HYDRO-ELECTRIC DEVELOPMENT IN TRAVANCORE

JULY 1939

Reprinted from THE ELECTRICAL TIMES July 20, 1939

India

HYDRO-ELECTRIC DEVELOPMENT IN TRAVANCORE

By R. L. CHANTRILL, B.Sc., M.I.E.E., and W. H. THOMPSON

ALONG the Western seaboard of the Indian Peninsula runs a range of hills known as the Western Ghats, terminating roughly at Cape Comorin, the southernmost point of India. An approximately triangular area is enclosed between these hills and the Arabian Sea with Cape Comorin as the apex. This area of 7,800 square miles is known as the State of Travancore, which has for many years been known for its high literacy and enlightened administration. The present capital is Trivandrum and the country is well served by a number of ports. The State has an extensive system of inland waterways and roads. Full use of these transport facilities has been made for the purpose of delivering to site the electrical machinery, apparatus and transmission line material for the Pallivassal Hydro-Electric Project.

Mr. K. P. P. Menon, the present Chief Electrical Engineer to the Government of His Highness the Maharaja of Travancore, carried out a large number of investigations on possibilities of hydro-electric development within the State boundaries. As a result His Highness the Maharaja's Government came to the conclusion that the development of a scheme utilising the water resources of the High Range possessed the most economic possibilities. In arriving at this conclusion various economic factors were taken into consideration to ensure that the project becomes self-supporting in the shortest space of time. The scheme now being developed is not necessarily the largest of the potential water power resources in the State.

The present scheme utilises the head available in the Munnar River after it leaves the High Range hills to fall in a series of cascades down to the Travancore plains below. This river draws its water from the catchment area of the Kanan Devan Hills of the High Range of the Western Ghats in Travancore. These hills have areas in which occur the heaviest rainfalls along the western seaboard of India, thereby ensuring a comparatively plentiful supply of water from a relatively small catchment area.

The first stage comprises the installation of the necessary machinery, civil works, etc., with transmission lines extending as far as Alwaye, Alleppey and Quilon, with a generating plant capacity suitable for supplying the initial load served by the transmission system. Originally this scheme comprised transmission lines from the generating station to the switching station at Kothamangalam, with further lines branching off to Alwaye in the west and Pallam in the south. Later

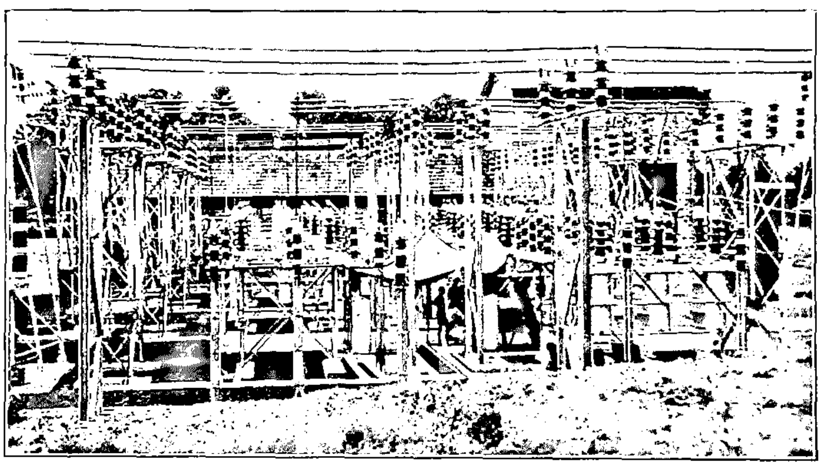

Fig. 2. Kothamangalam Substation, Pallivassal Hydro-Electric Scheme.

the Maharaja's Government sanctioned the extension of the first stage of the project to include further transmission lines south of Pallam to Mavelikara and Kundara with lower voltage lines from Mavelikara to Alleppey and from Kundara to Quilon and Punalur. Thus the first stage of the scheme covers a fairly considerable portion of the State's total area and it has been designed so that transmission system extensions can be added easily to distribute the supply of electricity to further areas, as and when such extensions are justified by load. In addition to the power potentialities in the ultimate development of the existing site there are other sites within the State which can be taken up and connected to the present system.

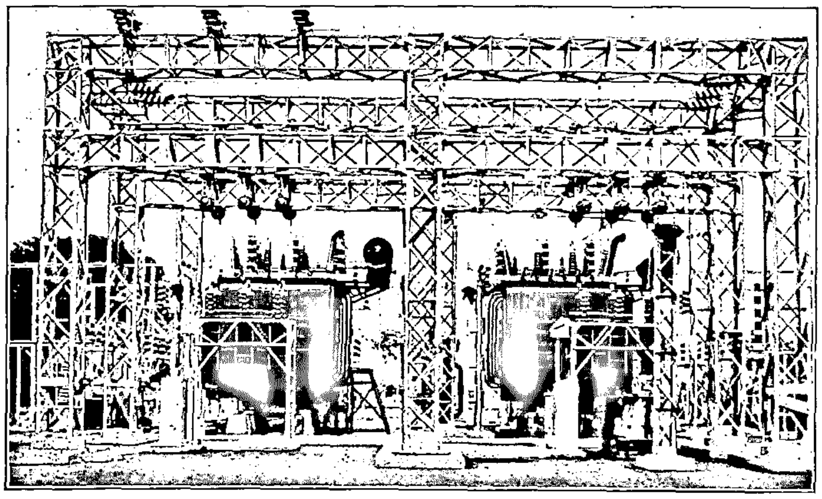

Fig. 1. View of Mavelikara Substation, Travancore.

The first hydro-electric scheme takes its name from the Pallivassal Tea Estate through which the pipe line passes on its way from the forebay to the power house. The maximum capacity to which the present power station can be extended is limited by the amount of water which can be stored economically in the hills to supplement the minimum flow of the river; this capacity will be about 25,000 kW. The ultimate development of this site will utilise the waters discharged into the present tailrace in a further drop of the Munnar River downstream of the present power house.

Hydraulic and Civil Works.—The off-take of the Munnar River has been located to make use of the largest possible catchment area from the Kanan Devan Hills consistent with the economic utilisation in the first stage of the maximum head available in the fall of the river. This catchment area comprises the western slopes of the Kanan Devan Hills, which have some of the highest annual amounts of rainfall of the Western Ghats. Some of the various tributaries of the Munnar River have suitable sites for dams to impound and conserve the high monsoon run-off in the catchment area. Such storage reservoirs will be built as and when required by load conditions to supplement the minimum flow of the river during the dry months.

The water of the river is decanted by a weir and then passes through a channel on its way to the tunnel and forebay. It was found impracticable to run an open or protected channel along the mountainside to the forebay because of the crumbling nature of the surface rock. For this reason a tunnel, approximately 10,000 feet long, has been built to connect the take-off with pipe line forebay and surge shaft. A pipe line, consisting of two separate pipes each 7,700 feet long in parallel for the first installation, connects the tunnel exit with the power house. Each pipe will supply the necessary water for one 6,000 b.h.p. turbine.

The level of the weir crest in the Munnar River at the off-take is about 4,760 feet above sea level, whilst the tailrace is approximately 2,000 feet below (2,750 feet above sea level approximately). This produces a net effective head of 1,877 feet at each turbine nozzle. The power house is located on rock on the banks of the Munnar River, with the tailrace arranged to discharge into the river.

Generating Station.—The first stage of the generating station comprises three 6,000 b.h.p. Pelton-type waterwheels running at 750 r.p.m. Each waterwheel is coupled directly to an alternator rated at 4,500 kW at 11,000 volts with the bucket wheel bolted to the overhung alternator shaft. The Pelton wheels are connected to the twin pipe line through valves arranged for two of the three machines to be operated from the two pipes comprising the first stage of the installation. The rise of pressure in the pipe line and the variations of speed of the generating units are kept within reasonable limits by special design of the governor and the provision of deflectors for the jets of the waterwheels.

In addition to ordinary load-carrying capacity, each alternator is also designed to be capable of supplying line charging current for the transmission system at the leading power factor usually associated with such systems under no-load conditions. Mechanically operated triple-pole air-break isolators, suitably interlocked, enable each alternator to be connected direct to one step-up three-winding 5,000 kVA transformer. These isolators in conjunction with a transfer busbar also provide the facility of connecting any one alternator to any one of the three transformers. One winding of each transformer is rated at 66,000 volts for transmitting power down to the plains, whilst a third winding is rated at 11,000 volts for transmitting power to the tea estates in the Kanan Devan Hills. This third 11,000 volt winding is introduced to avoid direct connection of overhead transmission lines to the alternator windings. The three 5,000 kVA outdoor transformers with the associated 66,000 volts switchgear have been placed out-of-doors alongside the power house with the outgoing double circuit 66 kV transmission line connected direct to this transforming station.

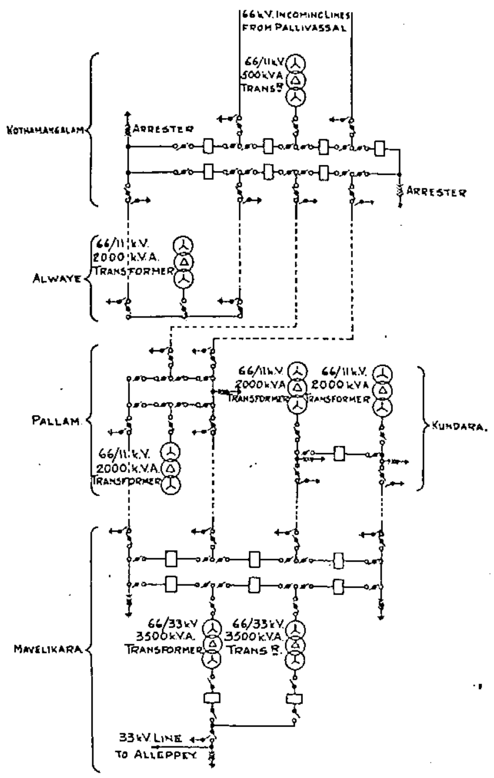

Fig. 4. Single-phase Diagram of Main Substations.

Transmission Lines.—The lay-out of the transmission system is indicated on the attached map, and comprises five double-circuit 66 kV lines totalling 135 miles, one double-circuit 33 kV line, 26½ miles long (one circuit being operated initially at 11 kV), one double-circuit 11 kV line 2 miles long, and twelve single-circuit 11 kV lines with a total length of 102 miles, while in addition there is 2¼ miles of 11 kV underground cable.

The 66,000 volt lines consist of stranded copper and cadmium copper conductors carried on double-circuit towers in vertical formation with a circuit on each side. For a distance of approximately one mile outside each substation the configuration of the conductors is changed to horizontal spacing with single circuit towers and two earth wires per circuit. The 33,000 volt line from Mavelikara to Alleppey has been built on 66,000 volt towers to permit the line voltage being raised at a later date. All the 11,000 volt transmission lines are carried on teakwood poles extracted from the teak forests of Travancore. A plant has been installed for treating the poles by the Ascu process to make the poles resistant to the attack of termites.

In the Hills Section of the 66,000 volt transmission lines from Pallivassal to Kothamangalam, the lines pass through very dense jungles inhabited by roaming herds of wild elephant in addition to other game. Special precautions have been taken to protect the lines from damage by elephants. These precautions take one of two forms:—

(a) Elephant trenches round the bases of the towers about 7 ft. deep and 5 ft. wide in places where the ground permits such trenches to be dug.

(b) Spikes grouted into the face of the rock where the towers have been erected on sheet rock.

Substations.—Switching stations have been provided at:

KOTHAMANGALAM to control the 66 kV branch line to Alwaye and the main 66 kV trunk line to Pallam;

MAVELIKARA to control the 66,000 volt trunk line and the branch lines at the lower voltages to Alleppey;

KUNDARA to control the present terminus of the 66 kV trunk transmission line.

Each one of these switching stations is also provided with transformers for supplying the requirements of the local load

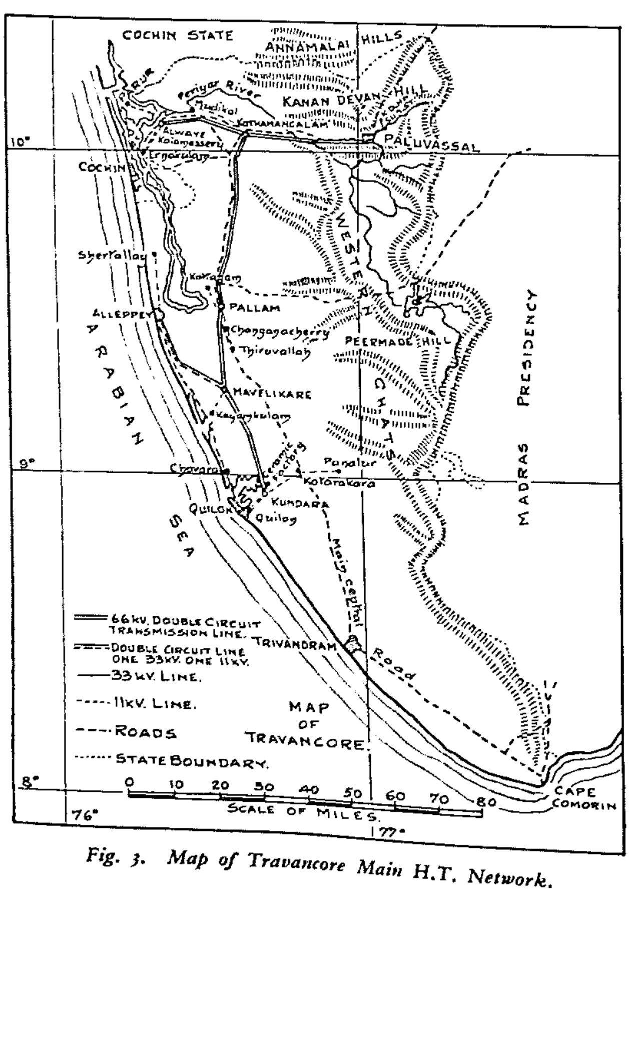

Fig. 3. Map of Travancore Main H.T. Network.

through the lower voltage branch lines radiating from these stations. In addition 66 kV transforming stations have been provided at Pallam and Alwaye and a 33 kV station at Alleppey with 11 kV transforming stations at Kottayam, Tiruvalla, Changanachery, Sherthaliay, Quilon, four stations forming the Alleppey distribution.

Three-phase transformers have been utilised throughout for stepping down the voltage and the following capacities have been provided:—

Kothamangalam.—Two 500 kVA units, ratio 66/11 kV.
Pallam & Alwaye.—Each with two 2,000 kVA units, ratio 66/11/11 kV.
Mavelikara.—Two 3,500 kVA units, ratio 66/11/33 kV.
Kundara.—Two 2,000 kVA units, ratio 66/11/11 kV.
Alleppey.—One 1,250 kVA unit, ratio 33/11 kV.
Quilon.—Two 250 kVA units, ratio 11/3.3 kV.
Each of the 11 kV substations has either a 125 kVA or 250 kVA unit, ratio 11,000/415 volts.

In the case of three-winding transformers the 66 kV windings are star connected with each neutral point solidly earthed. Each 3,500 kVA transformer has a 33 kV winding star connected with the neutral point earthed through an arc suppression coil; the 11 kV winding is connected in delta to suppress any harmonics which may otherwise arise. This 11 kV tertiary winding is connected through the substation switchgear to an earthing transformer so as to provide the 11,000 volt system with an earthed neutral point. In the case of the 2,000 kVA transformers each main 11 kV secondary winding is star connected and earthed solid, whilst each tertiary 11,000 volt winding is rated at 500 kVA and is connected in delta; this delta connected winding carries no load. With the exception of Kothamangalam station there are 66 kV neutral points solidly earthed at each one of the other 66 kV stations.

The 66 kV switching and transforming stations have all been laid out on the mesh principle; in many cases only the minimum amount of equipment has been installed and the mesh will be completed at some later date when the stations are extended. A complete mesh has been installed at Kothamangalam and Mavelikara.

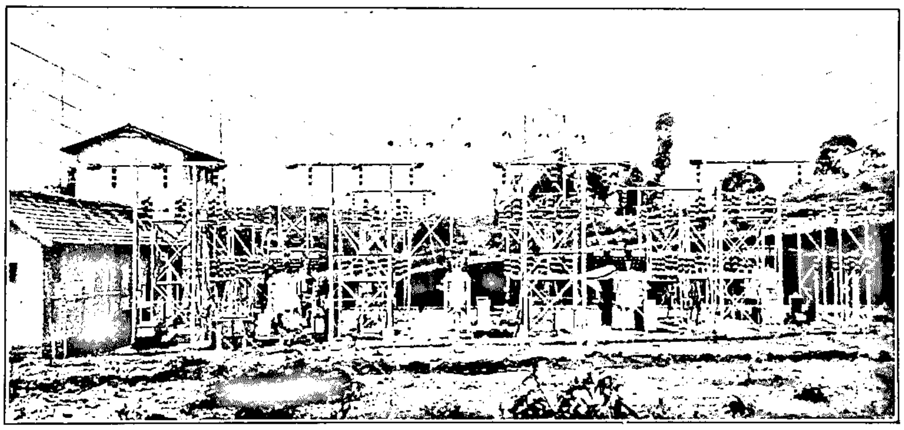

Fig. 5. View of Kothamangalam Substation, Travancore.

Special Climatic Conditions.—In supplying apparatus for this scheme, many points of special interest had to be provided for in order to make the apparatus meet satisfactorily the exigencies of the climate. During the south-west monsoon, which lasts from May to September, the atmosphere possesses exceptional humidity throughout the day and night. This humidity is frequently at dew point for days on end. Special measures had to be taken to preserve the insulation value of the dielectric strength of materials used in the construction of the outdoor apparatus. Outdoor insulation had to be arranged so that the desired insulation values are maintained both during conditions of extreme humidity and during the dry period which precedes the south-west monsoon when sun temperatures in excess of 150 deg. F have been recorded.

To protect the apparatus as far as possible from the vagaries of the climate, the following special features were adopted:—

(*a*) A heater element inside each oil circuit-breaker mechanism box to maintain the air temperature well above dew point, even when the outside air has a humidity approaching the dew point.

(*b*) A heater in each outdoor terminal box for the same reasons as described under (*a*).

(*c*) A heater in each outdoor oil circuit-breaker tank to maintain the top two inches level of oil approximately 10 deg. C. above that of the surrounding air, thereby ensuring that the air immediately in contact with the oil is at a temperature well above the dew point and is therefore reasonably dry.

(*d*) A heater in each outdoor power transformer conservator oil tank to serve the same purpose as that described under (*c*).

Correlation of Insulation.—The transmission line varies considerably in its height above ground. This has necessitated insulating the line so as to prevent as far as possible flash-over during thunder storms, and at the same time the insulation level of the approach lines had to be correlated so as to avoid surges of exceptional magnitude reaching substation apparatus with a magnitude likely to injure the insulation in the stations. To take care of these conditions, both in the hills and plains, outdoor switchgear and transformers have had their insulation values carefully correlated, based on impulse strengths of the various component parts forming each station. The various typical posts, insulator strings and bushing insulators were tested at the impulse generating station of the Metropolitan-Vickers High Voltage Research Laboratory. The wave shape used for these tests was 1/50 and both positive and negative impulses were applied. The tests were carried out under the direction of Messrs. Kennedy & Donkin, who acted as inspecting engineers for the Government of Travancore.

Having these tests carried out in one laboratory where each piece of apparatus is subjected to impulse tests under exactly the same conditions, it has been possible to arrive at correct calibration curves from which these impulse insulation levels of the various component parts of the system could be properly correlated so as to ensure that:—

(*a*) The transformer windings have the highest insulation level.

(*b*) The transformer bushings have an impulse strength lower than that of the windings.

(c) The impulse strength of the switchgear in the outdoor stations is lower than that of the transformer windings, but higher than that of the approach lines.

(*d*) The strength of the insulation in the transmission lines, apart from the approach lines, is as high as could be reasonably obtained.

In order to ensure the attenuation of impulse waves which may originate in the highly insulated overhead lines, the conductors of the double circuit lines are changed in their configuration from vertical spacing and are brought down to horizontal spacing as near the ground as is reasonably possible; these horizontally spaced lines are provided with two earth wires per circuit as against a single earth wire carried on the top of the double circuit towers.

66,000 Volt Switchgear.—The outdoor switchgear has been laid out on the mesh principle. This form of connection employs a ring type of busbar with oil circuit-breakers arranged in the ring. Two oil circuit-breakers have to be operated for a transmission line circuit or transformer to be either disconnected or connected to the station. The feature of this arrangement is that it provides complete accessibility to every insulator and piece of apparatus in the station without having to shut down a complete station if a busbar insulator is to be cleaned. Similarly a breaker can be attended to without having to shut down a particular circuit. From an operating and maintenance point of view this provides many advantages and at the same time permits a layout, which is known as a low level arrangement, maintaining the average height of the connections at a comparatively low level above ground, instead of the high galvanized steel latticed structures used elsewhere and developed originally in America.

The breakers provided for these stations are Metrovick type G3C/66 with each breaker fitted with a cross jet arc control device. The oil circuit-breakers were tested by the Switchgear Testing Co., Ltd., for interrupting capacity when they successfully broke short circuits in excess of 500,000 kVA at 66,000 volts. The breakers are operated by centrifugal operating mechanisms from 110 volt battery supply. Current transformers incorporated in the breakers have cores containing a proportion of mu-metal which gives good sensitivity and stability of the protective gear on heavy through-fault currents.

The high voltage isolating switches are of the Metrovick type AA2, which are particularly suitable for the outdoor duty in Travancore because of the type of high pressure contact embodied in their design. These switches are operated by suitable hand operating mechanisms and each mechanism is provided with auxiliary switches to provide indication on the control board. The line isolators are provided in addition with earthing switches also mechanically operated. The operating mechanism of the earthing switches is interlocked with that of the line isolators so as to prevent any possibility of earthing the line except when the line isolator is open.

11 kV Switchgear. — The 11,000 volt switchgear at the 66 kV and 33 kV stations, as well as in the four substations in Alleppey, and the substation at Quilon, comprises small 11 kV metal-clad draw-out indoor equipments. This ensures that the control of each station is under the direct and immediate supervision of the operators, who are suitably protected from the heavy monsoon weather. The various outdoor circuits are connected by means of paper insulated cables.

Protective Gear.—The double circuit 66 kV transmission lines have been provided with parallel feeder protective gear. In addition, each 66 kV circuit is provided with back-up overcurrent protection. The 33 kV transmission line from Mavelikara to Alleppey will be protected by an arc suppression coil tuned in for the particular length of line in service. The arc suppression coil is of non-resonating type; this permits accurate tuning and ensures continuity of supply being maintained to Alleppey even in the event of earth fault trouble on the line. All other circuits are provided with over-current protection having inverse time limit features.

The protective gear for the overhead lines was subjected to special tests by Messrs. Kennedy & Donkin. For these tests a set-up was made to represent as nearly as possible service conditions, the relays being connected up with the actual bushing type current transformers which would be used in service. By these means the sensitivity and stability values obtained can be taken as representative for actual service and not simply test conditions. The following relays were used:—

(*a*) The parallel feeder protective relays are of the attracted armature pattern and are of the differential directional type; these relays are used in conjunction with a type "AK" escapement pattern relay for time discrimination.

(*b*) For over-current protection and for standby protection Metrovick type "PB" and "NP" relays are used.

Control Cables.—To give the system the highest degree of immunity from troubles caused due to failure of the insulation of control cables, the following system has been adopted:—

(*a*) Between each control panel and the corresponding high tension oil circuit-breaker one multi-core paper insulated, lead covered cable has been run. This cable is terminated in a multi-core sealing box mounted at the bottom of the control panel. Tails are brought out from the sealing compound to terminate the cable on terminal boards suitably located at the bottom of the panels. The outdoor end of each cable is terminated by another sealing box which is housed in a special weatherproof housing located adjacent to each oil circuit breaker.

(*b*) From the outdoor terminal housing branch cables have been run to the auxiliary switches of the isolator operating mechanisms, the oil circuit-breaker operating mechanisms and the oil circuit-breaker bushing current transformers. These branch control cables are multi-core varnished cambric insulated, lead covered, served overall. The end of each varnished cambric cable is sealed by a special terminal device.

Control Boards.—The control boards have been located in small control houses adjacent to the outdoor switchgear. Special attention has been given to seal off all instruments and meters so that insects cannot penetrate into the cases. All panel wiring has been carried out with cambric insulated, fireproof treated, single-core cable as this has been found particularly suitable for the type of climate experienced in Travancore.

Main Contractors

GENERATING PLANT.—Volkart Bros. supplied Escher Wyss waterwheels and Brown Boveri plant.

66 kV SUBSTATIONS.—A.E.I. (India), Ltd., supplied Metrovick switchgear and B.T.H. transformers.

33 AND 11 kV SUBSTATIONS.—G.E.C. (India), Ltd., supplied 33 kV sub. at Alleppy and 11 kV rural subs. A.E.I. (India), Ltd., supplied 11 kV B.T.H. transformers and Ferguson Pailin switchgear at Quilon.

TRANSMISSION LINES.—Callender's Cable and Construction Co., Ltd.

PIPE LINE.—Harrison and Crossfield, acting for Boving and Co., supplied pipe line, made by Ferrum, Ltd.