle similar to the one which has been adopted in the U.S.A.

Profit over and above what is necessary to establish legitimate reserves/

reserves must be returned to the consumer by way of price reduction. This directive plays a particularly important part in the Government's general scheme of electricity supply. This, from its comprehensive nature, must of necessity be highly capitalised in the earlier stages, and as annual charges are largely independent of the load, a reduction in the cost per unit supplied must arise very largely from an increased consumption of units. While it is not suggested that demand will display unity elasticity (i.e. a percentage change in price being accompanied by an equal change in demand) some increase in sales will undoubtedly accrue from a reduction in price, particularly where the poorer sections of the community can be reached.

2. Application to Present Scheme ; Fifth-year Estimates

Load forecasts for 5 years for each individual place served by this project for system maximum demand in kW and in KWh have been made and these show that at the end of the 5th year the system maximum demand may be 620 kW, whereas the system has a firm capacity of 1500 kW.

The capital charges attributable to pooled transmission are as follows :-

Interest @ 3.5% on Rs. 2,032,000	71,120
Depreciation at various rates (based on the life of the works and 90% of the original costs) on the itemised statement of capital accounts	<u>42,250</u>
	Rs. <u>113,370</u>

The above figure divided by the effective capacity of line, viz. 1500 kW, gives the cost of pooled transmission to be Rs. 75.6 per kW per annum.

The charges attributable to the l.v. distribution and for administration are as follows :-

Interest @ 3.5% on Rs. 868,000	30,380
Depreciation at various rates (based on the life prescribed of the works and 90% of the original value of works) on the itemised statement of capital accounts	<u>21,500</u>
	Rs. <u>51,880</u>

Estimated management, operation and maintenance expenditures:

Repairs and Maintenance	27,044
Local Administration	35,644
Management	<u>35,371</u>
	Rs. <u>98,059</u>

The total of Rs. 149,939 is therefore required to meet the fixed charges on the fifth year of operation.

With this expenditure the estimated demand of 620 kW will be met at the 5th year. Consequently, the annual charge of Rs. 241.9 per kW per/

per annum is necessary.

The complete cost of energy at the consumer's terminal would therefore become -

	<u>Demand Charge per kW (at time of system peak)</u>	<u>Running Charge per kW hr.</u>
Cost for energy	Rs. 28.5	0.491
Cost for transmission	Rs. 75.6	
Cost for L.V. distribution, operation & administration	Rs. 241.9	
	<u>Rs. 346</u>	<u>0.491</u>

The above statement shows that the cost of peak period demand and energy are Rs. 346 per kilowatt per annum and 0.491 anna (approximately) per kWhr, at the system P.F. of 85% with coal at Rs. 23 per ton. On general grounds this represents the maximum cost except in very special isolated cases, on the basis of the highest  $\frac{1}{2}$  hour maximum demand in the year. If it is decided, however, to average out the demand and take a monthly figure, this involves a stepping up of the demand charge by 10% to Rs. 380.

The/

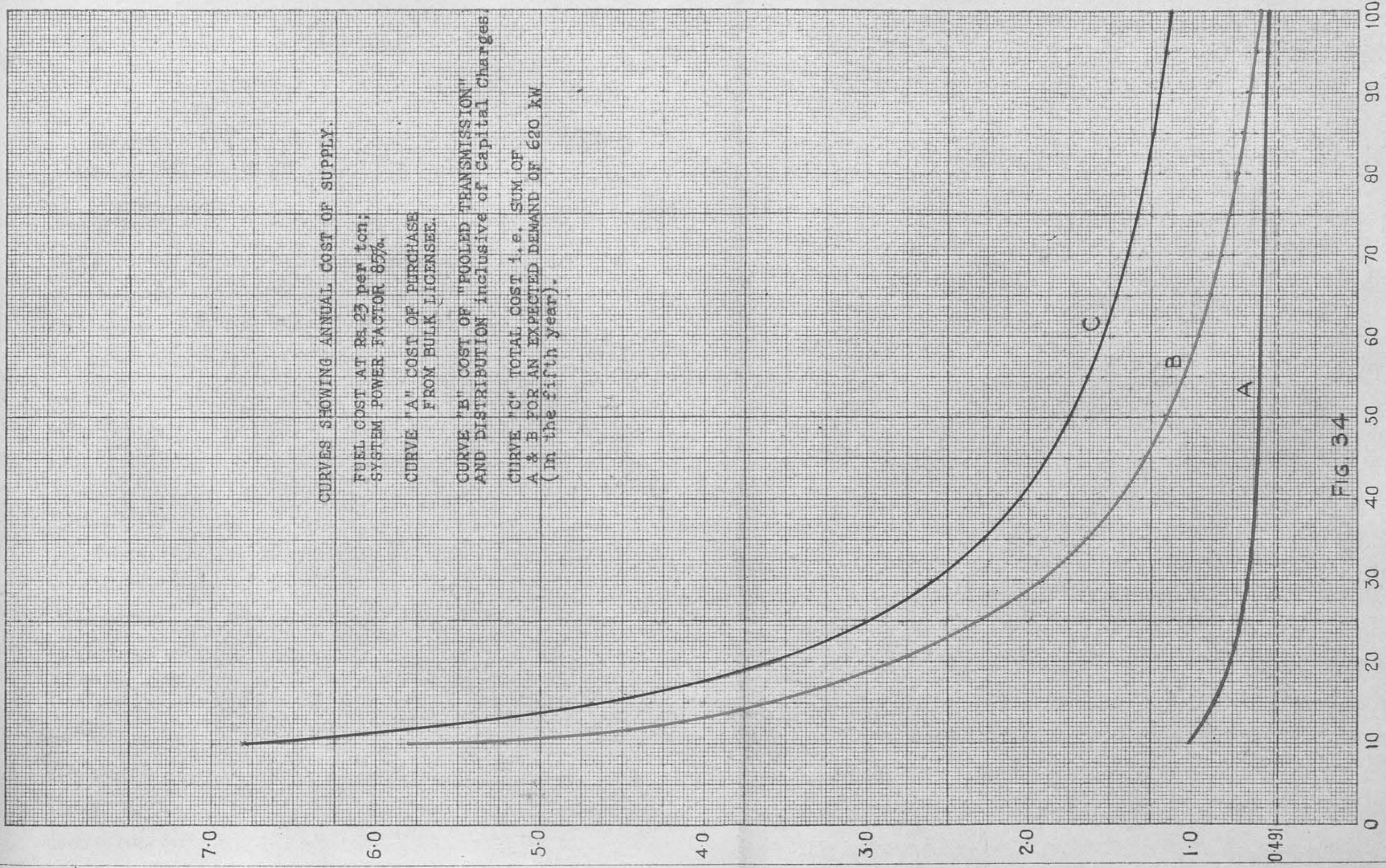
The running cost component is based upon the cost of coal and is subject to a fuel adjustment clause which provides for a variation of 0.007 anna per 8 annas variation in price of coal above Rs. 23 per ton. To allow for the losses in the system the charge to the consumer would have to be increased from 0.007 to 0.008 anna.

The provision of the coal clause automatically adjusts prices for bulk supplies or for large power supplies but not domestic or commercial small consumers. A margin in unit charge should, therefore, be provided to give cover for the increased coal price, but no such provision is made during the development period of the first 5 years in view of the nature of that period.

The main basis for determining the cost per unit of energy (kWh) produced per year, which is the basis of comparison adopted in this case, is the annual load factor at which energy can be sold to the various classes of consumers.

The component costs per kWh for load factor varying from 10 to 100 per cent and the summated costs in annas per unit sold are indicated in the Fig. 34. An examination of the curves will reveal the importance of load factor in reducing the cost of production and supply of energy.

The/



CURVES SHOWING ANNUAL COST OF SUPPLY.

FUEL COST AT Rs. 23 per ton;  
SYSTEM POWER FACTOR 85%.

CURVE 'A' COST OF PURCHASE  
FROM BULK LICENSEE.

CURVE 'B' COST OF "POOLED TRANSMISSION"  
AND DISTRIBUTION inclusive of Capital Charges.

CURVE 'C' TOTAL COST i.e. SUM OF  
A & B FOR AN EXPECTED DEMAND OF 620 KW  
(in the fifth year).

FIG 34

Annual Load Factor = %

Cost per unit in Annas / Kw hr.

The actual bases utilised for the calculation of the different tariffs are described in the section that follows.

2.1. NOTE ON TARIFF BASIS. It is to be noted particularly that the scheme will inevitably operate with heavy deficits for the first few years of development. As a basis for tariff formulation, however, it is assumed that in the fifth year of operation the revenue and expenditure shall balance. Recovery of the earlier deficit will be from the advancing profits of later years to recoup. The figures in 6.2 above are those for the fifth year on which the tariff is to be based.

3. Formulation of a Tariff

The expected load characteristics of the categories of consumers and the constituents of the demand at the time of system peak are shown in Fig. 11. These characteristics are of prime importance in the actual fixing of charges.

Generally, the method followed has been to group consumers within each main category (domestic, commercial, power, etc) in a frequency - distribution according to a few main load-factor categories; average annual energy consumption for these categories have then been calculated. Reading from the cost curve referred to above, the approximate rate for the/

the supply of energy has then been determined, and the most suitable quantity fixed for the primary block of units for the whole category of consumers. Any consumption in excess of the primary block can be offered at a lower rate, nearer the incremental cost. There will of course be some gains and losses amongst the various load-factor categories, but these will tend to balance and any tariff for general application must take account of this fact.

Finally, regard has been given to the tariffs already in force for existing undertakings in Bengal.

#### Domestic Tariff

This, the largest class, is mainly responsible for the system peak. The diversity within the class is negligible and the load factor is poor since the supply will, in the main, be used for lighting during a portion of the hours of darkness.

The following facts emerge :-

<u>L.F. %</u>	<u>Number of Consumers</u>	<u>Average Consumption kWh</u>	<u>Total Cost per unit. Annas.</u>
Below 10	445	213	7.0
10 - 12	605	235	6.0
12 - 15.7	430	209	5.0

The/

Commercial Tariff

The average consumption multiplied by the total cost per unit at the respective load factor would give the revenue which should be obtained. Any energy used in excess of the stated figures could be supplied at a little more than the incremental cost.

The average consumption is used therefore to fix approximately the size of the primary block. Where this is less than the average consumption (for purposes of administrative convenience) the loss in revenue can be made good by fixing the price for the secondary block at a margin above incremental cost.

The tariff proposed therefore is :-

For all units consumed up to 180 kWh per annum .....	6 annas
	per kWh
For all kWh in excess .....	3 annas
	per kWh

It should be pointed out that this rate involves subsidy by the other consumers, chiefly the power consumers.

Whilst the primary rate is large it is in line with current charges in West Bengal and can of course be lowered when development permits. The tariff is readily understood and the secondary rate is sufficiently low to induce the average householder to make extended use of the supply.

Commercial Tariff

This consumer category exhibits more progressive tendencies than the domestic class without perhaps being capable of great further development.

The consumers expected may be grouped as follows :-

<u>L.F.%</u>	<u>No. of Consumers.</u>	<u>Average Consumption per consumer</u> kWh	<u>Total Cost per unit.</u> Annas.
Less than 10	185	167	7
10 - 15	315	298	5.5
16 - 20	170	338	4
Above 20	30	133	3

No subsidy by other consumers is considered in view of the nature of the load, and the proposed tariff is therefore :-

For the first 180 kWh per annum ..... 6 annas per kWh  
For all kWh in excess ..... 4 annas per kWh.

Cinema Tariff

Cinemas contribute directly to the peak load on the system under review. Any undue incentive would serve only to stimulate the peak period demand without any corresponding improvement in load factor.

A load factor of 18% is forecast, with a resulting total cost of 4 annas per kWh. The proposed tariff therefore is a flat rate of 4 annas per unit.

The/

The possible alternative source of supply would be private generation, and this is unlikely to cost below 4 annas per unit generated for a small 5 to 10-kW set, and it would involve the consumer in a heavy capital commitment.

### Street Lighting

On an all-night lighting system, the average use is 4,000 hours per annum, which gives a load factor of 45 per cent.

Street Lighting is therefore a particularly desirable type of load for a power supply undertaking in that good lighting can form a base load for all small-town electrifications.

For the present, the lighting period is estimated to be up to 12 midnight and the load factor is approximately 20%. The cost for the supply is 3.6 annas per kWh.

Street Lighting is a community service, so where no large capital expenditure is required to give it, the unit charge would be 3 annas.

### Small-Power Tariff

Reference to the system load curve demonstrates that the power load is essentially off-peak, both as regards h.v. transmission and/

and l.v. distribution systems. Power consumers do not therefore incur any "peak responsibility". On these grounds, therefore, such consumers could be supplied at incremental cost, plus a charge for capital involved in the immediate supply to them and an additional margin for working and administration expenses. In practice, it would be undesirable to adopt this policy wholeheartedly in view of the likelihood of causing a shift in the system peak incidence which would disturb the balance of the proposed tariff scheme entirely whilst leaving no outlet for a corresponding increase in the small power charges.

The actual tariff therefore will be based primarily on "what the traffic will bear". The only alternative services available are diesel engines or diesel-driven generators, for which the estimated running costs per kWh are detailed below for a 40% load factor.

<u>Item</u>	<u>Annas per kWh</u>
Fuel	1.5
Contingencies	0.3
Repairs and Maintenance	0.2
Capital Charges: interest and depreciation at 7%	<u>0.6</u>
Total .....	<u>2.6</u>

At present, the maximum small power rates in force in West Bengal/

Bengal, do not exceed 3 annas per unit.

The proposed tariff is therefore :-

Up to 2400 kWh per annum	.....	3 annas per kWh
Consumption thereafter	.....	2.5 annas per kWh.

This tariff will provide a surplus over estimated costs of Rs. 80,000 approximately, to be in the main devoted to subsidising domestic consumers.

#### Bulk Supplies

No large power consumer can be expected at present, but because one of the objects of the Rural Scheme is to spread industry rather than have it concentrated in and around Calcutta, any bulk-supply rate will have to compete with that charged by the Calcutta Electric Supply Corpn. It must necessarily be slightly higher to cover the cost of transmission.

The following tariff is suggested. It is composed of the cost of energy plus the cost of "pooled" transmission, together with a proportion of the management expenses and capital charges on the new capital involved in giving supply.

H.V. Bulk Supply Tariff for energy delivered and metered at

11 kV, 3-phase, 50 c/s.

MAXIMUM/

MAXIMUM DEMAND: Rs. 10 per kW per month for m.d. up to 300 kW;  
Rs. 8 for excess up to 500 kW; and Rs. 6 for all excess  
above 500 kW.

ENERGY: 0.5 anna per kWh, subject to additions as below:

Fuel Charge: 0.008 anna for each 8 annas increase in price  
of coal above a base of Rs. 24 per ton.

Power Factor: Increase of  $\frac{1}{2}\%$  on sum of above charges in  
respect of each 0.01 by which the average  
monthly p.f. falls below 0.85 lagging.

6.10. Revenue Estimate

Schedule 8 details the gross annual revenue expected for the  
first five years of operation.

6.10.1. FINANCIAL DETAILS. Schedule 9 summarises the estimated annual  
capital and revenue expenditure, also a statement of the annual surplus  
and deficiency. During the first five years of operation, after  
providing for interest and depreciation, there is a deficit which  
decreases rapidly from a maximum of Rs. 141,000 in the first year  
to only Rs. 8,374 in the fifth. Thereafter the scheme should  
operate at a profit.

The net revenue from the sixth year onward should grow, and  
become available to balance earlier deficits and the interest on  
the/

the deficiency account. The time will then be ripe to reconsider the whole of the tariff structure to secure equitable operation.

10.2. LOAD GROWTH. With the offer of supplies at the above rates which are considered to be reasonable, coupled with active propoganda, it is estimated that by the end of the fifth year from the commencement of supply about 60% of all the permanent dwellings in the area will be connected, and the sales will have grown by that year to an average of about 10 kWh per head of population in the area or 568 units per connection.

11. CONCLUSION

The scheme, although based on a close economy, is technically feasible and economically sound. A market for power exists. Besides selling retail to consumers in the eight selected localities, energy will also be available for any tube-well, lift-irrigation or low-head pumping schemes that may be promoted by the Agriculture and Irrigation Departments of the Indian Government. The planning of such schemes and their adoption would add largely to land fertility and flood control in those places where vagaries of climate do not coincide with the vegetation cycle.

Rural development in other countries has always been achieved by a slow and gradual process. If the development of electricity supply in the Province of West Bengal is to be pursued on a national basis/

basis a bold and forward policy is required which will entail much educational effort, extensive organisation and above all the investment of a great deal of capital. But the importance of this and similar undertakings lies really in their vital significance in the social progress of the human population. This, and not economics alone, is their justification.

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SCHEDULE NO. 1EAST CALCUTTA RURAL ELECTRIFICATION PROJECTCalculation of the Rate of Charge for Energy Purchase  
(East Calcutta & North Calcutta Schemes put together)

Year of Operation	North Calcutta			East Calcutta			Both combined with a D.F. = 1.05			Rate of Purchase of kWhr.			
	M.D. kW	L.F. %	kWhrs x 1,000	M.D. kW	L.F. %	kWhrs x 1,000	M.D. kW	L.F. %	kWhrs x 1,000	Basic (as)	Fuel adj. (as)	P.F. adj. (as)	Overall rate
1st	1910	42.4	7,090.1	279	21	512.682	2,085	41.6	7,602.782	.321	.217	.025	.563
2nd	2375	43.9	9,144.5	420	22.5	828.928	2,661	42.8	9,973.428	.306	.217	.025	.548
3rd	2936	45.5	11,714.6	521	23.6	1,081.177	3,292	44.4	12,795.777	.304	.217	.025	.546
4th	3230	46.7	13,213.9	604	24.3	1,283.954	3,651	45.3	14,497.854	.292	.217	.025	.534
5th	3751	49	16,091.8	671	24.7	1,452.841	4,211	47.5	17,544.641	.288	.217	.025	.530

- Notes:
1. It is assumed that the East Calcutta Rural Electrification Project will be brought into operation from the 2nd year of operation of the North Calcutta Scheme.
  2. Coal is assumed at Rs 23/- per ton. Adjustment - 0.007 anna per kWhr for every -/8/- variation in the cost of coal above the basic price of Rs 7/8/- per ton.
  3. The System Power Factor is assumed to be 85%. Power Factor Surcharge = .0025 anna per kWhr for every one per cent. by which the average monthly Power Factor falls below 95%.

SCHEDULE NO. 2

EAST CALCUTTA RURAL ELECTRIFICATION PROJECT

COST of ELECTRICITY

Year of Operation	Total Sales to Ultimate Consumers (kWhrs).	Total Purchase (kWhrs) (including system losses)	Overall Rate of Purchase per kWhr. (Anna)	Cost of Electricity (Rs)
1st	420,400	512,682	.563	18,040
2nd	696,300	828,928	.548	28,391
3rd	919,000	1,081,177	.546	36,895
4th	1,104,200	1,283,954	.534	42,852
5th	1,278,500	1,452,841	.530	48,125

NOTE:

A partial supply for the Scheme will be obtained from the Calcutta Electric Supply Corpn. Ltd. along with the requirements of the Barrackpore Undertaking at a slightly higher rate of charge depending on the combined demand and L.F. of the supply with that of Barrackpore Undertaking.

Cost of whole energy supply to this project, however, has been estimated on the combined demand and L.F. of the North and East Calcutta Project at the Chord Road Receiving Station.

SCHEDULE NO.3EAST CALCUTTA RURAL ELECTRIFICATION PROJECTProgress of Capital Works and Expenditure

Year of Construction	Year of Operation Chargeable	Asset	Expenditure	
			Rs.	Rs.
1	-	Land 33 kV Line 6 kV Line to Barasat 6 kV Switchgear 6 kV Transformer L.T. Distribution Barasat L.T. Services " L.T. Meters "	15,000 728,000 156,000 8,000 3,000 58,000 10,000 5,000 5,000 10,000	
		Tools & Instruments Transport	5,000 10,000	
			998,000	
		Approx. 10% Contingencies	100,000	1,098,000
2	I	11 kV Transmission Line Buildings (33 kV Switchgear (11 kV " (33 kV Transformers (11 kV " 100 kVA & over do. under 100 kVA Transport Furniture & Office Equipment Tools & Instruments L.T. Distribution Barasat L.T. Services " L.T. Meters " Other L.T. Distribution " " Services " " Meters L.T. Switchgear	663,000 50,000 122,000 61,000 12,000 15,000 10,000 10,000 6,000 2,000 1,000 223,000 136,000 60,000 16,000	
			1,387,000	
		Approx. 10% Contingencies	139,000	
			1,526,000	
		Add 1st year Expenditure	1,098,000	
		Add capitalised interest on 1st year construction	38,000	2,662,000

Year of Construction	Year of Operation Chargeable	Asset	Expenditure	
			Rs.	Rs.
		(Interest on the capital expended during the first year of construction has been capitalised in accordance with para. XVII(6b) of the Sixth Schedule to the Electricity Supply Act (India) 1948)		
3	2	L.T. Distribution Barasat	6,000	
		" Services	2,000	
		" Meters	1,000	
		" Distribution Others	25,000	
		" Services	14,000	
		" Meters	7,000	
			55,000	
		Add approx. 10% Contingencies	6,000	
			61,000	
		Add 2nd year expenditure	2,662,000	2,723,000
4	3	L.T. Distribution Barasat	7,000	
		" Services	2,000	
		" Meters	1,000	
		" Distribution Others	26,000	
		" Services	15,000	
		" Meters	8,000	
			59,000	
		Add approx. 10% Contingencies	6,000	
			65,000	
		Add 3rd Year above	2,723,000	2,788,000
5	4	L.T. Distribution, Barasat	7,000	
		" Services	1,000	
		" Meters	1,000	
		" Distribution Others	30,000	
		" Services	18,000	
		" Meters	8,000	
			65,000	
		Add 10% Approx. - Contingencies	6,000	
			71,000	
		Add 4th Year above	2,788,000	2,859,000



SCHEDULE 4EAST CALCUTTA RURAL ELECTRIFICATION PROJECTANNUAL DEPRECIATION CHARGES2nd CONSTRUCTIONAL YEAR

Assets	Original Cost of Assets	90% Original Cost of Assets	Life Prescribed	Rate of Depreciation	Amount of Depreciation
				%	Rs
1. Land	15,000	-			
2. 33 kV line	728,000	655,200	30	1.78	11,663
3. 6 kV line to Barasat	156,000	140,400	25	2.4	3,370
4. 6 kV Switchgear	8,000	7,200	20	3.36	242
5. 6 kV Transformer	3,000	2,700	35	1.36	37
6. L.T. Distribution	58,000	52,200	25	2.4	1,253
7. L.T. Services	10,000	9,000	25	2.4	216
8. L.T. Meters	5,000	4,500	15	4.99	225
9. Tools & instruments	5,000	4,500	15	4.99	225
10. Transport	10,000	9,000	7	12.66	1,139
	998,000				18,370
Contingency	100,000			Av. rate 1.84%	1,840
<b>Total</b>	<b>1,098,000</b>				<b>20,210</b>

Note: 1. Life of the works is assumed to be the same as provided in the Electricity (Supply) Act, 1948 (India).

2. Depreciation is allowed on the Sinking Fund Method, and the rate of accumulation in the Sinking Fund is assumed to be 4% as provided for in the above legislation.

3. Annual percentage charge is taken from Table V, page 150 of Interest and Annuity Table by Kent.

SCHEDULE NO. 4ANNUAL DEPRECIATION CHARGES  
FOR FIRST YEAR OF OPERATION

Works	Original Cost of Works	90% Original Cost	Life Prescribed	Rate of Deprn. %	Amount of Depreciation (Rs)
<u>H.T. Lines &amp; Equipments</u>					
1. Land	15,000	-	Inf.	Nil	Nil
2. Buildings	50,000	45,000	50	.65	292
3. Transmission Line 33 kV	728,000	655,200	30	1.78	11,663
4. do. 11 kV & 6 kV	819,000	737,100	25	2.40	17,690
5. Switchgear	130,000	117,000	20	3.36	3,931
6. Transformer 100 kVA & Over	64,000	57,600	35	1.36	783
7. Transformer under 100 kVA	12,000	10,800	25	2.40	259
8. Transport	25,000	22,500	7	12.66	2,848
9. Furniture & Office Equipments	10,000	9,000	10	8.33	750
10. Instruments & Tools	15,000	13,500	15	4.99	674
Total	1,868,000				38,890
<u>L.T. Distribution Services &amp; Meters</u>					
1. L.T. Distribution Lines	287,000	258,300	25	2.4	6,199
2. Services	148,000	133,200	25	2.4	3,197
3. Meters	66,000	59,400	15	4.99	2,964
4. L.T. Switchgear	16,000	14,400	20	3.36	484
Total	517,000				12,844

GRAND TOTAL 2,385,000

At the 51,734

Contingencies 239,000

average rate  
of 2.17

5,186

56,920

SCHEDULE NO. 4 (CONTD.)

2nd YEAR OF OPERATION

Additional Provision for Depreciation  
for L.T. Distribution & Services & Meters

Works	Original Cost of Works	90% Original Cost	Rate of Deprn. %	Amount of Annual Deprn. (Rs)
1. L.T. Distribution	31,000	27,900	2.4	670
2. Services	16,000	14,400	2.4	346
3. Meters	8,000	7,200	4.99	359
	55,000			1,375
Contingencies	6,000		av. 2.5	150
	61,000			1,525
Add Prev. year's total	2,624,000			
Capital to date	2,685,000			1,525
			Prev. year's Deprn. Charge	56,920
			Total Deprn. Charge for the year	58,445

SCHEDULE NO. 4 (CONTD.)

3rd YEAR OF OPERATION

Additional Depreciation Provision Reqd.

Works	Original Cost of Works	90% Original Cost	Rate of Deprn. %	Amount of Annual Deprn. (Rs)
1. L.T. Distribution	33,000	29,700	2.4	713
2. Services	17,000	15,300	2.4	367
3. Meters	9,000	8,100	4.99	404
	59,000			1,484
Contingencies	6,000		av. 2.51	151
	65,000			1,635
Add Prev. year's total	2,685,000			
Capital to date	2,750,000			1,635
			Prev. year's Deprn. Charge	58,445
			Total Deprn. Charge for the year	60,080

SCHEDULE NO. 4 (CONTD.)

4th YEAR OF OPERATION

Additional Provision for Depreciation

Works	Original Cost of Works	90% Original Cost	Rate of Deprn. %	Amount of Annual Deprn. (Rs)
1. L.T. Distribution	37,000	33,300	2.4	799
2. Services	19,000	17,100	2.4	410
3. Meters	9,000	8,100	4.99	404
	65,000		av.	1,613
Contingencies	6,000		2.48	149
	71,000			1,762
Add Prev. year's total	2,750,000			
Capital to date	2,821,000			1,762
			Prev. year's Deprn. Charge	60,080
			Total Deprn. Charge for the year	61,842

SCHEDULE NO. 4. (CONTD.)

5th YEAR OF OPERATION

Additional Provision for Depreciation

Works	Original Cost of Works	90% Original Cost	Rate of Deprn. %	Amount of Annual Deprn. (Rs)
1. L.T. Distribution	44,000	39,600	2.4	950
2. Services	20,000	18,000	2.4	432
3. Meters	8,000	7,200	4.99	359
	72,000		av.	1,741
Contingencies	7,000		2.5	169
	79,000			1,910
Add Prev. year's total	2,821,000			
Capital to date	2,900,000			1,910
			Prev. year's Deprn. Charge	61,842
			Total Deprn. Charge for the year	63,752

Total Yearly Salaries & Wages

Local Administration	Rs 35,000
Repair and maintenance	Rs 25,000
	Rs 60,000
	Rs 42,700

SCHEDULE NO. 5EAST CALCUTTA RURAL ELECTRIFICATION PROJECTLIST OF PROPOSED STAFF

	Monthly salary or wages Rs	Rs
<u>District Offices</u>		
<u>Officers</u>		
2 District Managers @ Rs 400 + 17 $\frac{1}{2}$ %	940	
<u>Office Staff</u>		
2 Senior Grade Clerks @ Rs 100 + 22	244	
2 Junior Clerks @ Rs 60 + 22	164	
2 Typists @ Rs 60 + 22	164	
<u>Showroom</u>		
2 Showroom Attendants @ Rs 60 + 24 + 35	238	
<u>Meter Readers</u>		
4 Meter Readers @ 60 + 24 + 35	476	
	<u>2,226</u>	
Monthly Total		
Add 5% Provident Fund Contribution	111	2,337
<u>Installation Section</u>		
2 Foremen @ Rs 150 + 17 $\frac{1}{2}$ % = Rs 350 (Estimated proportion of time devoted to capital expenditure during first 5 years - 50% - already included in capital Budget.)	175	
4 Linesmen @ Rs 75 + 27 + 35 = Rs 548 (Estimated 80% - Capital (erecting service lines) 20% - revenue maintenance)	110	
4 wiremen @ Rs 60 + 24 + 35 = Rs 476 (Estimated 50% - Capital (installation of new meters) - 50% revenue (maintenance) )	238	
4 wiremen's mates @ Rs 20 + 8 + 25 = Rs 212 (Estimated 50% Capital, 50% revenue)	106	
2 meter repairers	350	
2 durwans @ Rs 15 + 6 + 25 = Rs 46	92	
2 sweepers @ Rs 13 + 6 + 25 = Rs 44	88	
	<u>1,159</u>	
Monthly Total		
Add 5% Provident Fund Contribution	58	1,217
	<u>1,217</u>	
Total		<u>3,554</u>

Total Yearly Salaries & Wages

	Rs
Local Administration	28,044
Repair and maintenance	<u>14,604</u>
	42,648
Say	<u>42,700</u>

SCHEDULE NO. 6

EAST CALCUTTA RURAL ELECTRIFICATION PROJECT

Annual Cost of Transport

(2 - 30 cwt. lorries)

		Rs
<u>Wages</u>		
2 drivers @ Rs 60 + 24 + 35 = Rs 119		2,856
<u>Petrol and Oil</u>		
Based on an annual mileage of 15,000 miles per lorry		3,400
<u>Spares, Repairs and Maintenance</u>		
Tyres - 1 set per 2 yrs.	Rs. 130	
Repairs and maintenance	Rs. <u>260</u>	390
<u>Licences etc.</u>		
Licence Fees	Rs. 120	
Insurance	Rs. <u>200</u>	<u>320</u>
		<u>6,966</u>

Allocation first 5 years

<u>60% Capital</u>	Rs.	4,180
10% Local Management	Rs.	696
30% Repairs and Maintenance	Rs.	<u>2,090</u>
		<u>6,966</u>

Note: As a matter of convenience interest on capital and depreciation has been included in the gross amounts included for these purposes.

SCHEDULE NO. 7

EAST CALCUTTA RURAL ELECTRIFICATION PROJECT

Proportion of Head Office Salaries & Wages  
allocated to the Project for Management

Administrative Officers

	Rs
1 - Chief Electrical & General Manager ( $\frac{1}{4}$ of his basic salary)	500/-
1 - Rural Distribution Engineer ( $\frac{1}{4}$ of his basic salary)	300/-
1 - Commercial Officer ( $\frac{1}{4}$ of his total salary)	300/-
1 - Accountant ( $\frac{1}{3}$ of his total salary)	250/-
2 - Senior Grade Clerks to deal with consumers' accounts & store records @ Rs 100 + 22	244/-
1 - Steno-typist @ Rs 60 + 22	<u>82/-</u>
Monthly Total	<u>1,676/-</u>
Annual Total	20,112
Provident Fund - 5% p.a.	<u>1,000</u>
	<u>21,112</u>

EAST CALCUTTA RURAL ELECTRIFICATION PROJECT

CALCULATED REVENUE

Class of Consumer	1st YEAR		2nd YEAR		3rd YEAR		4th YEAR		5th YEAR	
	No. of Consumers	Rs.	No. of Consumers	Rs.	No. of Consumers	Rs.	No. of Consumers	Rs.	No. of Consumers	Rs.
Domestic	497	42,779	852	71,674	1,102	87,649	1265	99,263	1,480	111,281
Commercial	232	33,695	419	50,602	553	58,367	673	64,542	695	68,737
Industrial	13	17,112	19	34,180	33	56,816	50	76,656	61	95,912
Cinema	6	12,875	6	14,800	7	15,925	7	16,500	7	18,150
Street Lighting	1	1,369	4	4,781	5	7,537	5	8,231	5	10,312
<b>TOTAL REVENUE</b>	<b>107,830</b>		<b>176,037</b>		<b>226,294</b>		<b>265,192</b>		<b>304,392</b>	

Capital		
Interest	57,170	57,170
Depreciation	56,920	56,920
Net Interest		
Working Capital		
Total	2,43,000	2,43,000

The annual cost of the immediate...

EAST CALCUTTA RURAL ELECTRIFICATION PROJECT  
REVENUE AND EXPENDITURE ACCOUNT

Capital Expenditure	Preparatory Year	1	2	3	4	5
Capital Expenditure during year		61,000	65,000	71,000	79,000	
Total Capital Expenditure to date	2,662,000	2,723,000	2,788,000	2,859,000	2,938,000	

REVENUE ACCOUNT

Year of working	1	2	3	4	5	Year of Working	1	2	3	4	5
Units purchased	512,682	828,928	1,081,177	1,283,954	1,452,841	Total units sold	420,400	696,300	919,000	1,104,200	1,278,500
Price p. unit (Annas)	.563	.548	.546	.534	.530	Av. price p. unit sold	4.1	4.0	3.9	3.8	3.8
kW bought	280	420	520	605	670	Units sold p. consumer	560	535	540	552	568
Expenditure:-											
I. Cost of Electricity	Rs 18,040	Rs 28,391	Rs 36,895	Rs 42,852	Rs 48,125	Sale of Electricity	Rs 107,830	Rs 176,037	Rs 226,294	Rs 265,192	Rs 304,392
II. Operation	29,326	30,792	32,331	33,947	35,644	Meter rents	-	-	-	-	-
III. Repairs & Maintenance	22,250	23,362	24,530	25,756	27,044						
IV. Management	29,100	30,555	32,083	33,687	35,371						
Total	98,716	113,100	125,839	136,242	146,184	Total	107,830	176,037	226,294	265,192	304,392
V. Capital charges:-											
Interest	93,170	95,305	97,580	100,065	102,830	Deficit	140,976	90,813	57,205	32,957	8,374
Depreciation	56,920	58,445	60,080	61,842	63,752	Surplus	-	-	-	-	-
VI. Interest on Working Capital	Not included during development period										
Total	248,806	266,850	283,499	298,149	312,766	Total	248,806	266,850	283,499	298,149	312,766

The annual cost of the immediately surplus h.v. line capacity is included above, although excluded in tariff formulation. See p. 178.

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