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DEVELOPMENT OF THE HIGH VOLTAGE GRID SYSTEM IN THE UK, PRE-NATIONALISATION: Part 1.

by Andrew F Smith

Andrew first gave this subject as a talk via zoom to a limited membership, so it seemed appropriate for this to be circulated more generally as it is an important part of the nation's electricity history.

One of my favourite quotations is by George Santayana, Spanish philosopher and poet, 1863 – 1952:
"Those who cannot remember the past are condemned to repeat it."

The starting point for this subject can be hard to define, but the endpoint is fairly clear, although there could be some room for discussion as to when it occurred, namely:

- The introduction of the Electricity Bill on 29th December 1946,
- Royal Assent 13th August 1947,
- Followed closely, 15th August 1947, by the establishment of a Central Authority known as the British Electricity Authority (BEA) under the chairmanship of a notable ex-Trades Unionist, Lord Citrine, or
- Vesting Day of the 1st April 1948 for the BEA and the fourteen Area Electricity Boards.

Following nationalisation, responsibility for generation and main transmission came under the BEA from 15th August, 1947. As our topic is the HV grid system pre-nationalisation, I suggest this should be the end point. The initial developments in generation and distribution were, of course, also relevant to the establishment of an HV Grid System, being the reference points or foundations. There were other considerations as well, the practical in that there is no point in a grid system if it is not under-pinned by a reliable generation base, the technology available, and the political, which probably revolved about the perceived need, its cost, its structure, and probably principally what the voters would accept or want.

A chronological approach will be taken, as far as possible, but there will inevitably be deviations. Reciprocating steam engines were the principal prime movers for generators, with some use of hydro power, before Charles Parsons created the first steam turbine in 1884. This was followed closely by his creation of the first turbo-generator in the world, producing a Direct Current (DC) output.

By 1900 the world's first 3-phase turbo-alternator was developed by Parsons followed by the first public 3-phase Alternating Current (AC) supply, in Newcastle, closely followed by London. In 1902 Parsons introduced the rotating field concept having had some problems with his first design which had a rotating armature. The rotating field became adopted universally and is still used. In 1910, Sebastian Ferranti, in his Presidential Address to the Institution of Electrical Engineers (IEE), advocated full-scale national electrification to conserve coal. Apparently he proposed that this would be economical if stations were of a uniform plant size and rating achieving a 25% thermal efficiency at 60% load factor.

Subsequently the following committees were set up (and their recommendations):

- 1916, Viscount Haldane: Reorganise generation and transmission by regions.
- !916, Sir Charles Parsons, Electrical Trades Committee (Board of Trade).
- 1917, Sir Archibald Williamson: Generation & transmission to be publicly owned. (Board of Trade.)
- 1918, Sir Charles Parsons 1916 Committee produced what sounded like a scathing report on the mismanagement of electricity supply through earlier legislation. It recommended a "new and independent Board of Commissioners free from political control and untrammelled by past traditions". (Board of Trade initiative.)
- 1919, Sir Henry Birchenough: Recommended that "Generation & transmission should be a single unified system with state regulation and finance." (Ministry of Reconstruction initiative.)

The subsequent legislation, the 1919 Electricity Supply Act, established the Electricity Commissioners, also recommended by Haldane, to provide central co-ordination on a regional basis. They had no compulsory powers, so they had no real teeth. This was a distinct disadvantage especially when dealing with the larger supply companies who naturally would tend to want to maintain their sovereignty.

In the meantime distribution to the consumer was developing as a patchwork of systems differing in respect of size, both geographically and electrically, frequency employed or none at all in the case of DC, generation and distribution voltages, and ownership, principally Local Authorities or private companies. To a very limited degree it had already been realised at a local level that there were benefits in terms of capital expenditure if there was a certain amount of interconnection, but still at distribution voltages.

In 1920 the Electricity Commissioners issued Regulations, under extra high voltage, a)"for Securing the Safety of the Public" and b) "Ensuring a proper and sufficient supply of electricity".

In 1921 the importance of developing hydro power was recognised by the committee under Sir John Snell, 80% of which related to Scotland. (Board of Trade).

It is clear that the Government was approaching the problem piecemeal. What was the relevance of Board of Trade's involvement? It was also responsible for the certification of Merchant Marine Officers and Engineers, for example.

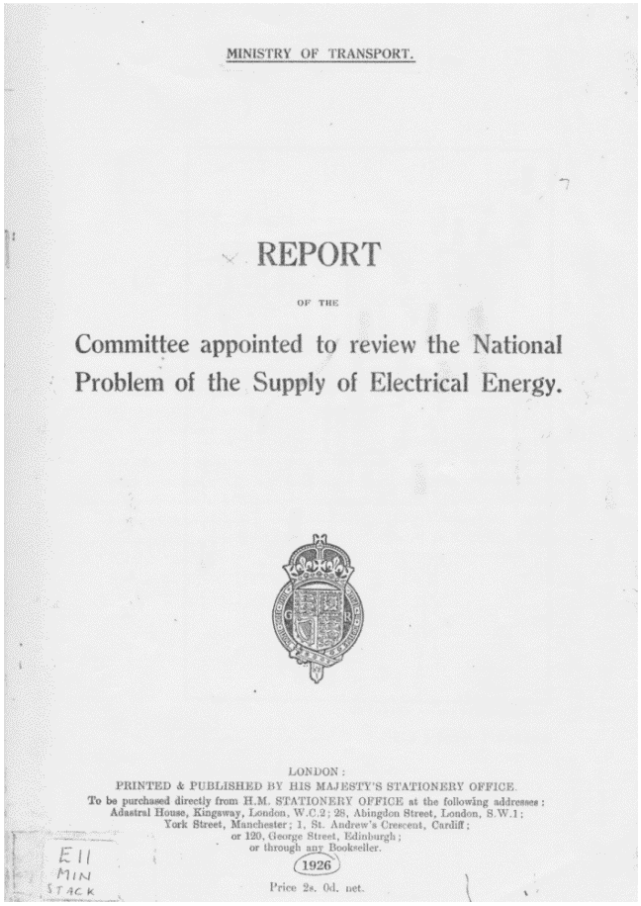
This impression was confirmed by the ambiguous outcome of the 1922 Electricity (Supply) Act, which allowed the creation of Joint Electricity Authorities which could not supply electricity in the area of a power company. So what was the point?

As an aside, early in 1925 the Prime Minister set up a Sub-Committee to consider a Severn Barrage, under Lieutenant-Colonel JTC Moore-Brabazon. Enough said.

The Ministry of Transport now got involved in 1925 and set up a Committee under Lord Weir. See Fig. 1 below.

The position in 1925 may be summarised as follows:

- 600 Authorised Undertakings (AUs), Local Authorities, Electricity Companies and Power Companies.
- 482 Generating stations owned by AUs + 103 others, eg railway companies, collieries etc.
- Plant installed: 3,096,535 kW.
- Maximum load: 1,844,000 kW.
- Total capital expenditure on generation & distribution & other £161,750,000.


MINISTRY OF TRANSPORT.

REPORT

OF THE

Committee appointed to review the National Problem of the Supply of Electrical Energy.

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1926

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Fig. 1: The 1926 Weir Report

This was a particularly clear and hard-hitting report, produced with a real sense of urgency. It was the principal instrument in bringing the Government to a realisation that a point had been reached when something actually had to be done, rather than just appoint another Committee.

The outcome was the Electricity (Supply) Act, 1926. Initially the layout of lines was described as a 'National Gridiron' of connections, but it rapidly just became the '(National) Grid'.

The principal aims may be summarised as follows:

- To concentrate generation in a limited number of "Selected" stations.
- To interconnect these stations by the erection of a high-tension main transmission system.
- To standardise the frequency of alternating current nationally in order:
- To establish effective interconnection.
- To purchase the output of the Selected Stations for sale to local undertakings.

The Act also created the Central Electricity Board, (CEB, or just 'the Board'), as a public corporation; the same principle as the BBC. After considering the situation, both nationally and internationally, the HV system voltage was established as 132,000

volts, now generally written as 132 kV and the whole system would operate as an alternating entity at a frequency of 50 cycles per second, 50 c/s, now 50 Hertz (50 Hz). Having an alternating voltage at a set frequency meant that changing from one voltage level to another could be achieved by 'transformers', which was not a simple option with a DC system. It also meant that as the Grid was originally intended to run as separate areas that as they were all running at a common frequency it would be possible to synchronise some or all of them if the need arose. In the early days there were doubts about the latter.

The following may give an idea of the potential scale of the problem:

There was this great variety of voltages and frequencies. Apparently by 1926 there were 17 different frequencies across the UK[1] (London alone having ten different frequencies), 50 different systems of supply, and 24 different voltages[2].

The Electricity Commissioners had an important role in the new scheme of things, as they were charged with determining how the UK should be divided into areas for the application of the Act. Having done this it was necessary to do the engineering and planning of the proposed system for each area, to produce the 'Scheme' for each 'Area'. They engaged eminent consulting engineering companies to help. Their involvement in establishing new sub-stations continued into the '60s, Kennedy & Donkin in the SW.

3. PROCEDURE UNDER THE ACT [3] "The method by which the policy embodied in the Act of 1926 is given effect to is briefly as follows:-

The Electricity Commissioners prepare and transmit to the Board Schemes relating to large areas, which together will ultimately cover the whole country. Each Scheme:-

(a) determines what generating stations (whether existing or new) shall be the 'selected stations' at which electricity shall be generated for the purposes of the Board;

(b) provides for the interconnection by means of main transmission lines to be constructed or acquired by the Board of the selected stations with one another and with the systems of authorised undertakers in the area of the Scheme and with the system of the Board in adjoining areas;

(c) provides for such standardisation of frequency as may be essential to the carrying out of the proposals for interconnection, and

(d) enables or requires temporary arrangements to be made by which the Board can obtain supplies of electricity during the carrying out of the works specified in the Scheme.

The Board are required to publish each Scheme as received from the Commissioners and to give not less than one month's notice of a date by which authorised undertakers and other persons interested- may make representations thereon. After considering the Scheme and the representations and after holding such inquiries (if any) as they think fit, the Board may adopt the Scheme with or without modification and must publish each Scheme as so adopted by them.

As soon as a Scheme is adopted and published it becomes the duty of the Board to carry it into effect subject (in certain circumstances-) to the right (exerciseable [*sic*] during the following month) of any authorised undertakers to have referred to arbitration any obligations imposed on them by the scheme which they regard as prejudicial to them.

The execution of each Scheme necessitates the construction or acquisition by the Board of the main transmission lines (including the transformers and switchgear) specified in the Scheme and the making of arrangements with the owners of the 'selected stations' for the operation and, where required, the extension of their stations so as to generate as from such date as may be fixed by the Board such quantity of electricity at such rates of output and at such times as the Board may direct. By the Act the owners of the selected stations are under an obligation to sell to the Board all the electricity so generated and the Board are under an obligation to supply to the owners of the selected stations and to other undertakers within the area of the Scheme either directly or indirectly all the electricity which they require for their undertaking on the basis of price prescribed by the Act."

The above clearly defines the role of the Board in the implementation of the Scheme.

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[1] : Cochrane, R, *Power to the People*, 1985

[2] : Wikipedia: *Utility Frequencies*

[3] : *CEB First Annual Report, 1928*, (1929

[To detail UK changes everywhere would be onerous and beyond the scope of a Supplement.]

Therefore the Scheme for South West England and South Wales will be used as an example of what had to be done across the UK. It was adopted on 23rd May, and published on 3rd June, 1930.

In the course of eleven close typed, approximately A5 pages, including the cover, paragraph headings on the pages 2 - 4 addressed the 'Area of the Scheme', 'Selected Stations', 'Main Transmission Lines', 'Standardisation of Frequency', 'Temporary Arrangements', and 'Miscellaneous'.

Pages 5 and 6 covered the 'FIRST APPENDIX, PART I, Description of Area'. This covered all the Administrative Counties giving, where appropriate, the Cities, Boroughs, Urban and Rural Districts and the Parishes. 'PART II. Map.' The map was a folded, un-paginated sheet showing the Area. Fig. 2 below.

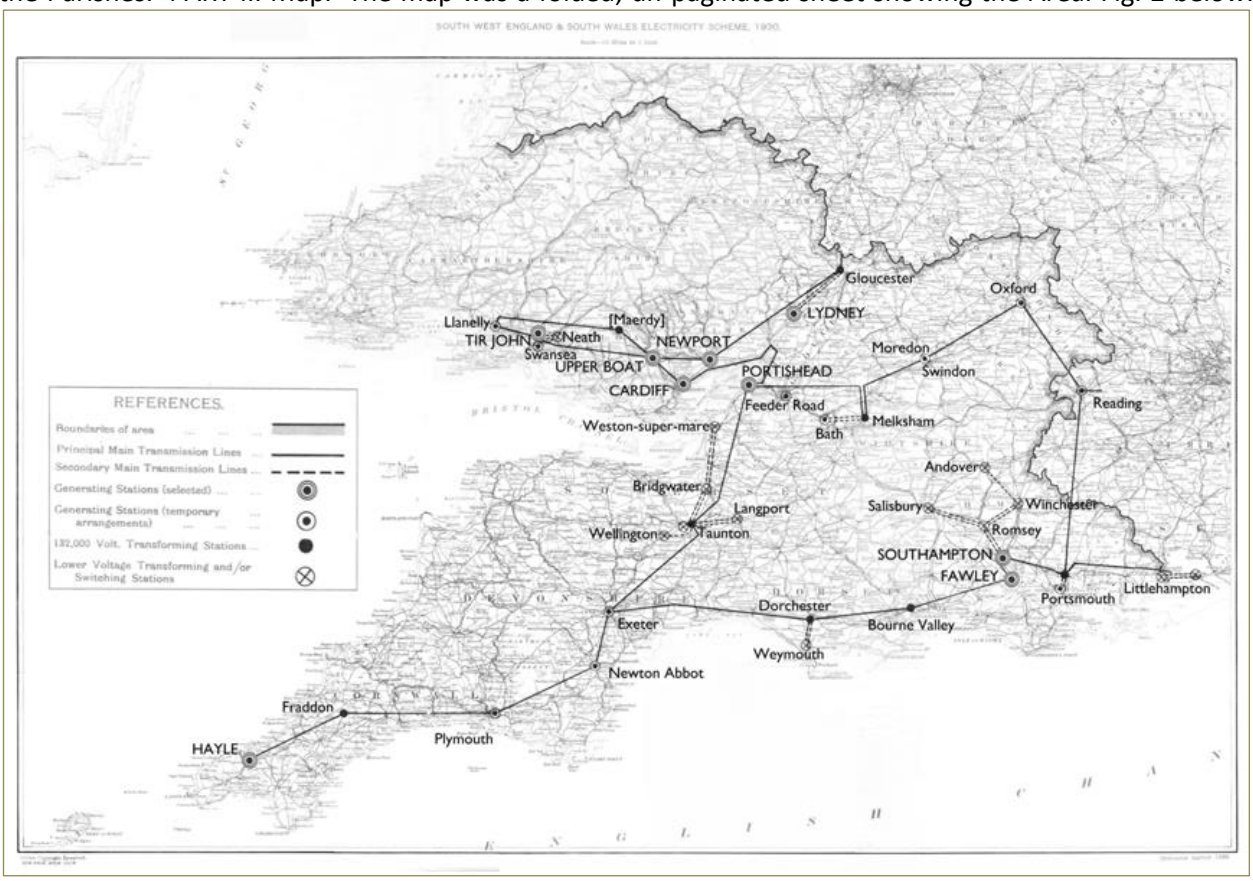

Fig. 2: 1930 Scheme Map.

Page 7 covered the 'SECOND APPENDIX, Selected Stations and New Selected stations,' seven off and two off respectively, with ownerships. On pages 8 & 9, the THIRD APPENDIX detailed the Principal Main and secondary transmission lines and associated transforming stations, 22 for the former and 14 for the latter.

The FOURTH APPENDIX on page 10 listed the twenty councils and companies which would be affected by the frequency change from 25 c/s to 50 c/s. The FIFTH APPENDIX in page 11 listed the seventeen generating stations, and their owners, which would come under 'Temporary Arrangements'.

In giving this detail, the original of which is from the WPEHS library, but still has to be referenced therein, it has meant departing from the declared aim of progressing chronologically.

To resume, in March 1927 Sir Andrew Duncan was appointed as Chairman of the CEB, with its HQ in London, with the first Scheme issued in June of the same year.

It will be clear that a great deal of work had to be accomplished in a relatively short time. This had to include all the necessary negotiations with many Authorised Undertakings as far as operating arrangements and frequency changes were concerned, but there was also the negotiating of all the required wayleaves for the overhead lines and substations.

[AU s were described as 'Undertakings', as under the earlier legislation by which they were established, they undertook to provide a supply of electricity in their given areas.]

Fig. 3: The complete scheme, excluding the North of Scotland, as proposed in 1928, amended to show Areas and their order of adoption. (From the First Annual Report of the CEB to December 1928.)

My father, A Smith, was one of the first employees of the CEB in 1927, being interviewed by the Chairman, Sir Andrew Duncan, and the Chief Engineer and Manager, Archibald Page [1929: Sir Archibald Page], in a Glasgow hotel, for the position of draughtsman. At that time the Glasgow office had not yet been acquired, as he had a story involving the search for a suitable building with his manager.

The Central Scotland Scheme (1) was adopted on 29th June 1927; Schemes 2, 3 & 4 progressively through 1928, 5 in March 1929, 6 in January 1930, 7 on 23rd May 1930, 8 in July 1930 and 9 in July 1931.

Reference back to Fig. 2, from 1930, above, will show that in the case of South West England and South Wales there was already a considerable number of differences from the first proposal shown in Fig.3, dated 1928.

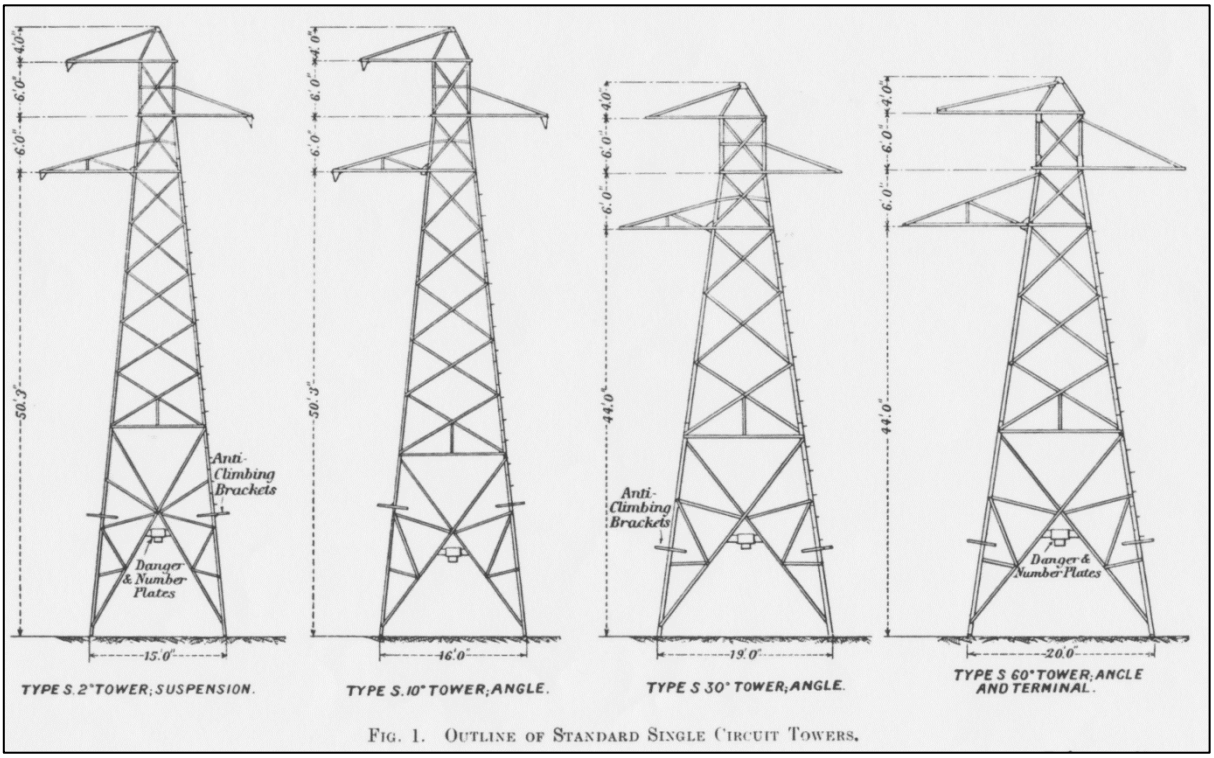

FIG. 1. OUTLINE OF STANDARD SINGLE CIRCUIT TOWERS.

Fig. 4: Outline of Standard Single Circuit Towers.

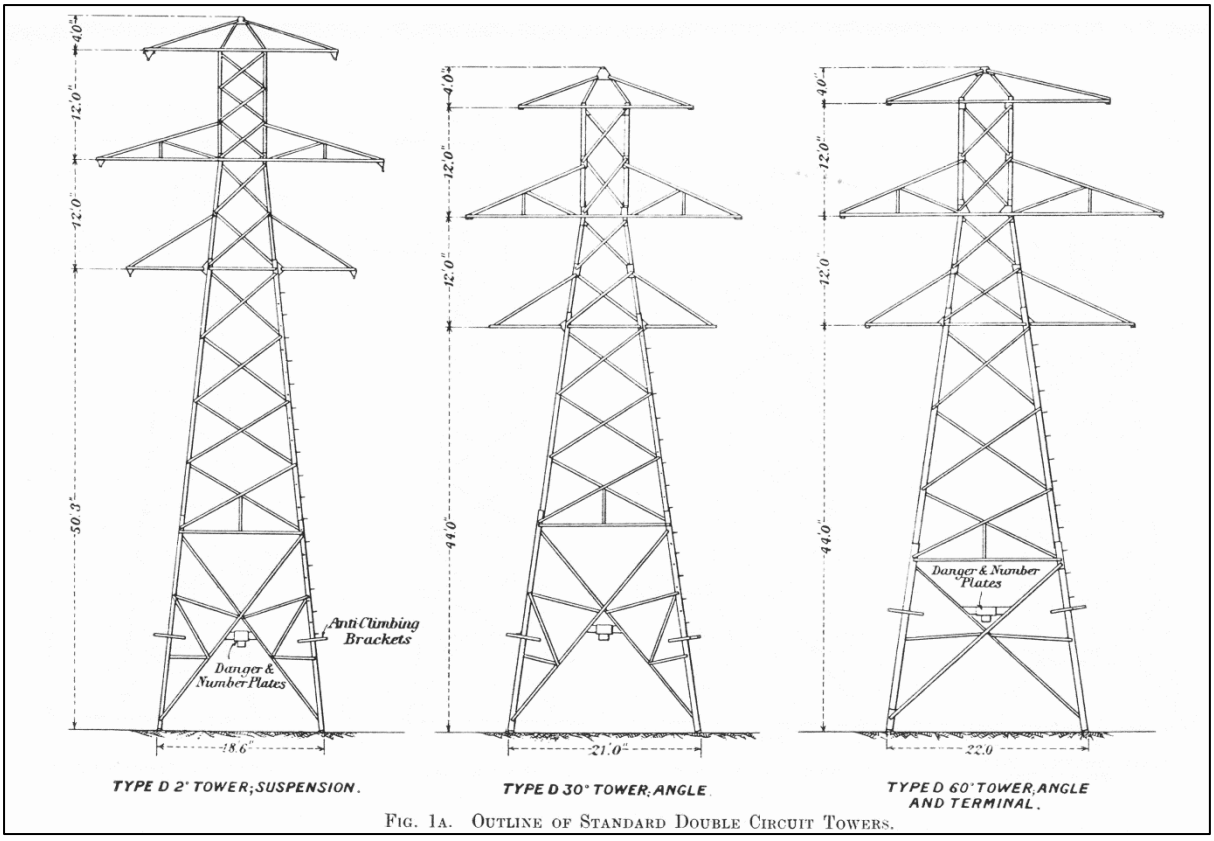

FIG. 1A. OUTLINE OF STANDARD DOUBLE CIRCUIT TOWERS.

Fig. 5: Outline of Standard Double Circuit Towers. [Figs 4 and 5 from CEB 1st Annual Report to December 1928]

Designed by Sir Reginald Blomfield R.A., in consultation with the Board.

Transposition towers were also considered, but it seems that it was in response to concerns from the Postmaster General with respect to possible interference with telephone/telegraphy circuits, rather than balancing system losses. There was one near Hallen, north-west of Bristol but it was quickly rewired straight[4] through when it was realised that neither exigency applied to the relatively short lines in UK practice.

The South West England and South Wales Area was geographically the second largest to the North of Scotland (never included as a Scheme), and greater than the sum of the next two largest Areas.

[4] : A Smith, *pers. comm.* 1962

1st Grid tower erected near Edinburgh, 14th July 1928.

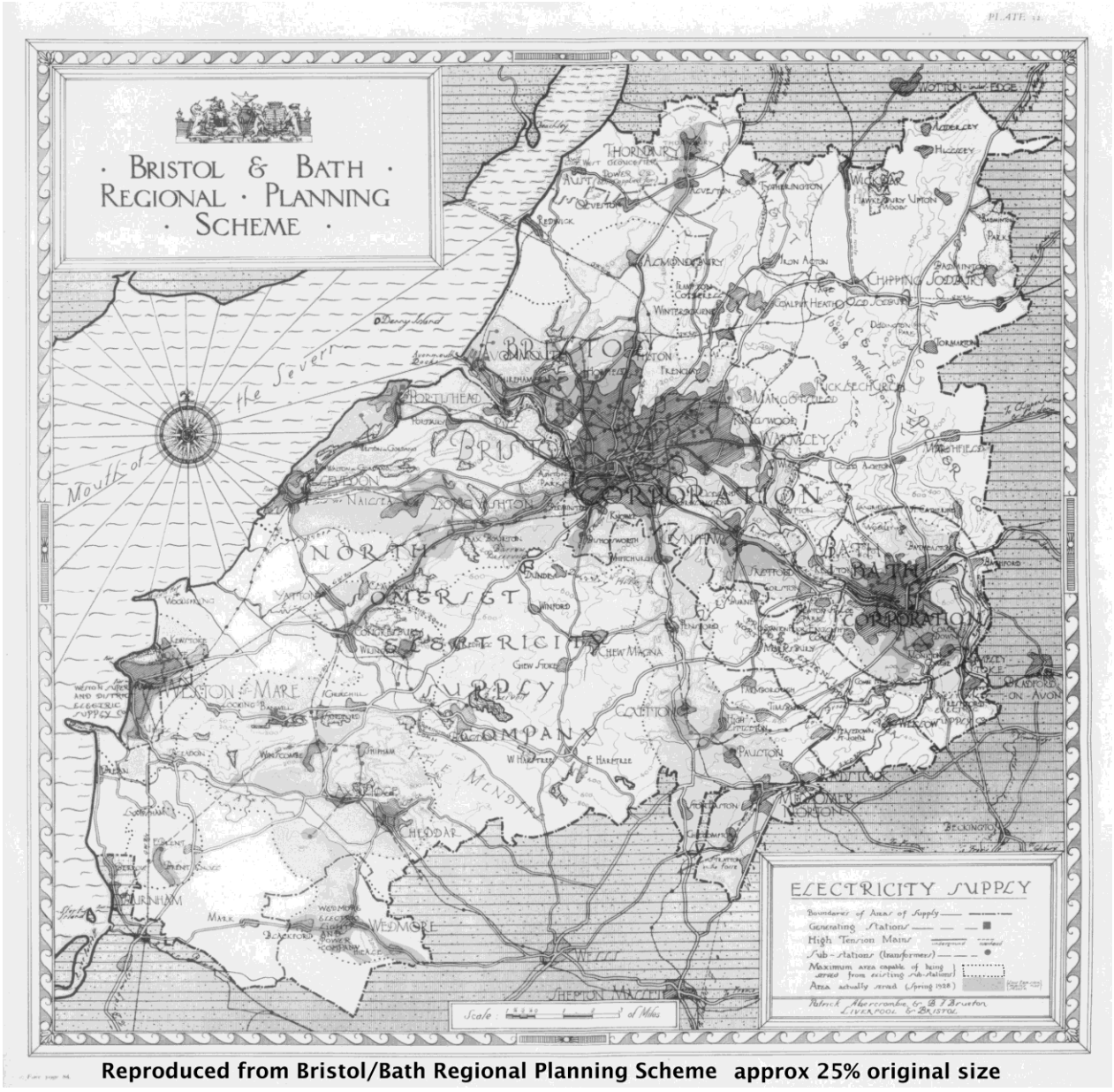

Fig. 6: Electricity Supply in 1928 Bristol – Bath area. From a comprehensive Planning Report by Abercrombie and Brueton.

Fig. 6 is an example of the extent of distribution systems in 1928. There is no 132 kV system present.

The Scheme map for South West England and South Wales, included in the CEB 1929 Second Annual Report, still showed Taunton as a node on the route from Portishead to Exeter. This was still the position in the 1930 Third Annual Report. It was only at the end of 1931 that the Fourth Annual report showed that Bridgwater Main had superseded Taunton as the nodal point. No reason has been found, but it may have been as a result of on-site conditions in the vicinity of Taunton proving unsuitable or inadequate, as there was a number of lower voltage circuits in the Scheme to feed out.

There were several other adjustments to the Scheme in both parts of the Area, but while this was one of the more significant for our ex –SWEB members, there were certainly others in what eventually became SWaEB (South Wales Electricity Board) and MEB (Midlands Electricity Board) areas.

These are considered difficult to appreciate if the maps are reproduced at too small a scale.

One which did strike as odd was the persistence of the Portishead – Uskmouth route crossing the Severn in the vicinity of Aust when its final position was to cross at Arlingham, some 18 miles north. This was only corrected in 1932, the same year as the high crossing towers at Arlingham, Avonmouth, Portishead and Uskmouth were built. These were all part of a single contract and stood just over 300 feet high.

In 1929 Portishead ('A') was commissioned. Owned by Bristol Corporation it was to be one of the larger new Selected Stations to be connected in due course. I do not have any details of the cause, but by Christmas 1930 it had suffered a fairly major fire. Also 1929: only 4% rural homes connected to a supply.

30th April 1930:-Inauguration of the first Grid Scheme. The Minister for Transport, Herbert Morrison, closed a switch to energise a 132 kV line from Portobello power station, near Edinburgh. Until then there had not been a High Voltage Grid System in the UK.

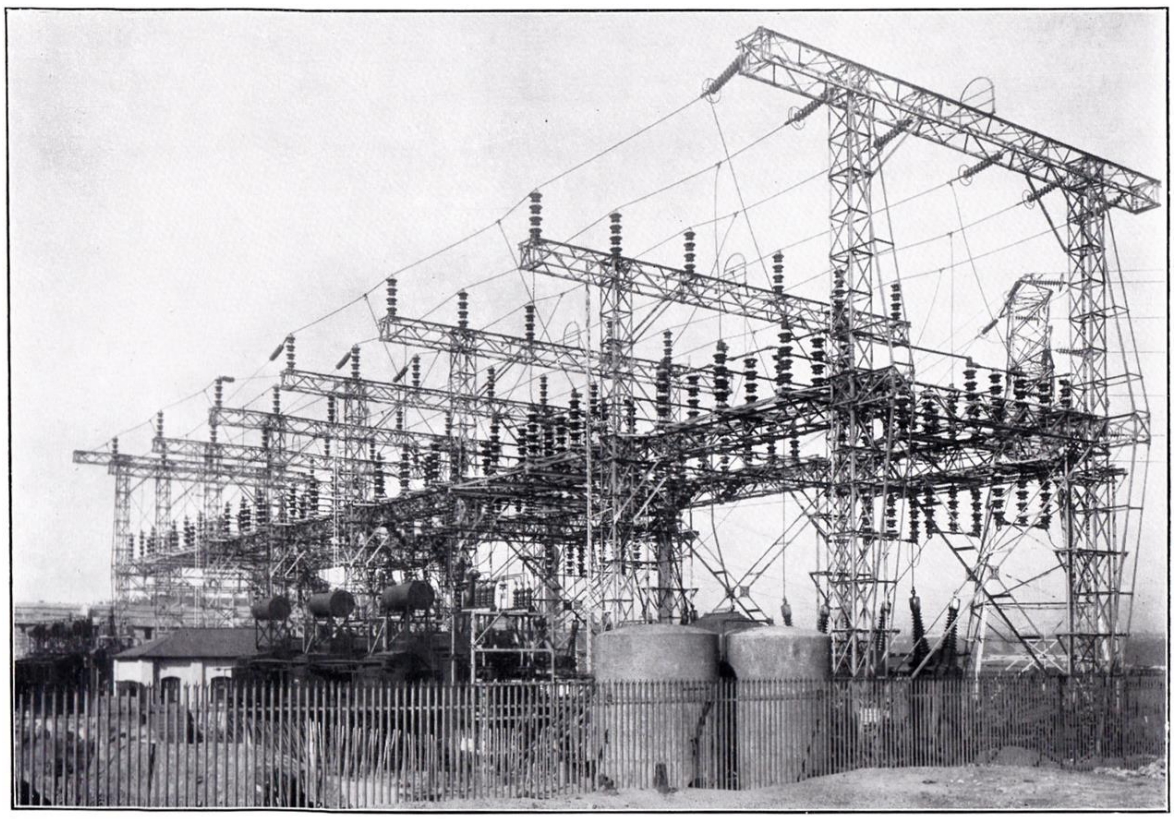

Fig. 7: Dalmarnock Transforming Station, [south-east Glasgow, on the Clyde] (Captioned as such in 1929 Annual Report, Fig. 18), but clearly an example of a High Double Busbar substation.

On 23rd May1930 the South West England and South Wales Scheme was adopted by the Board, so presumably the Area Office must have been established about that time. When my father came to Bristol to take up the position of 'Chief Draughtsman' on August Bank Holiday Monday (4th August), 1930 "the office was above an estate agent's in Queen's Road"[5]. It would seem to have been a very temporary measure as the Kelly's Directory for 1930 has no entry for the CEB. It does state that Lalonde Parham and Brothers, Estate Agents, were then at Number 64, Queen's Road. However the 1931 edition gives Oakfield House, Oakfield Road, Clifton as the CEB address. It had previously belonged to the Maggs family, home furnishers, and Frank Jones, one of their staff, came with the building. It was very quickly renamed "Grid House", in line with those in the rest of the UK.

Up until 1930, initially pilot-wire protections were favoured, having proved stable at lower voltages, but over the longer distances of the Grid, pilots were going to become expensive. Distance protection was being developed but, surprisingly, the voltage element was derived from supplementary lower voltage lines feeding substation auxiliaries. In 1930 voltage transformers were developed to take the relay supply direct from the 132 kV grid, which made discrimination much more effective.

Conductors were generally ACSR, ('Aluminium Conductors, Steel Reinforced') with two standard sizes. Each had seven steel cores. 0.110 inches in diameter; the standard earth-wire had twelve strands of aluminium, 0.110 inches in diameter so known as 19/.110 ACSR, internationally known as 'Horse'. The first standard current-carrying conductor was 37/.110, again 7 steel but with 30 aluminium strands in two layers, known as 'Lynx' (0.175 ins^2 Copper equivalent). 'Zebra' came later, still with seven steel cores, but 54 aluminium strands, all strands 0.110 inches in diameter, so 61/.110, (0.4 ins^2 Copper equivalent).

By 1931 conductors were being laid up using preformed aluminium strands, as it was thought that they would lie more evenly and closer, so having a higher resistance to corrosion between the two metals. There was also an experiment with sector shaped aluminium strands to have the same effect and at the same time give a smooth profile, but this did not seem to be widely implemented. Eventually inter-strand greasing would be required but not within the scope of this review.

[To be continued.]

[5] : A Smith, *pers. comm.*