

Industrial Outlook.

Future of Electrical Development in India.

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GENERAL OUTLINE.

THE unprecedented grid-developments from water power during the last five years in the Punjab, United Provinces and Madras Presidency has well established the adaptable possibilities in fields of Industry and rural electrification, that can be attained from the energy of the vast water resources of India. At the same time the recent decision of the Government of United Provinces to erect 1,500 tube-wells for irrigational purposes at the expenditure of 12,000 kw to 28,000 kw, the present ultimate generating

capacity of its hydro-electric scheme shows clearly how the problem of irrigation must always be the predominant partner when dealing with water and its uses in India, whereas in most countries irrigation is unimportant or is on equal terms with power. Table I shows the sceptic outlook with which the water-power development in India is treated; in spite of the fact that other countries possessing such practical potentialities were fast harnessing the aforesaid source of energy with all the latest improvements in hydraulic and electric machinery.

TABLE I.
Hydro-Electric Works in India.¹

Locality	Power installed KW or K.V.A.	Units Generated p. a. (millions)	Transmission Line—Miles	Head Feet	Province and its Probable Ordinary minimum Power in KW.
Shillong	300	0.4	?	?	Assam 621,100
Darjeeling	1000	1.6	3	275 & 650	Bengal 1000,000
Kurseong	400	?	..
Tata Power Co. ..	109,500	200	77	1640	..
Tata H. E. Power Co.	60,000	120	43	1725	..
Andhra Valley ..	60,000	160	56	1740	..
Gokak Mills Co. ..	1570	6	?	210	..
Bhatghar Dam ..	1024	1	?	46 to 100	Bombay 773,000
Kashmir	4000	2	54	390	..
Jammu	1200	1	?	26	Kashmir 458,000
Pykara	23,430	..	316 route miles	3000	..
Karteri	1000	2	3½	650	..
Munar	1100	1.7	?	380	..
Annally	110	0.1	..	800	..
Kotagiri	70	0.1	?	700	Madras 400,000
Malkhand	250	0.2	?	8	N. W. F. 1000 000
Uhl River	48,000	..	173 and others	1800	..
Amritsar	525	0.5	..	6 to 10	..
Patiala	213	0.2	..	8	..
Simla	1750	6	21	540	Punjab 1190,000
Ganges H. E. Scheme ..	9000	..	1000	9—18	..
Nainital	450	0.8	..	1500	..
Hardwar	450	0.3
Mussorie	3750	3.5	10	1000	U. P. 605,000
Canvery Falls ..	37,500	153	200	400	Mysore

Though the probable reserve of Indian Coal as estimated by T. H. la Touche reaches the stupendous figure of 79,500 million tons,² still her immense potentialities in

water-power, both intrinsically and because of the distance to which coal has to be carried are significant enough, to cause serious thought. Moreover, recent and almost revolutionary advances in the design of hydraulic turbines of the propeller type have greatly modified the whole aspect of low-fall hydro-electric schemes, another dominant factor embodied in such enterprises in India.

¹ Mears, *Water Power*, 1934.

² T. H. Ronaldson, *Monographs on Mineral Reserves with Special Reference to Our British Empire*, John Murray, 1920.

Though, during the last decade the steam and Diesel Engines have played an important part in increasing the capacity of electric

supply undertakings in this country, still the concentration on India's water-power resources are fully justified.

TABLE II.
Indian Power Resources.^{2,3}

WATER POWER		COAL			
Probable ordinary minimum power (k-watts)	Probable maximum for development (k-watts)	Actual reserves in Tons	Output of Indian coal-fields in Tons		
			1916	1917	1918
7,532,000	12,680,000	4,45,833 × 1000	17,254,307	18,212,918	20,721,543

Considering the inferior nature of Indian Coal, we might take 1-hp-year as being equal to 4 tons as a fair average. On this basis the 1918 output is capable of yielding 5180385-hp-year or 3865960 kw-year, which is only about half the probable ordinary minimum available water-power out of which hardly 5% has been developed; five years back there were only Bombay and Cauvery Falls hydro-electric schemes worth the name of recording.

Till now it has been a characteristic feature of the hydro-electric power systems in India that wherever they have developed so far, the consumption *per capita* has gone up in comparison with other regions of electric power. For instance, in Bombay, which has made available the largest amount of hydro-electric energy in India, the consumption *per capita* is over 200 units.⁴ In Mysore and Bangalore the Cauvery Falls Hydro-electric Scheme has made possible a consumption of about 100 units⁴ *per capita*. Whereas in the cities possessing up-to-date steam power plants the consumption *per capita* is much less. Thus Calcutta, which ranks both in industrial and intellectual reputation with Bombay consumes about 110 units.⁴ In Madras, which is a neighbouring city of Bangalore and the third port city of India, the consumption *per capita* is as low as 30 units⁴ only. The average demand per head of population varies from 5-6 kwh in the smaller cities.

There is thus considerable market for electrical energy and if cheap power can be made available it will be readily absorbed.

Of late, these expectations have been amply fulfilled by the three important provincial projects undertaken by their respective Governments, even to the extent of rendering rural electrification successful. At present owing to the encouraging demands each of these provinces have proposals on hand to develop the schemes still further.

PROPER UTILISATION OF WATER-POWER.

With some idea of the status of water-power resources in India, we can now consider the problem of rational distribution of electrical energy as far as possible over a vast area of 4.66 million square kilometers, with its far and widely located water-power resources. Also, the Indian conditions differ materially from elsewhere, owing to her dependence on well-defined "monsoons" instead of casual rainfall all the year round. As a direct consequence of this India has one type of hydro-electric development without parallel elsewhere, namely that found in the Tata chain of schemes in the Western Ghats of Bombay. For the proper utilisation with profit an immediate and new orientation in the trend of development of transmission systems in India, is needed, most probably in the direction of increased interconnections. With the following proposed Indian super-power grid systems (Fig. 1, Map of India) it is feasible to supply economically the entire energy requirements of the country with the exception of certain restricted areas where power transmission is very difficult. These six sections of Extra High Tension lines will cover a total distance of nearly 6,000 miles. The longest of these are each nearly 1,200 miles in length, while the shortest line between Tuticorin and Madras has

³ Mears, *Hydro-Electric Survey of India*.

⁴ Basu, *Proc. World Power Conference* (held at Berlin), 1930, Vol. 10. (D. Ing. J. N. Basu of Bengal Technological Institute of Jadabpur, Bengal).

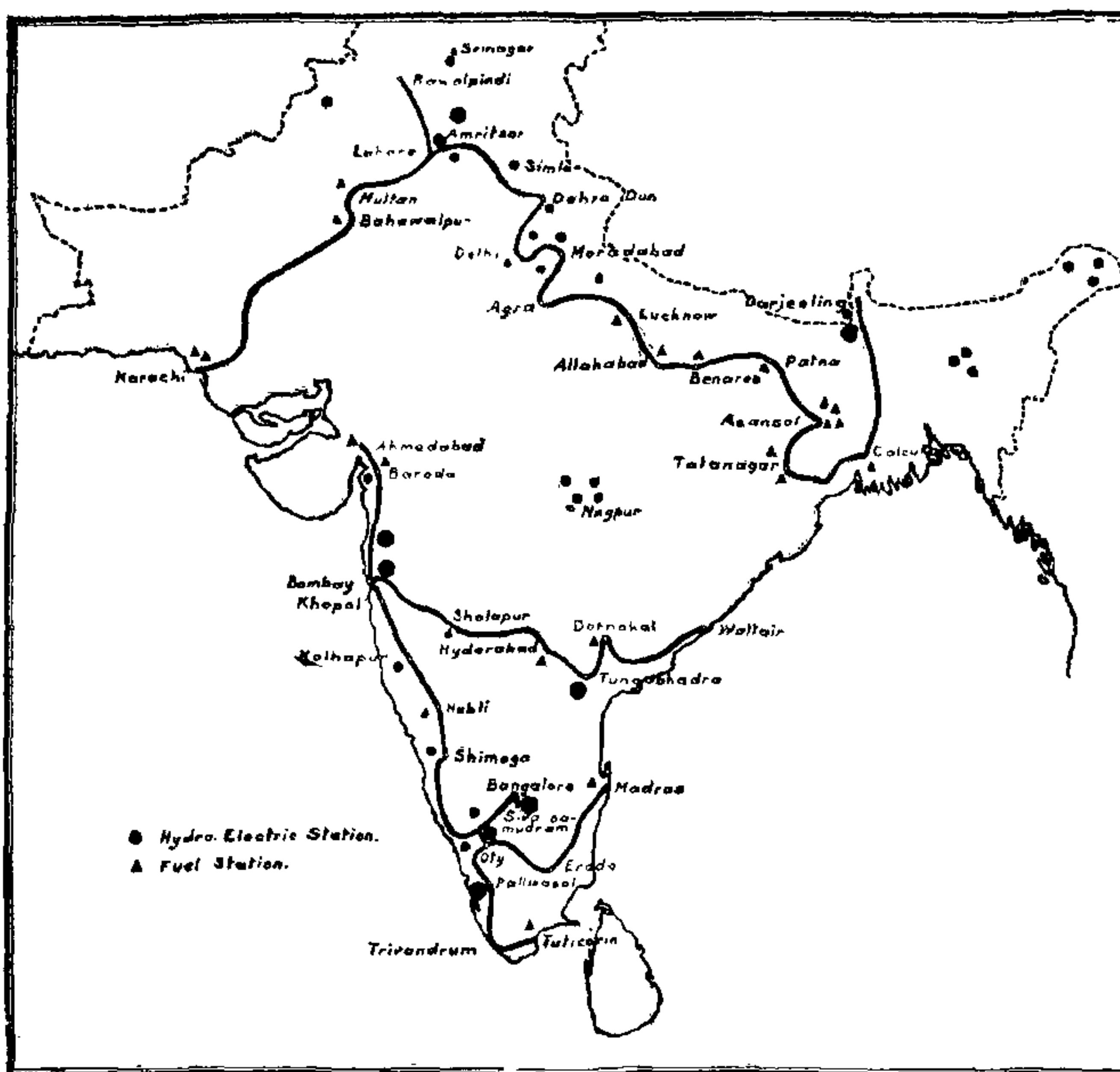


Fig. 1.

a length of 700 miles. In view of these unusual distances and vast interchange of power over such a system the minimum transmission pressure tends to increase somewhere about 400 kv. In order to secure stability in a project of such a nature, it is of vital importance to augment the power by the energy generated at the would-be super-power stations situated on the coal fields, say, for example, in Bihar Province.

As the extent and development of water-power in a country varies in accordance with topographical and climatic changes and is also affected by variations of policy in different administrations, so the first natural sequence will be the immediate formation of a Central Electricity Board of an all-India nature. It must be represented by Engineers, Industrialists and Chemists in order to prepare regular and systematic power survey reports and to investigate thoroughly the nature and extent to which the cheap electric power, thus made available, can help to create new industries. Amongst these may be mentioned (a) The electric smelting of indigenous iron ores and electric production of steel and alloys,

(b) Electric welding, (c) The production of aluminium from the local bauxite deposits, (d) The manufacture of calcium carbide and its numerous derivatives, (e) The electrolytic production of chlorine gas and the preparation of phosphorus and of abrasives like carborundum. (f) Pulp and paper industry with printing, (g) Manufacture of electro-chemical products such as synthetic fertilisers for which there is a great demand in India, (h) Economical irrigation of a vast area of uncommanded land by tube-well pumping or by gravity lifts from existing canals, (i) Reclamation by draining waterlogged lands. In addition to these attempts can be made to increase the domestic load and accelerate the electrification of Indian Railways in suburbs.

Considered from the expenditure side, the adequateness of such a scheme with a well-defined objective and policy can undoubtedly be established in its favour. For example, taking Madras Presidency, which imports coal and fuel oil (excluding petrol) worth more than Rs. 300 lakhs, a transmission network interconnecting the projects of Pykara, Perriar and Papanasam

can be provided in order to distribute 120,000 kw all over the province at an estimated total capital expenditure of Rs. 950 lakhs, provided the total fixed charges on the capital outlay of Rs. 950 lakhs does not come up to over Rs. 70 lakhs. It would be reasonable to expect that the decrease in the value of the imported fuel, on account of motive power supplanting raw fuel engines, will be in excess of these charges.⁴

In India there are several provinces (say Assam) where the demand is far less than the available supply owing to the distances of the sources from the industrial centres. The energy in such localities might be utilised with the help of chemical endothermic processes, for the production of compact materials for transportation to the industrial centres where by exothermic processes they might generate heat and power.

In India unlike in other countries it is possible to build up a load only in those places which are to be served by these super-grids after their completion. In fact the author estimates that these projects after the completion on the suggested line will be able to supply power at any point in the grid at an average price of 1 anna,* about Rs. 200 per kw-year whereas from the bulk of the smaller oil-driven plants throughout the country the rate is about 2 annas per kwh (unit). River Teesta in Bengal with a hydro-electric power generating capacity of 1,000,000 kw and River Koyna in Bombay with 250,000 H.P. need immediate attention for harnessing purposes.

THE TREND OF TRANSMISSION PRACTICE.

With an eye to the proposal, let us examine the noteworthy advances in transmission practice which go to materialise a scheme of this character. Within the last ten years a number of 220 kv lines have been put into successful operation in different countries and this voltage has now become the standard transmission voltage for very long distances. Further to keep down the weight of copper and hence the cost of the line it was proposed at the World Power Conference in 1930 to examine the practicability of 400 kv for the operation of an European Super-power Grid of nearly 7,000 miles; and with such values of transmission

distance and transmission voltage the difficulties mentioned below are introduced.

Transmission line requires excitation or charging current which varies with the load, and its supply has to be regulated by means of Synchronous Condensers. This charging current being wattless contributes towards the transmission losses, which depends upon the capacitive reactance of the line which is again proportional to the length of the line and to the frequency of the alternating current; hence it is at once seen that by reducing the frequency the power-transmitting or kilo-watt capacity of the line can be raised. By using direct current we drop the frequency to zero and it is thus that the inevitable conclusion is reached that it is the only means of increasing the transmission distance. Inductance and Capacitance vanish. The transmission line becomes stable under all possible conditions of loading and intermediate stations for compensating reactive drops become unnecessary. Apart from these advantages,

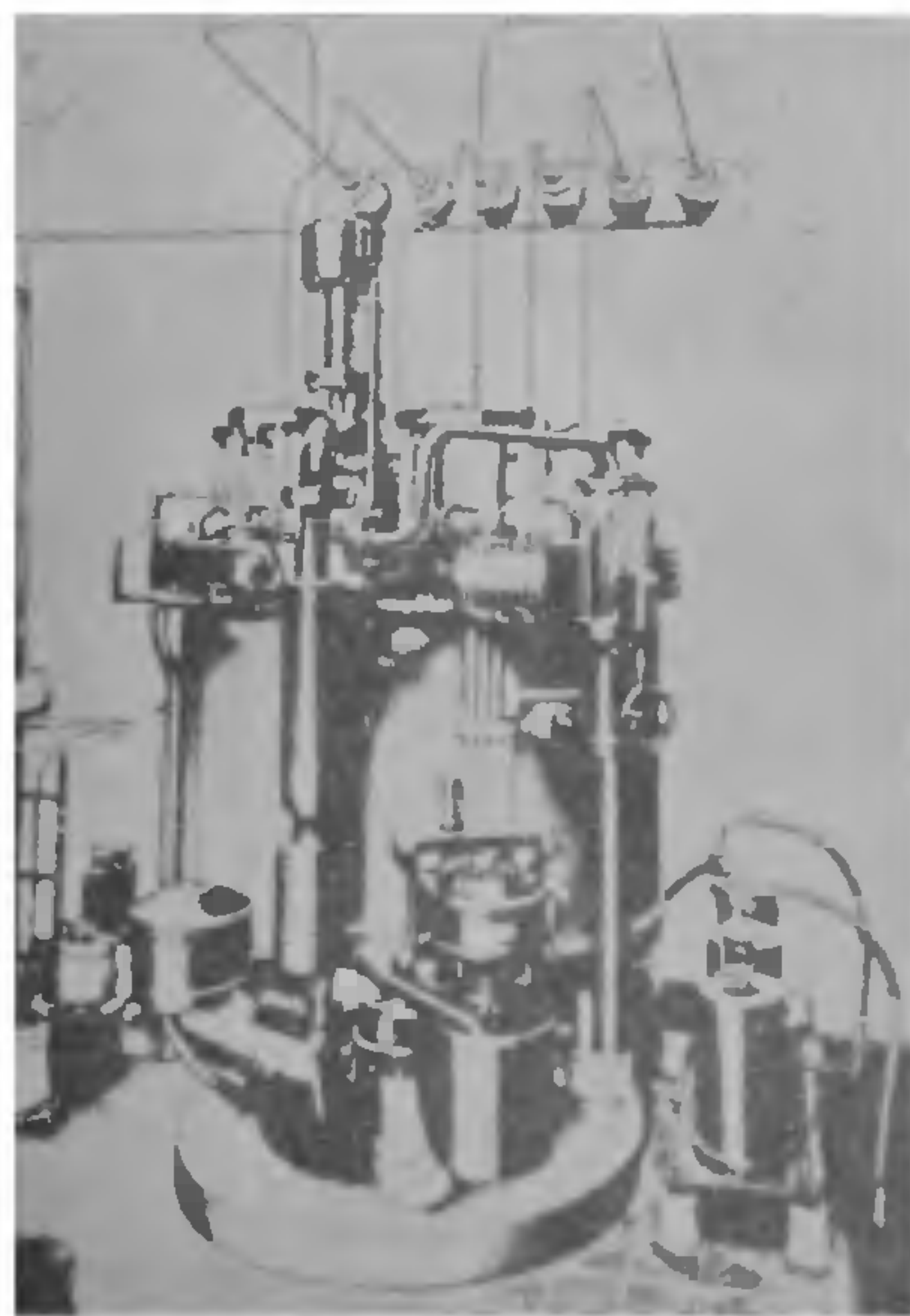


Fig. 2.

Steel tank rectifier 750 kw capacity at 15,000 volts.

⁴ Basu, *Proc. Second World Power Conference*, 1930.

* 1 Rupee = 1¼sh. = 16 annas.

the skin effect, characteristic of alternating current at high voltages is absent in the case of direct current. Corona loss with direct

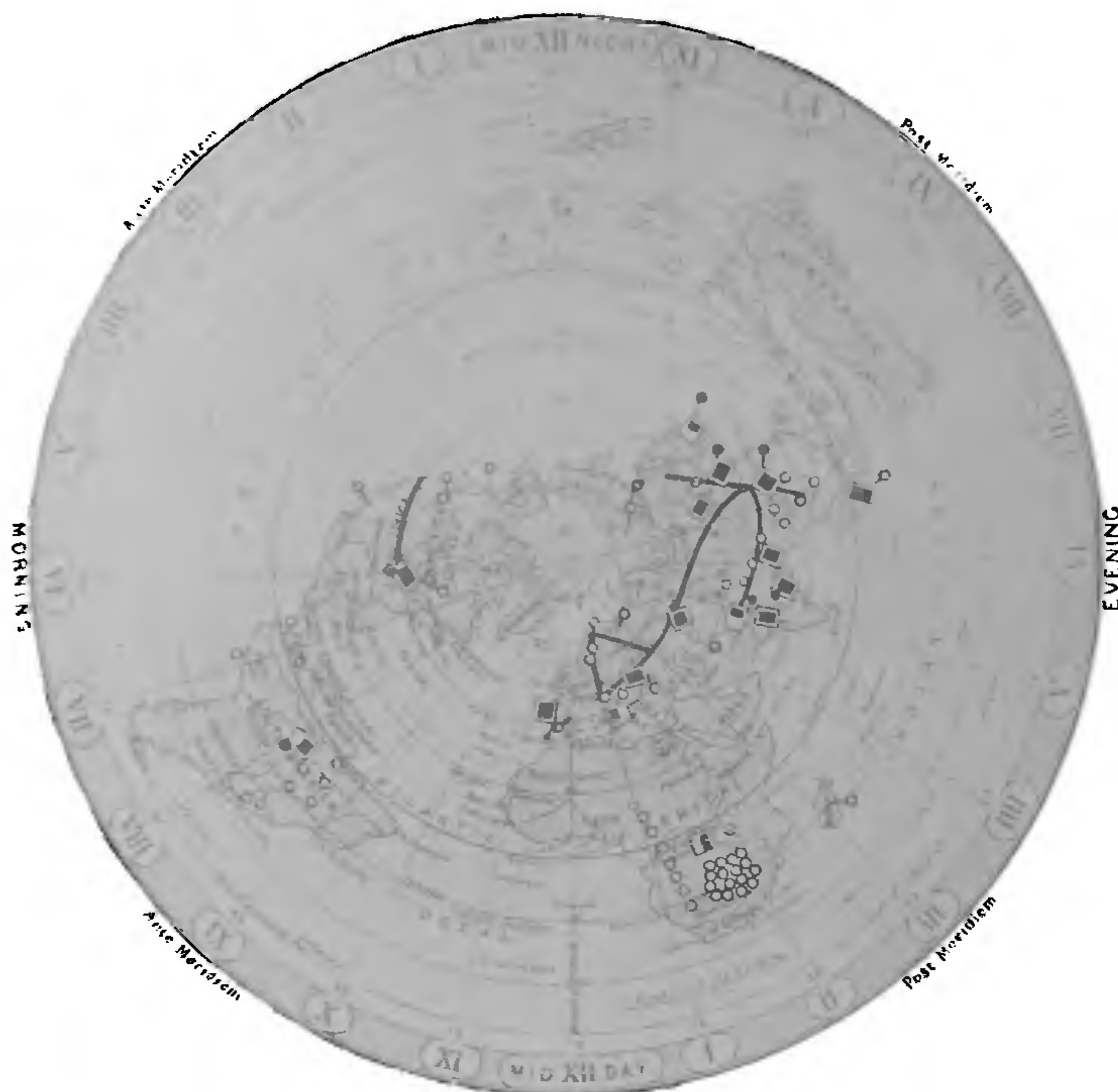


Fig. 3.

current is considerably less and for the same degree of insulation to earth the operating voltages for d.c. and 3 phase a.c. transmission are in the ratio of 65 to 23.

Even though the d.c. transmission is to form the future basis of long distance transmission, it is still essential to generate first alternating current in large high-speed machines and then to convert it to d.c. in relatively few units of efficient apparatus of static nature. It is, furthermore, equally essential that similar apparatus be employed for transforming the high tension d.c. back again to 3 phase a.c. at constant voltage for subsequent distribution throughout the existing power networks. Such apparatuses have already been manufactured on a smaller scale and are known as Rectifiers and Convertors (Fig. 2). Experimental transmission in the laboratory at 15,000 volts has very recently been achieved by the General Electrical

Company of Schenectady in America for 3000 kw lines. They employed static type of Rectifiers and Convertors commercially known as Thyatron and Phanotron respectively. The efficiency of conversion with larger units under investigation are expected to be as high as 98 to 99 per cent. Thus the present double circuit line of 132 kv of the Punjab can, without further alteration, be utilised as a triple circuit direct current line operating at 370 kv between positive and negative conductors, whilst with the assumption of similar line losses in both the cases the power which can be transmitted is nearly seven times.

Besides, through the success and organised co-operation of long distance d.c. transmission we can go still a step further by interconnecting the hydro-electric and other electric systems internationally for the reduction of power cost with a more

satisfactory equalisation of load. Another method through which the equalisation of power can be attained will be to utilise the rotation of the earth. The idea behind the proposal is to get power plants which are situated at different meridian distances in an east-westerly direction to co-operate systematically. An extreme case of such co-operation would be between a power plant which is situated on the extreme east of Asia and a similar one on the extreme west of Europe (Fig. 3). These power plants should work with a day and night displacement of 12 hours, in spite of the fact that according to absolute time calculations no time displacement exists. In this way night power in the extreme west of Europe could be transferred to day power in the extreme east of Asia

and *vice versa*. At present it is rather difficult to visualise so great a relative time displacement between the maximum load of similar power plants. But even with a time shift of 3 or 4 hours much can be gained, specially in electrical tramways and suburban railway services.

The exploitation of water-power resources is essential for the needs of India. However great the distances to be covered, there are no inherent difficulties from the engineering point of view that could not be surmounted. Industry and agriculture are both in need of a "grid scheme". Sooner or later the provision of a "grid" supply is inevitable, and the Government should look ahead and find the necessary capital for the scheme.

Reviews.

NEW PATHWAYS IN SCIENCE (Based on the Messenger Lectures of 1934). By Sir Arthur Eddington. (Cambridge University Press, 1935). Pp. x+333. Price 10s. 6d. net.

Six years have elapsed since Sir Arthur Eddington's "*The Nature of the Physical World*" was published. These years have not witnessed any revolution in theoretical Physics such as that represented by the birth of quantum mechanics. The time, however, has been utilized to take stock of the implications of the new theory and much that was obscure and changing has cleared and crystallized. Sir Arthur has seized the opportunity afforded by the Messenger Lectures delivered by him in 1934 to write a sequel to "*The Nature of the Physical World*" which bears the impress of this process of taking stock. On the other hand, recent years have produced astounding discoveries in the realm of experimental physics: we have had the neutron, the positron, heavy hydrogen and induced radio-activity coming in rapid succession before our astonished gaze. These discoveries have had their repercussion on the problems of Astrophysics so near and dear to Sir Arthur. We accordingly find in the present book a portion dedicated to the consideration of the internal constitution of stars and of the expanding Universe; another part describes the philosophical outlook of modern science as Sir Arthur interprets it. The connection between the Universe of the

Relativity theory and the atom of the Quantum theory which is the theme of Sir Arthur's theory of the fine structure constant is dealt with in another chapter. Incidentally we find a treatment of Probability and the Theory of Groups included. An introductory chapter will enable any one not conversant with the modern development of Physics to get a rapid acquaintance with the most recent discoveries. The subject is throughout treated in the charming pictorial style which we have come to associate with Sir Arthur. In spite of the difficult nature of some of the topics dealt with, even a layman will have a chance of understanding the direction in which modern Physics is advancing as viewed by Sir Arthur. The Indeterminacy Principle, Eddington's recondite theory of the fine structure constant, and the theory of Groups are all explained in such a lucid manner that we feel we have understood something of even these difficult matters. Sir Arthur thus provides an example of how even higher mathematics may be made intelligible to laymen.

This success in providing a popular exposition of such difficult subjects has, however, one drawback: the language is imaginative and picturesque, but the metaphorical statement sacrifices something of precision and the reader is likely to mistake a vague idea which he sometimes obtains for a profound understanding of the subject. Thus Pauli's principle that no two electrons