401.—EXTRA HIGH VOLTAGE TRANSMISSION DEVELOPMENTS IN AUSTRALIA

Presented in the Name of the Australian Sub-Committee to No. 9 Study Committee.

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SUMMARY

The growth of electricity consumption and corresponding power developments led to the conception of a large 330 kV transmission system serving the needs of the States of New South Wales and Victoria. In South Australia, a special transmission problem will be solved by the use of 275 kV.

Some of the background to these developments is explained and their main technical features are described.

REPORT

1. INTRODUCTION

Australia is going through a period of rapid growth. In eight post-war years the population has increased by one fifth, i.e. at an average annual rate of 2.4 %. The generation of electricity is developing in harmony with the expanding population and economy at a rate of about 10 % p.a. It reached 15,000 Million kWh in the year ending March 1955, or 1,630 kWh per head.

The map in *figure* 1 shows the boundaries of the six States of the Commonwealth, their capital cities, and indicates the size of the

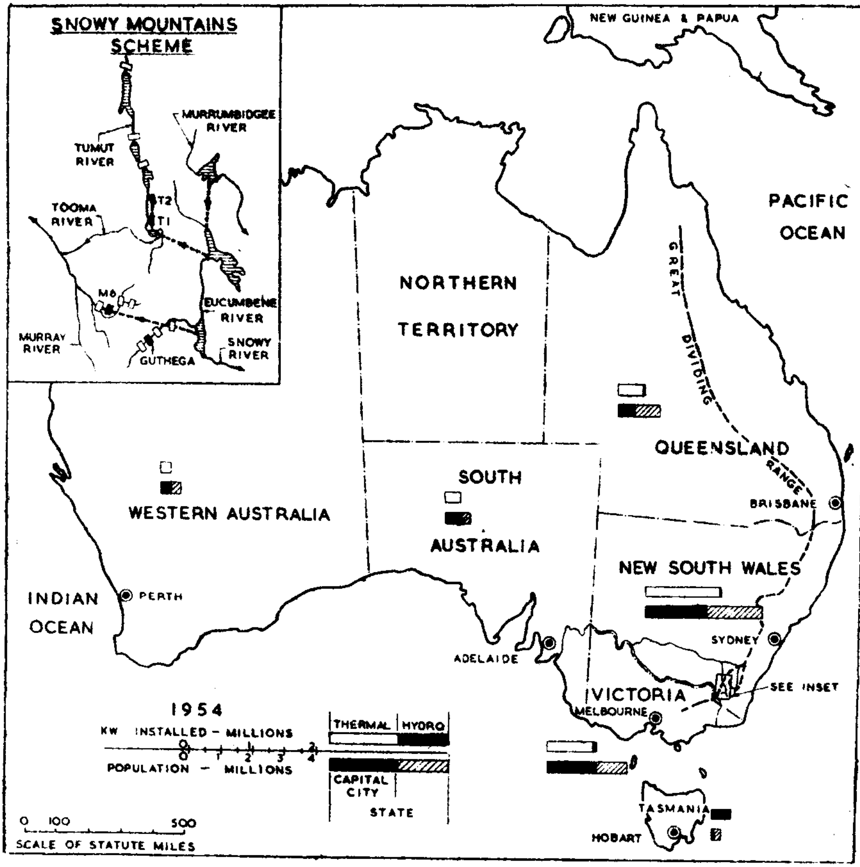

FIG. 1.—Australia, Population and Installed Generating Capacities.

population, the amount of installed generating capacity, and the distances that are relevant to transmission problems. The following fundamental facts emerge: The bulk of the inhabitants live in the Eastern States which are favoured by relatively high rainfall in the coastal strip situated east and south of the Great Dividing Range. In general, approximately half the population of each State lives in the Capital city where industry and commerce are concentrated. The population density is lowest in the tropical North and in the arid centre of the Continent.

These facts are reflected in the structure of existing power systems; steam power stations are located in or near the capital cities, and transmission systems remote from the cities are relatively weak. The great distances between the main load centres have hitherto precluded the interconnection of the State systems for purposes of more economical generation and pooling of reserve plant.

Nevertheless, interconnection between the Southern and Eastern States is a technical possibility although the economic justification for large-scale interconnection exists at present only in the case of New South Wales and Victoria, and this only because of the advent of the Snowy Mountains project which is located approximately mid-way between the main load centres of the two States. Western Australia and the Northern Territory are still beyond the practical range of E.H.V. transmission.

The electricity supply systems in each State are controlled by State Government undertakings which in general distribute power to the ultimate consumer but are restricted in some cases to generation, power station interconnection, and supply in bulk.

The Federal Government of Australia does not directly interest itself in Electricity Supply (apart from some small systems in special locations) but it has embarked upon the development of the water resources of the Snowy Mountains which, being situated near the border of New South Wales and Victoria, will provide controlled irrigation water and large blocks of hydro-power to each of these States. As indicated above, the establishment of the hydro-stations assists materially the economic case for long distance interconnection between New South Wales and Victoria.

2. THE PROJECTED E.H.V. SYSTEMS IN NEW SOUTH WALES AND VICTORIA

(*a*) **Power Developments in New South Wales** (1).—New South Wales possesses large bituminous coal deposits within a 100 mile radius of Sydney. In the past, practically all of Sydney's demand has been met by coal fired power stations situated close to the City. The relatively small country demand imposed no transmission problems that could not be met satisfactorily by the use of voltages of 66 kV and 132 kV.

Since the war there has been a rapid increase in the load at large country centres and this load, together with the large blocks of power required by the capital, will in future be transmitted from modern

(1) For amplification of these brief notes on power developments in New South Wales and other Australian States reference should be made to the bibliography.

power stations located on the coal fields south, west and north of Sydney. Unit sizes of turbo-generators up to 120 MW are under consideration for use in these power stations. The blocks of power to be transmitted are such that investigations into the establishment of a State-wide grid to be superposed on the 132 kV system was undertaken.

At this stage a voltage of 275 kV was favoured, as a relatively large number of substations would be required throughout the State. This voltage would also have been suitable for any hydro development of the Clarence River area in the far north of the State, which has a potential capacity of approximately 300 MW.

The case for an E.H.V. system was greatly strengthened by the advent of the Snowy Mountains Hydro-Electric Scheme which presented a clearcut high-power, long-distance transmission problem. For this and other reasons referred to later, the initial proposal to use 275 kV was abandoned in favour of 330 kV.

The Snowy Mountains scheme provides for the diversion of the waters of the Snowy River and its tributary, the Eucumbene, through two tunnels, 14 and 22 miles long, into the Murray River system. Irrigation water amounting to 1.8 Million acre feet (2,200 Million m^3) per annum will become available by diversion and regulation, to augment the water used in existing irrigation areas and to allow for further development. A series of hydro-electric power stations will generate 5,830 Million kWh of energy per annum.

Because of irregular flows and the need for large costly storages, the most economical arrangement is for the Snowy scheme to provide power at capacity factors lower than the system load factor; the base load will, therefore, be generated by thermal power stations. The optimum value of the capacity factor is still being studied but the present view of the Snowy Mountains Hydro-Electric Authority is that the ultimate firm power should be near 3,000 MW. Of the power developed, two-thirds will be supplied to N.S.W. and one-third to Victoria. The overall transmission distance for the main blocks of power is approximately 250 miles (400 km) in each case.

The first power station of 60 MW, which has been in service since February 1955, feeds into the N.S.W. 132 kV system. The units of the next two power stations, with a combined total output of 600 MW, will go into commission at intervals during the period from 1959 to 1963; they will feed into the 330 kV system described below. The rate of construction is co-ordinated with the development of the thermal systems to give optimum overall economy. Completion of the scheme may therefore take 20 to 30 years; this circumstance had an important bearing on the choice of voltage.

(*b*) **Power Developments in Victoria.**—For many years, most of the base load power requirements of Victoria have been supplied from a power station on the rich brown coal deposits of Yallourn, 80 miles east of Melbourne which is the main load centre. Other power requirements were met from various peak load thermal stations and minor hydro schemes and, as in New South Wales, transmission was carried out satisfactorily with voltages ranging up to a maximum of 132 kV. When the details of the Kiewa Hydro-Electric Scheme (300 MW, 160 miles from Melbourne) were being fixed about 1946, a transmission voltage of 220 kV was chosen. The first circuit of this system was put into operation in 1955, certain 66 kV circuits having been used prior to that date. The voltage of 220 kV was also found suitable and economical for the transmission of a large block of power (350-400 MW) from new thermal stations at Yallourn to Melbourne, and the first two circuits operating at 220 kV will come into service in 1956; they will be interconnected with the Kiewa transmission and will feed into four main Metropolitan switching and transformer stations. The voltage of 220 kV is also to be used for the transmission of smaller amounts of power over a State network to country centres, in some cases the amounts of power being quite small and the centres concerned far inland, e.g., the length of the proposed transmission line from Kiewa to Mildura is about 380 miles.

With the prospect of having to transmit, ultimately, up to 1,000 MW from the Snowy Mountains over a distance of 210 miles to Melbourne, it became necessary to consider the adoption of Extra High Voltage transmission, and an economic study showed that 330 kV, the voltage selected for transmission from the Snowy Mountains into New South Wales, was also admirably suited for the link to Victoria.

In addition to the coal fields at Yallourn, there are several other rich brown coal fields in the Latrobe Valley, about 100 miles east of Melbourne, and steps for their development are now actively in hand. The first generator at Morwell is expected in 1958, to be followed by the first set at Hazelwood in 1962, with further developments, including a power station on a coal field at Loy Yang, up to a total output of about 3,000 MW.

As part of the output of this group of stations will be absorbed by local industries, it will probably be possible to use existing 220 kV lines for the early stages of transmission. However, about 1962, the first circuit of two transmission lines will be brought into service, probably at 330 kV, between Hazelwood and Melbourne with the second circuit shortly afterwards, and about 10 years later two further circuits from Loy Yang are likely to be required at a still higher voltage. The voltage to be used will be selected in due course, on the basis of a separate economic study.

Present proposals are that these transmission lines should feed into the 220 kV ring encircling Melbourne, and as they will be coupled with the 330 kV Snowy transmission system through the 220 kV network only, there is no inherent reason why they could not be of a different voltage.

(c) **Choice of Voltage.**—Economic studies of the cost of transmission from the Snowy Mountains to Sydney and Melbourne were undertaken by the Snowy Mountains Hydro-Electric Authority. Particular detailed attention was paid to the E.H.V. system in New South Wales which will absorb most of the Snowy power and will, at that stage, be larger in extent than the Victorian E.H.V. system. The decision of the choice of voltage was taken by the Electricity Commission of N.S.W. and the Snowy Mountains Hydro-Electric Authority. As already mentioned, the State Electricity Commission of Victoria found that the same voltage would be satisfactory for the extension of this system to Melbourne.

In order to be as realistic as possible, the principal technical feature of systems of various voltages from 220 to 380 kV were first determin ed, such as: general layout of the collecting system for 16 hydro power stations in the Snowy Mountains, economical tower designs, insulation levels of lines and apparatus, reactive requirements, etc. To resolve some of these technical points, quite detailed studies had to be undertaken, including studies of stability and of dynamic overvoltages which involved the use of the A.C. network analyser of the State Electricity Commission of Victoria and the micro-network of Electricité de France. The methods employed were substantially those discussed by other contributors at previous C.I.G.R.E. conferences.

No test equipment was available for the study of corona behaviour of line conductors ; however, sufficient data had been published abroad to inspire confidence in a choice of conductors based on deductions from the test results obtained from other sources.

Various arrangements of the collecting system for the power from the hydro-stations, which will extend over a perimeter of about 150 miles, were considered. The main object was the reduction of the cost of E.H.V. switchgear. The idea of using for collection a lower voltage than for main transmission, possibly omitting switchgear on the E.H.V. side, proved uneconomical because of the increase in losses and reduction of stability caused by double transformation. A single voltage was adopted, except in the case of groups of smaller power stations whose output will be conveyed by short 132 kV lines to the nearest switchyard of a major power station, where it can be economically transformed to E.H.V. by large transformers.

In studying the economy of different voltages, the monetary value of transmission losses has to be assessed. This is a difficult matter, particularly in the case of a combined hydro-thermal system, on which opinions differ. The effect of varying the value of losses over a likely range was therefore studied together with the effect of different long term interest rates. Fortunately, these variations are of moderate influence because the most economical voltage and cross section vary according to the fourth root of these quantities.

The following factors had to be given sufficient weight: firstly, the amount of transmitted hydro-power is not constant but will grow to its maximum value over a prolonged period; secondly, the use of the E.H.V. system in New South Wales as a "grid", superposed on the 132 kV system, requires the early establishment of several transformer stations in various parts of the State which will not be fully utilised for some years; thirdly, for reasons of reliability, seeing that hydro-power will supply about one-third of the system load, it is ncessary that the main transmission links between the Snowy Mountains and the New South Wales load centres be duplicated at an early stage. All these factors tend to increase the capital charges for the E.H.V. system during the early stages of relatively light load; the higher the voltage, the greater this burden. It was therefore advisable to give more weight to the annual charges during the early years; this could be achieved by the use of the "present worth" method of assessing annual charges.

The calculated total cost curves showed a minimum at approximately 330 kV, with the usual flat range below and above the optimum voltage.

Careful consideration was given to the suggestion that one of the nearest standard voltages proposed by I.E.C. (275 or 380 kV) be adopted; however, the final choice remained 330 kV. The main reasons for this decision were:—

The adoption of 380 kV would have meant too large a step in relation to the existing 132 kV system in New South Wales. It should be kept in mind that, at least in respect of the transmission of Snowy power, the ultimate transmission requirements are known within reasonably narrow limits; it could therefore be foreseen that the additional capital expenditure entailed by the choice of 380 kV would not show any compensating profit during the depreciation life of the equipment. The question of international interconnection at 380 kV does not, of course, arise in this case. The rival claims for finance for other developmental projects also discouraged excessive capital investment.

The voltage of 275 kV, on the other hand, was rejected because, compared to 330 kV, the capital saving would be small and the loss

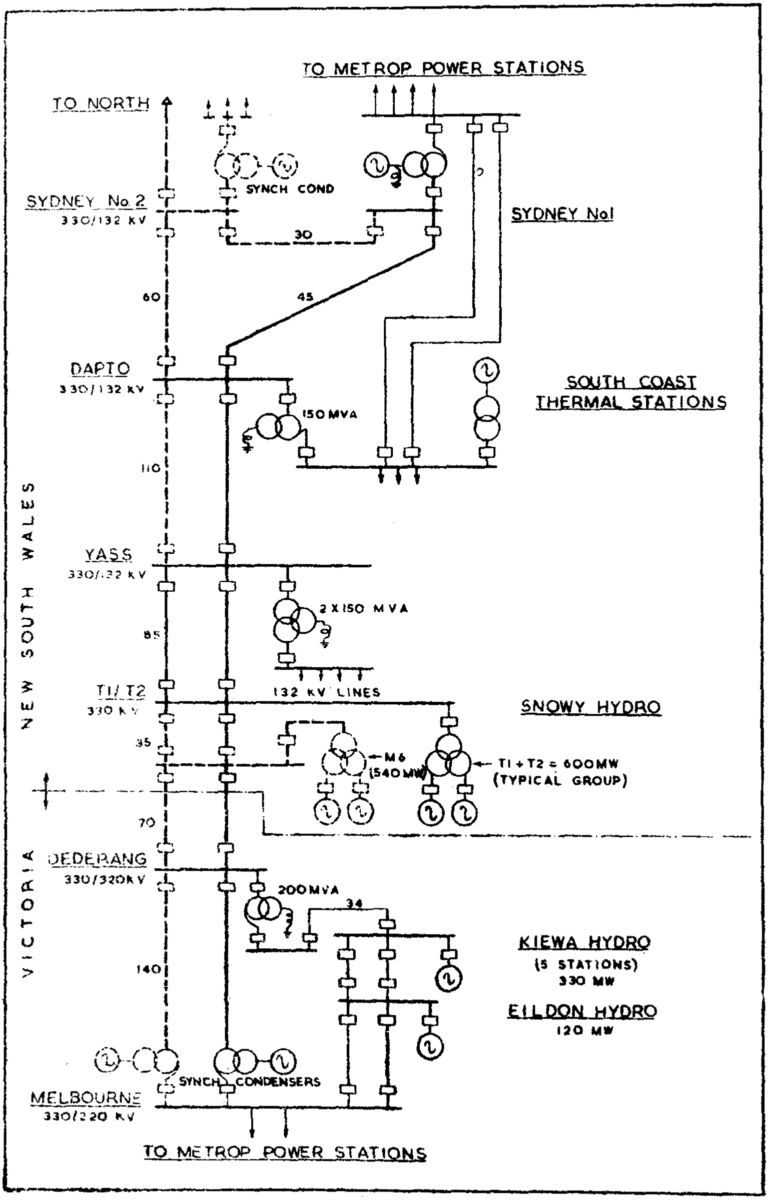

FIG. 2.—Schematic Diagram of 330 kV System about 1962.

in transmission capacity undesirable in view of prospective developments; the adoption of this voltage would also have diminished the chance of achieving a common voltage in the two adjoining States.

From enquiries made amongst representative manufacturers it was also found that the choice of 330 kV in preference to one of the voltages recommended by the I.E.C., would cause neither difficulties of manufacture of heavy equipment nor extra costs.

(*d*) **System layout.**—*Figure* 2 shows the layout of the system at the stage when T1 and T2 hydro-power stations are completed. As more hydro and steam stations are added the system will expand. The next stage of extensions corresponding to the addition of Station M6 of 540 MW is shown dotted.

It is thought that ultimately the Snowy Mountains area will be connected by four lines to the New South Wales system at Yass and by two lines to the Victorian system at Dederang. With the further extensions north of Sydney to connect the large steam power station developments on the northern coalfields, the total 330 kV line length will ultimately be of the order of 1,500 miles.

It is expected that by 1959 the first links of this system will have been constructed, providing a direct connection between the two adjoining States and spanning a total distance of 500 miles (800 km) between main load centres. The generators of the Snowy Mountains hydro-electric stations will constitute a fixed voltage point and stabilizing centre midway; they can also be operated as synchronous condensers.

(*e*) **330 kV Transmission lines.**—Design studies confirmed the findings of other authorities that the use of double-circuit lines permits a saving over the cost of two single-circuit lines if identical design assumptions are made in respect to broken conductor conditions. Single-circuit lines were, however, preferred as they suit better the relatively slow development of the system and afford greater reliability and convenience of maintenance.

The single-circuit suspension tower shown in *figure* 3 (*a*) was designed as a "light" type for use on ice-free routes which comprise most of the total line length. This tower will withstand the breakage of both twin conductors of the centre phase. If, however, an outer phase should break, the crossarm would fail at a load that would ensure that the body of the tower would not be subjected to a greater load than that corresponding to a breakage of the centre phase. This design made the cost of two single-circuit lines approximately equal to the cost of one double-circuit line. For the double-circuit tower, it would have been undesirable to relax the design assumption of full breakage of any phase, considering the large amount of power carried by each tower and the disastrous consequences of a failure of both circuits.

For altitudes from 3,000 to 5,200 ft., where ice and streng wind are experienced, a single-circuit tower designed for full breakage of any phase will be used. Table 1 gives main data for both types:—

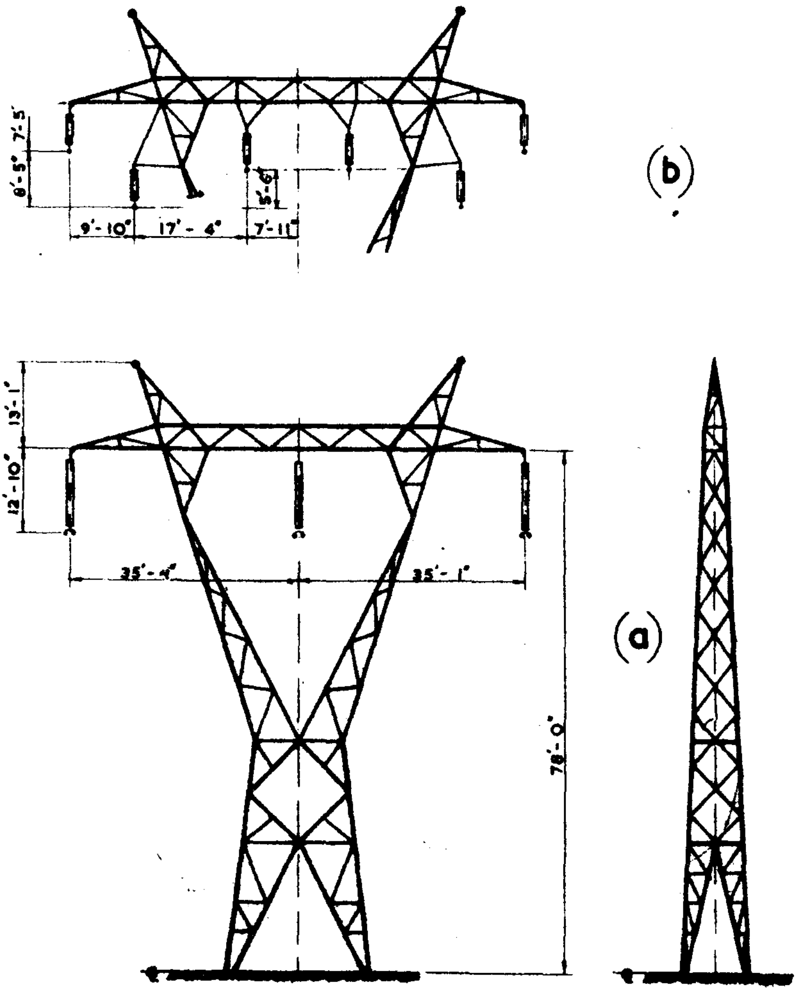

Fig. 3.—330 kV Suspension Tower (Low Altitude).
(a) As 330 kV single-circuit line.
(b) As 132 kV double-circuit line.

TABLE 1.

First 330 kV Circuit, T1/T2 to Dapto.

	"Light" Construction below 3,000 ft.	"Heavy" Construction 3,000 to 5,200 ft
Conductors	Twin bundles: 54/0.117 in. Aluminium and 7/0.117 in. Steel, diameter 1.053 in; bundle spacing 15 in.	
Earthwires	Two 7/0.144 in. steel	
Insulators, Cap and Pin	20 — 10 in. × 5 3/4 in.	22 — 10 in. × 5 3/4 in.
Phase spacing	35 ft.	37 ft.
Clearance to structure (Suspension tower):—		
at 30° swing angle	105 in.	115.5 in.
at 40° swing angle	84 in.	92.5 in.
at 60° swing angle	60 in.	66 in.
Normal span	1,270 ft.	1,180 ft.
Approx. weight of suspension tower.	5.3 tons	6.2 tons
Approx. weight of towers per mile.	25 tons	29.5 tons

The conductor cross section of 0.71 sq. in. (456 m²) equivalent copper was chosen from economic considerations. By dividing this section into twin conductors, the corona and radio-interference requirements will also be met and the use of a special design of conductor is avoided. Due to the generally mild Australian climate, "twisting" of bundle conductors and other difficulties experienced elsewhere need not be feared except perhaps on some short sections in the mountains. For very heavily loaded line sections, that may be required in the future, larger conductors than indicated above might be chosen.

Figure 3 shows the arrangement of the six conductors (*a*) for 330 kV use and (*b*) for temporary use as double circuit 132 kV lines. The line section Yass-Dapto (*fig.* 2) now under construction, will be operated for several years according to (*b*) and later converted to arrangement (*a*).

The lines from the Snowy Mountains to Victoria will have the same conductors as the lines to New South Wales. Their clearance to the structure are however under investigation with a view to reducing them below the values shown in Table 1. This should be feasible as the reliability of these lines need not be as great as those in New South Wales, particularly in the early stages.

(*f*) **T1 Power Station.**—This station will be the first of five stations on the Tumut River and is scheduled to energise the first 330 kV line section to Yass Substation at the end of 1958. The station will consist of four 110,500 H.P. high-head Francis turbines driving four 80 MW, 0.95 power factor, 12.5 kV, vertical-shaft generators at 375 r.p.m.

Generator electrical characteristics of interest will be: synchronous reactance (direct axis) 78 %, (quadrature axis) 43 %, transient reactance 24 %, sub-transient reactance 15 %, inertia constant 4.3 kWs per kVA.

The generator transient reactance and the transformer reactance were chosen somewhat below the values corresponding to lowest first cost; the gain in stability compensates for the extra expense. The inertia constant was however accepted as required from hydraulic considerations; any increase above this value for the purpose of improving stability proved uneconomical, mainly because of the associated increase in generator losses.

A single generator in T1 power station will be capable of energising any of the transmission line sections radiating from the switchyard (maximum length 100 miles) with hand regulation and positive excitation.

The generators will be equipped with high-speed "transductor"-type automatic voltage regulators which permit stable operation with negative excitation at greatly increased capacitive currents. This feature is desirable in certain abnormal operating conditions.

Seven single-phase step-up transformers, $12.5 \Big/ \frac{330}{\sqrt{3}}$ kV, 56 MVA will be installed in the underground power station. Each 168 MVA bank will be supplied by two generators which can be switched separately.

This arrangement was chosen with a view to (i) using the largest (and hence cheapest) transformers that can be transported over the mountain roads, and (ii) economising in 330 kV cable and switchgear. The station output will be brought to the surface by seven 330 kV cables, each 1,500 feet long, directly connected to each transformer through a cable box attached to the transformer bank. One of these transformer-cable combinations is intended as a spare, to be substituted when required, by means of simple links, for any of the other six units.

All 330 kV transformer neutrals will be solidly earthed. The transformers will be shell-type, water-cooled, with graded insulation; reactance 10 %; 50-cycle induced voltage test 575 kV; impulse withstand level 1,300 kV full wave, 1,500 kV chopped wave. Their transport weight will be 90 tons without oil. Lightning arresters will be installed at the junction of cable terminations and overhead lines. Their characteristic data determine the cable and transformer insulation level. Shunt reactors have been kept out of the power station to simplify the main power circuits; they will be installed in substations and connected to transformer tertiaries.

(*g*) **T2 Power Station.**—T2 Power Station (projected for commissioning in 1962) will be situated about 6 miles downstream of T1; it will be laid out on similar lines to T1 but the four generators will be rated 70 MW each.

(*h*) **T1/T2 Switchyard.**—Because of the difficult terrain, both power stations will be connected by extended transformer "leads", about 3 miles long, to a common 330 kV switchyard at 4,500 ft. elevation. At the time of writing, switchgear had not yet been ordered. It is proposed that 10,000 MVA circuit breakers, with 3 to 4 cycles switching time will be used.

The impulse insulation level is expected to be about 1,450 kV to allow for altitude effect.

(*i*) **Yass Substation.**—This substation, 90 miles from T1/T2 switchyard, will be the first of the New South Wales 330 kV substations to be commissioned. It will initially be brought into service to feed the output of T1 power station into the south-western 132 kV network. The surplus of power in this area will flow over three 132 kV lines (including two formed by the Yass-Dapto 330 kV line operating as a double-circuit 132 kV line) to the industrial area on the South Coast near Dapto and thence to Sydney. Due to the low capacity factor of the Snowy Mountains stations, this surplus will only be available during the heavy loading period each day; at other times a reversal of power flow is necessary to feed the south west area from the South Coast steam power stations.

When T2 power station is brought into service, the three 132 kV lines between Yass and Dapto will be inadequate to transmit the south-west surplus to Sydney; then the double-circuit 132 kV line will be converted to 330 kV operation. At that time, the Yass Substation will act as a step-down substation for power flow into the south western 132 kV system from both T1/T2 and the South Coast power stations.

Initially two transformer banks will be installed consisting of six single-phase three-winding transformers, plus one spare,

$$\frac{\dfrac{330}{\sqrt{3}}}{\dfrac{\dfrac{138{,}6}{\sqrt{3}}}{11.55}}$$

kV, with on-load tap changer (plus minus 12 %); single-phase rating 54/50/20 MVA; basic insulation levels 1,300/650/110 kV.

The 330 kV windings will have solidly earthed neutral and graded insulation, the 132 kV windings will supply a Petersen coil protected system and have full insulation, whilst the delta-connected tertiary winding will serve to connect shunt reactors for the compensation of line charging current.

(*j*) **Dapto Substation.**—This substation is required to step-up the surplus output of the South Coast steam power stations for transmission at 330 kV to Yass Substation at times when T1 and T2 power stations are not running and for transmission to Sydney at other times.

The substation will consist of a single 330/132 kV, 150 MVA, auto-transformer bank with delta tertiary for the connection of reactive plant. There will be no need to increase the capacity of this substation until a second major power station is built on the coalfields south of Sydney. Such a station would be required to export the whole of its output, and would step-up direct to 330 kV.

(*k*) **Dederang Switching Station.**—This substation will serve to interconnect the 330 kV lines Snowy to Melbourne with the 220 kV transmission system from the Kiewa Hydro-Electric Scheme to Melbourne and in so doing will add to the stability of the 330 kV lines. Single-phase auto-transformers, 330/220 kV, with an ultimate total capacity of 400 MVA, are proposed.

(*l*) **Sydney Substations.**—The first Metropolitan 330 kV substation is required by the time the combined surplus from the southern power stations exceeds the capacity of three 132 kV lines between Dapto and Sydney (one line being a 330 kV line operating temporarily as a single 132 kV line). This substation, which is on the soutern fringe of the City, will initially consist of two 330/132 kV, 150 MVA, auto-transformer banks with delta tertiaries for the connection of reactive plant, and will feed into the Metropolitan 132 kV network, which has its neutral point solidly grounded.

Provision has been made in the plans for a 330 kV ring around Sydney with further substations on the western and northern outskirts receiving power from the major steam stations to be developed in the north.

(*m*) **Insulation Co-ordination.**—The basic insulation level chosen for the New South Wales 330 kV system is 1,300 kV and is thus 10 % higher than for 330 kV systems in the U.S.A. During the initial period, which may be prolonged, there will be long single lines and low short-circuit MVA. Dynamic overvoltages can be expected to be high resulting in the necessity for lightning arresters with high reseal voltage. At the hydro-power stations, the cable connections between the arresters and transformers will cause surge voltages at the transformers to be up to 20 % greater than the discharge voltage of the arresters. It is expected that, as the system develops, a reduction of the B.I.L. will be permissible. The insulation level of the Victorian System is still being studied.

(*n*) **Single-Pole Automatic Reclosing.**—For an initial period, only single circuits will be in service between T1/T2 switchyard on the one hand and Yass and Dederang on the other. At a later stage, there may also be a single line only from Yass to Dapto for some years. The results of stability studies hold out the promise of a substantial reduction in outages by means of single-pole reclosing. Theoretical calculations of arc currents and residual voltages, corresponding to the line length of about 100 miles, gave values which, by comparison with published information, appear to be within the limits of self-extinction assuming "dead" times of approximately 25 cycles. Conditions seem therefore favourable and conducive to single-pole auto-reclosing, and it will mainly depend on the procurement of satisfactory relaying equipment whether this mode of operation will be successful.

3. THE PROJECTED 275 kV SYSTEM OF THE ELECTRICITY TRUST OF SOUTH AUSTRALIA

(*a*) **Power Developments.**—South Australia was until 1944 completely dependant for its electricity supply on power stations in Adelaide fuelled by black coal imported from N.S.W. but has, since the war, developed some sub-bituminous coal deposits in open-cut fields at Leigh Creek, 350 miles from Adelaide.

Because of lack of cooling water at the coal fields, this coal has to be railed 160 miles to Port Augusta power station which is located on the sea coast; from there power is transmitted over 190 miles at 132 kV to the capital and intermediate sub-stations. It is proposed to extend Port Augusta power station up to an ultimate output of 270 to 330 MW, the limit set by available coal reserves at Leigh Creek. The new section of the power station, which is scheduled to commence operation in 1959, is planned for three 60 MW-turbo-alternators with provision for a fourth 60 MW unit. It is regarded as a base load station of the first priority; its total output will be transmitted to Adelaide.

Any substantial extension of this isolated system is unlikely because of the paucity of conventional fuel and the complete absence of water power. Great hopes are entertained that nuclear power, based on the uranium deposits found in this State, will solve its power problems.

(*b*) **Selection of Transmission Voltage.**—From economic considerations the proposal to increase the transmitting capacity of the existing 132 kV system, so that it would be able to handle the combined output of both Port Augusta Power Stations, was discarded. The investigation of costs indicated that the voltages of 220 and 275 kV are economically comparable, with the annual charges slightly lower for the higher voltage. Owing to the better stability conditions in the 275 kV scheme, it has been possible to achieve certain savings in the overall cost of equipment of this scheme by the omission of an intermediate switching station and by permitting a relatively high value of synchronous reactance for the generators. As a consequence the capital cost of the 275 kV alternative will be practically equal to that of the 220 kV scheme for 270 MW of plant installed at Port Augusta. If a greater capacity should be installed, savings would result.

Apart from economic considerations, the higher transmitting ability of the 275 kV lines, compared to that of 220 kV lines is regarded as a valuable potential advantage. This voltage also appeared to be a most natural higher voltage step to the existing 132 kV level. The adoption of the 275 kV voltage in Great Britain for the National Supergrid and in Japan for the Shin-Hokuriku transmission system were also stimulating influences.

For all the above reasons, the 275 kV voltage has been decided upon for the new E.H.V. transmission lines despite the fact that there seems to be no likelihood of this voltage being used in any other part of Australia in the foreseeable future.

(*c*) **General Features of the 275 kV System.**—It is proposed to construct two single circuit lines, separated by as great a distance as practicable, with the object of minimising the possibility of simultaneous outages on both circuits during storms or lightning disturbances. One line will be able to carry the full load normally transmitted over the two circuits without departing from the usual sending and receiving end voltages.

Under normal operation the level of the sending end voltage will be varied with the load in such a manner that the minimum total losses in lines and in terminal equipment will be achieved.

The new lines will parallel the existing 132 kV system, which has the additional duty of distributing power to the intermediate country sub-stations.

It is proposed to interconnect the 132 and 275 kV busses at Port