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DEVELOPMENT OF THE HIGH VOLTAGE GRID SYSTEM IN THE UK, PRE-NATIONALISATION: Part 2.

by Andrew F Smith

Andrew first gave this subject as a talk via zoom to a limited membership. It seemed appropriate for this to be circulated more generally as an important part of the nation's electricity history. Part1, S79, December, 2021, dealt largely with creating the Central Electricity Board (CEB) and the South West England and South Wales Area, and briefly protection and line conductors.

Circuit breakers would all appear to have been bulk oil at 132 kV and, together with transformers, would not have appeared to be too different externally from maybe 30 years later, but improvements were being steadily made to deal with the question of arc-quenching and improving the fault-breaking capacity with faster operating times.

CEB SOUTH WEST ENGLAND AND SOUTH WALES AREA - 1931

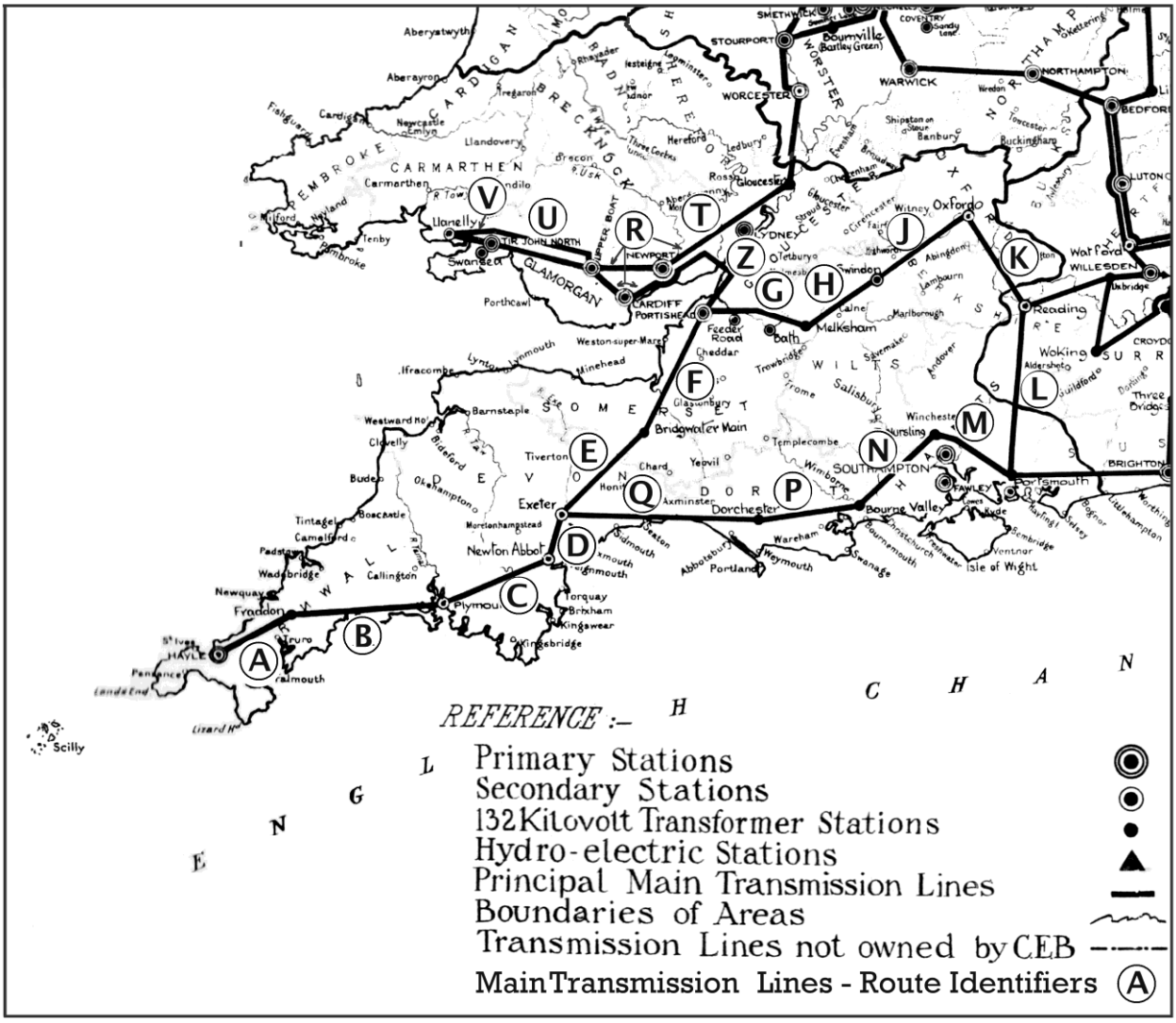


Fig. 8: Extract from Map No. 1, Fourth Annual Report, 1931, with 1939 route designations added, Jan. 2020, AFS

[Maerdy (S Wales) has already disappeared from the map, and Bridgwater Main has replaced Taunton.]

This would make a suitable point to again compress timescales and put down the completion dates as in in the Electricity Commissioners' Volume VIII, Tables XXXIV *et seq*.

Oct. 1931: Routes C, D, J, R, Z. Mar. '32: A, B, G, H. Oct. 1932: E, F, T, U, V, M, N, P, Q. Oct.1933: K, L. I am not sure how much reliance to place on these dates, but at present they are the only ones available. It is not clear whether these were planned or actual data, but a certain logic can be envisaged.

From the list above there was a slightly amusing story about 'P' route, which ran from Dorchester to Bourne Valley [became Bournemouth]. There were ['Lack of', to the staff] 'Progress Reports' to be submitted to CEB London HQ monthly. From Tolpuddle, of 'Martyrs' fame, the '*River Piddle or Trent*' [OS 'Landranger 194' Map] runs roughly south-east to Poole Harbour. One Report stated that "There is difficulty getting 'P' across the Piddle." This drew a smart rebuke from HQ that 'levity was not appropriate in Progress Reports'.

Single switch transforming stations had been used at lower voltages but were introduced for 132 kV working in 1931, particularly where the local load did not warrant extra expenditure. They were however built with room for future development in mind. The number of switches in the title refers to the number of circuit breakers on the HV side. See Fig. 9 below.

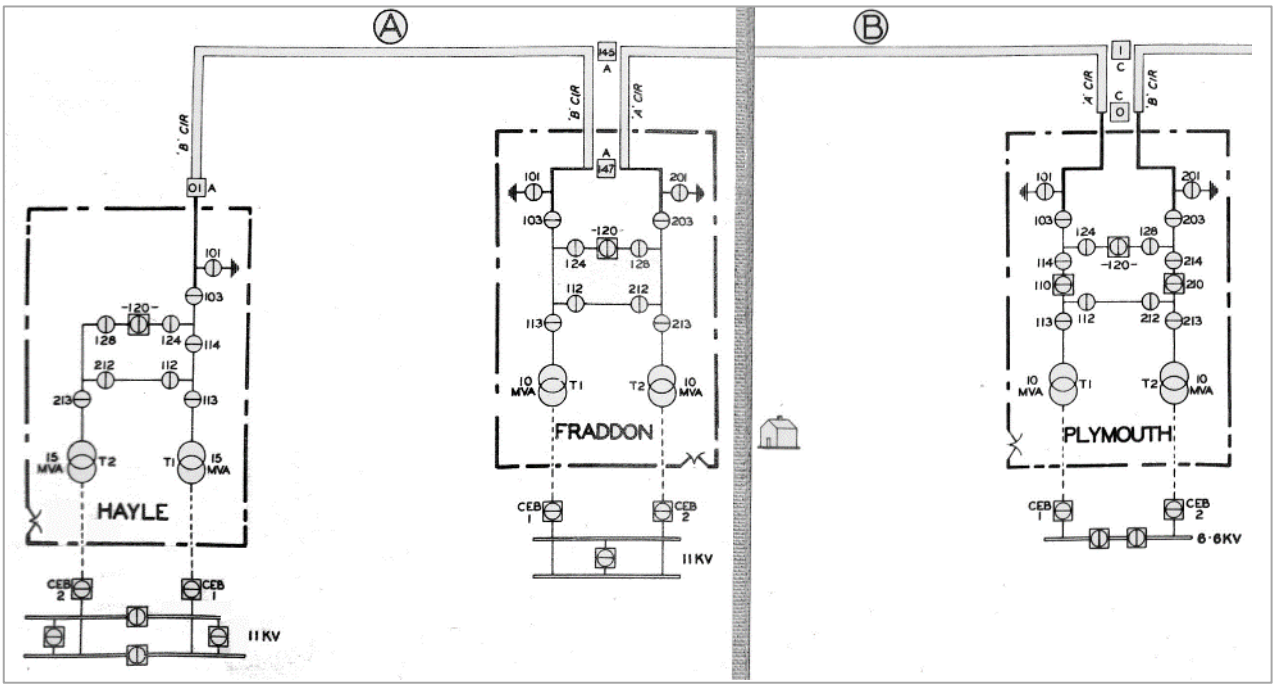


Fig. 9: Examples of Single-switch, Hayle and Fraddon, and 3-switch, Plymouth, transforming stations. Lower voltage circuit breaker designations 'CEB 1' & 'CEB 2' eventually became '1TO' and '2TO' respectively, probably after nationalisation. [SW England and S Wales 'Operation Diagram' Drg. No. 184, May 1939.]

1932: Estimated cost of constructing the Grid: £M26.7. Bedford – Little Barford circuit had carrier current interlock protection installed, which proved valuable and reliable.

Nationally another 1000 miles approximately of secondary circuits at 66 kV and below also became part of the overall scheme. Apparently this had not been envisaged by the Weir Committee, assuming that the work would have been done by supply authorities at their own cost. However it became clear to the Electricity Commissioners, and the Board agreed in due course, that building these additional lines would make sense of the new development, and increase the penetration of electrification to areas where it had not been available, with consequent economic development.

Equipment was being installed for Bristol Grid Control Centre (GCC) in the Oakfield Road extension. Father was asked to go to the District Manager's office to identify a drawing brought in by someone to whom he wasn't introduced. It was apparently a more up-to-date drawing for the new control room than they had in the Bristol Drawing Office, and it turned out that it had been found in the lodgings of an Irishman in Manchester, in whom Special Branch had an interest.[1]

This last paragraph draws attention to a somewhat confusing, in retrospect, use of nomenclature. In Part 1, Fig.3 showed the Areas into which the UK was divided for the purpose of implementing the National Scheme. The geographic description, e.g. 'Central Scotland' was applied to both the Area and the particular Scheme, but in the first three Annual Reports the head offices for each Area was described as the 'District Office', and the senior man was the 'District Engineer'. The latter had become the 'District Manager' by the Fourth Annual Report, but the use of 'District' as applied to the '[Area Head] Office' and the 'Manager' persisted certainly until 1947/8.

[1] A Smith, *pers. comm*.

The 1932 Annual Report states that the "South West England and South Wales Scheme provides for the construction of 605.7 miles of primary transmission lines … and 107.7 miles of secondary lines. By the end of the year all the wayleaves, with the exception of a few miles had been obtained…and 551.5 miles of primary line towers and 22.6 miles of secondary towers had been erected."

It also mentions the use of the 'low' type of station with reinforced concrete structures in view of the high amenity landscapes in the Area. As "the Selected Stations are relatively few … the Grid supply points spread over an extensive area, five of the primary transforming stations" are associated with lower voltage stations situated "approximately [at] the centres of load distribution for the secondary lines." As they are distant from Selected Stations there will be combined control rooms and associated cottages for the attendants. Fraddon is an example.

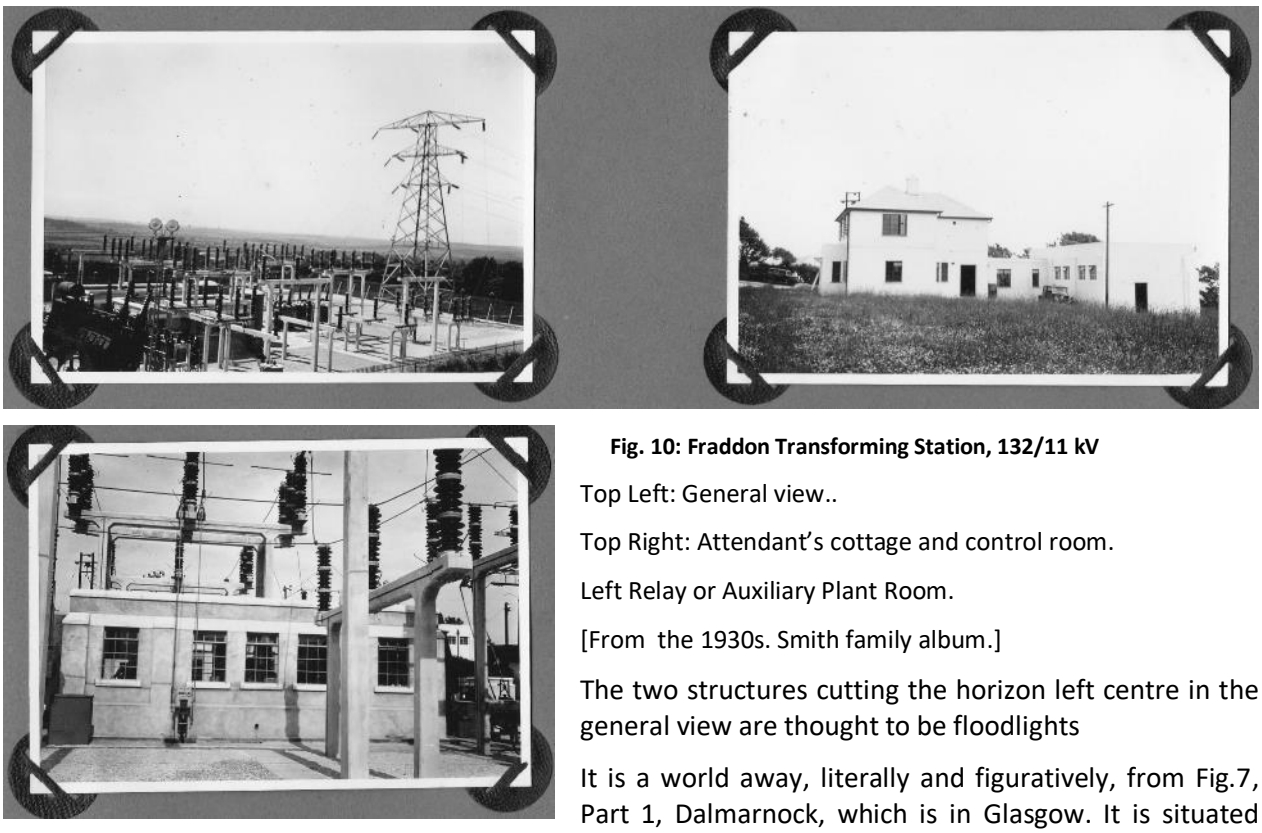


Fig. 10: Fraddon Transforming Station, 132/11 kV

Top Left: General view..

Top Right: Attendant's cottage and control room.

Left Relay or Auxiliary Plant Room.

[From the 1930s. Smith family album.]

The two structures cutting the horizon left centre in the general view are thought to be floodlights

It is a world away, literally and figuratively, from Fig.7, Part 1, Dalmarnock, which is in Glasgow. It is situated east of the city centre, directly north of the River Clyde.

The control rooms in Glasgow and Leeds went into service.

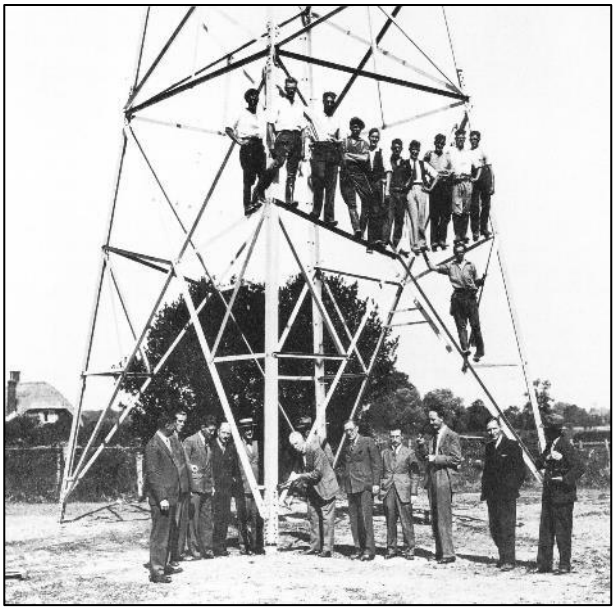
1933: Control rooms were completed in London, Birmingham, Manchester and Bristol. The latter was was marked out as different from those completed earlier where "the indicating equipment takes the conventional form used for operating panel of power swithboards, and the control engineer's desk is provided with a miniature [hand-dressed] diagram of the whole system in his area."

The difference for Bristol was that "the indicating equipment has been reduced to a more compact form and is mounted on the control engineers desk."[2]

Fig. 11: Bristol control room, 1932. [SWEHS 5.1.017.jpg]

[2] : CEB Sixth Annual Report, p 6, 1933

The other significant event for the whole system also occurred in the South West England and South Wales Area, namely the completion of the final tower of the original scheme.



This was on the Nursling – Bourne Valley (Bournemouth) route 'N' "at Breamore near Fordingbridge, on the outskirts of the New Forest, roughly five years after the erection of the first tower near Edinburgh." It is believed that might have been due to getting the "few miles of wayleaves" completed which, unspecified, were outstanding from the previous year's report.

Fig. 12: Final tower of the original Scheme,

Mr J W Beauchamp, District Manager, is symbolically tightening the last bolt. 5th September, 1933, the contractor's staff 'manning the yards'.

By 1935 the Grid was in full commercial operation, and further construction continued in response to rising demand.

In fact, by the end of 1935 the expansion in the output of electricity in Great Britain since 1929 had been 70% compared with a world figure of 20%. The Grid's transformer capacity had increased during the year by 453.1 MVA, and generation capacity was increased by 277 MW. "All 132 kV conductors had been fitted with vibration dampers to prevent weakening or breakage of the aluminium strands at suspension or tension clamps", presumably as a result of operational experience.

In May, 1936 the Report of the Committee on Electricity Distribution, set up by the Ministry of Transport, known as the McGowan Report, was published. It recommended that "The reorganisation of generation was an essential preliminary to any detailed investigation of the organisation of distribution … ." While it did not consider immediate action was necessary, its ultimate aim, within 50 years, should be the bringing of all undertakings within public ownership. [In fact, in the event it was just outside that period that the whole industry was privatised.] In addition it recorded that at the end of 1933-34 there were 643 undertakings with 13 declared AC voltages from 100 to 480 AC, & 12 DC over the same range.

Year	Units sold, millions	Consumers, as at year end
1920-21	3,512	-
1927-28	7,003	2,600,000
1933-34	11,467	6,109,000

Table 1: Progress, as reported.

There is a map of the South West England and South Wales Area dated 8/7/37 in the office at Cairns Road which is at variance at several points with the folding Operation Diagram of the Area, Drg. N$^{o.}$ 184, dated May 1939. It is difficult therefore to be categorical about the actual position. See Fig. 13, below.

Areas had been connected to a very limited extent to meet specific system requirements but the whole National Grid was first established unofficially overnight on Friday 29th October 1937, and it hung together. Officially: October 1938 was the first time the entire Grid was connected together, as the predicted winter load in the south would be greater than the installed capacity in the area.

This success meant that the full interconnection was retained and continued, thus creating the largest interconnected electrical Grid under one control in the world and this record held for many years to come. It would prove to be of immense benefit during the coming World War II, and it was recognised.

'Snail clamps' for line terminations were seen still in service on the Gloucester – Ebbw Vale route in the early 1970s, and those and the 'Pairard' mid-span joints were both mechanical in function, relying basically on friction. It has not been determined when compression joints came in to service. [These create a homogenous joint of both steel and aluminium, under something like a twenty-ton hydraulic compression pressure applied to two-part dies.]

Annual reports were now concentrating much more on the financial side rather than much of technical interest, but in 1938 the Upper Boat – Ebbw Vale double circuit 132 kV line was completed to feed a new Steel Works. This was the last year for which we have an Annual Report in our records. In that, it is recorded that the total cost of standardisation of frequency was a little over £M17. This would be recovered by the Board from the Electricity Commissioners, on a 40-year repayment basis, who in turn

recovered the costs via a levy on all the Authorised Undertakers on the revenue from the sales of electricity. A note in 'The Grid' identified this as 0.0075 pence per unit in 1946.

Fig. 13: The Grid in 1937, in "The Wonders of World Engineering", [Part 3, p.75, March 16, 1937.]

Fig. 13 agrees very closely with the situation in Drg. N$^{o.}$ 184, dated May 1939, mentioned above.

By the end of 1937 there was a new form of carrier current protection, which being a 'Unit' protection meant a very positive discrimination of faults. Oil circuit breakers with a higher speed of operation and a higher rupturing capacity were being installed at the new transformer station at Lydney and also at Littlebrook, Dartford, Kent.

The generation aspects have not really been considered, other than in passing. The main factors involved in the decision to designate a power station as 'Selected' were:

"(i) The cost of coal delivered to the station;

(ii) The abundance of water for condensing purposes;

(iii) Technical characteristics of the station such as type and size of the plant units, steam pressure, etc;

(iv) Proximity to load; and (v) The possibilities of the site for the further expansion of the station."

There were special agreements with the owners under which the Selected Stations were operated:
"To operate and, where required, extend their stations to generate to meet the Board's requirements for electricity.

Under the Act they shall sell to the Board all the electricity required.

The Board are obliged to supply them and other undertakers within the area of the Scheme either directly or indirectly all the electricity which they require at price prescribed by the Act."

'Selected Stations' included in the original 1930 Scheme: Cardiff, Portishead, Hayle, Lydney, Newport, Plymouth, Southampton, & Upper Boat.

By 31/12/1946, it had become the above-mentioned plus: Bath, Castle Meads*, Earley*, Exeter, Llanelly, Llynfi**, Moredon [Swindon], Newton Abbot, Portsmouth, Plymouth, Southampton, & Tir John North†.

*Wartime build, in service 1942, ** in service 1943, † with Fawley (1st 500 MW gen. 1969, eventually), as 'New' 1930 scheme selected stations, 60 to 240 MW, (Part 1, p.4.) In 1941 the Government withdrew approval of the CEB proposal for new generation in 1943 and 1944, "as not necessary to the war effort."

Mention of Llynfi reminds me of one of Father's experiences. An example of wartime conditions may be shown, as he had to attend a meeting held there during construction. Apparently they were invited to lunch in the contractor's canteen, and the steak he was served was so big that he could only manage half and brought the rest home in his handkerchief. It would seem that special provision was being made to feed the men doing an important and physical job, way beyond civilian ration-book quotas.

Some of these stations only became 'Selected' because the rise in demand was outstripping the build of new stations, and they were therefore required to be bound more closely to the Board operationally.

By 1938 the government was already taking steps to ensure that there was matériel in the form of spares for, and of, switchgear, transformers, etc, etc, located strategically round the country. Tucked out of the way off the Fosse Way was the 'Cirencester' stores, and at Newbridge Hill House, Bath, the fall-back alternative if Grid House in Bristol was put out of action, a number of cable drums were stored beneath the chestnut trees lining the back drive, and smaller overhead line fittings, insulators, etc. spares were stored in the stables. I know, because I used to watch the line gang loading them up. There was also a very satisfactory 'clunk' when a conker was poked into the axle hole of a cable drum.

Father's conviction that war was inevitable was such that he suggested the Bristol control room should have a steel structure erected in it carrying steel sheeting as a canopy to protect the control engineers from falling glass from the extensive overhead skylight, in the event of a near miss from a bomb. It would not have protected from a direct hit, and it became known as "Smith's Folly", but when war was finally declared in September 1939 it was the only control room in the CEB to have any sort of protection.

Fig. 14: Bristol Grid Control Room, 1945. [SWEHS 5.1.021.jpg]

The frieze of three rows of acoustic tiles were the outcome, much earlier in the life of the control room, when it was found that there was a risk of cross-talk between control engineers and field staff at the other ends. Father, having been told to find a solution, consulted the BBC and acoustic tiles were the result, which cured the problem. Note the much bigger diagram on the desk compared with that in Fig. 11, above.

Under '**Operation'** on p.13 of the eleventh CEB Annual Report for 1938, the latest to hand, "Interconnection through the Grid made it possible so to control the operation of the 171 generating stations under the direction of the Board that only 30 ran for the full year."

The following table shows the extent to which

generator operation was restricted:-

Number of Stations.	*Hours run.*
30	8,760 (full year)
21	Between 6,600 and 8,760
68	Between 2,400 and 6,600
43	Less than 2,400
9	None (shut down)
171	**Table 2: Density of 'Hours Run'.**

Fourteen of the most economical stations supplied 50% of the total units generated for the Board.

The Civil Defence Act was passed in July, 1939, ensuring provision for the care of employees, amongst other things, and this was probably why the main cellar at Newbridge Hill House was lined out with steel sheeting over RSJs, and brick blast walls were built outside high-level windows to the cellar. In the early stages a Home Guard Post was established in the corner of the property overlooking the road to Bristol, and in the event of invasion Father was under orders to destroy all documentation. We lived in largely what had been the service part of the house; the rest was given over to the Estates and Wayleaves staff offices. I can still recall the aroma of polished linoleum overlaid with that of cigarette and pipe tobacco.

To put some perspective on the sums of money to be quoted: the landlord had offered my parents the house they rented, a 1930's semi-detached in a nice part of Bristol, for £650, [present value = £630,000] but Father thought that was £25 too much. He was not prepared to invest in bricks and mortar when they could so easily be destroyed in the coming conflict.

'The Grid' p.14, states that while it is difficult to estimate the overall capital saving from the reduction of standby or reserve plant not needing replacement, "by the end of 1946 it was probably equal to the £40,000,000 capital expenditure on the construction of the Grid and its extensions and reinforcements to that date." If that is scaled up to match house prices we probably couldn't now afford it. It continues, "The second major economy resulting from the interconnection of generating stations through the grid is in the consumption of fuel … ." That, together with "the coming into operation of the more modern plant installed in the Selected Stations" … [means] "that, whereas in 1946 the average price per ton of fuel consumed at the generating stations operating under the Board's control was 194% above the 1932 level, the average cost of generation per unit sent out had increased by only some 23% while the average fuel consumption per unit sent out was 16% less than under the conditions of independent operation prevailing in 1932."

From 1941 onwards there were new connections in South West England and South Wales:- Gloucester – Ebbw Vale, Gloucester – Oxford, Oxford – Watford, Melksham - Andover, Andover – Nursling and Dorchester – Weymouth (33 kV). The materials were found because the majority of this work was to support the war effort directly; 500 miles in 1941 and 1942 alone. ['The Grid'].

It may well have been one of these when Father was picked up for questioning by security forces in the vicinity of the south coast. Presumably this was before the Normandy invasion, and somebody had reported a man with a map clearly reconnoitring the country. Apparently all signposts had been removed for miles back from the coast.

In 1943 the North of Scotland Hydro-Electric Board became vertically integrated covering generation, transmission and distribution in all areas outside those of existing undertakers.

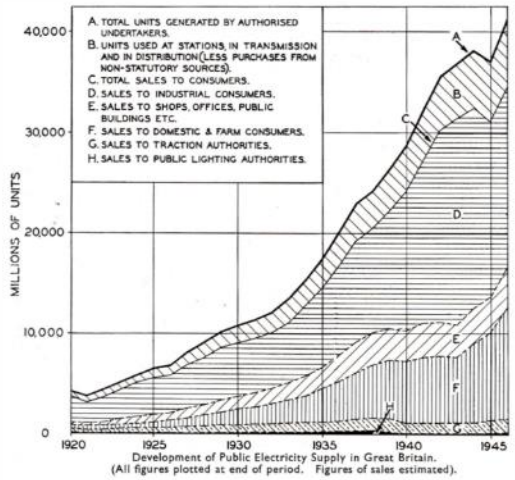


Fig. 15: Total Units v. Year

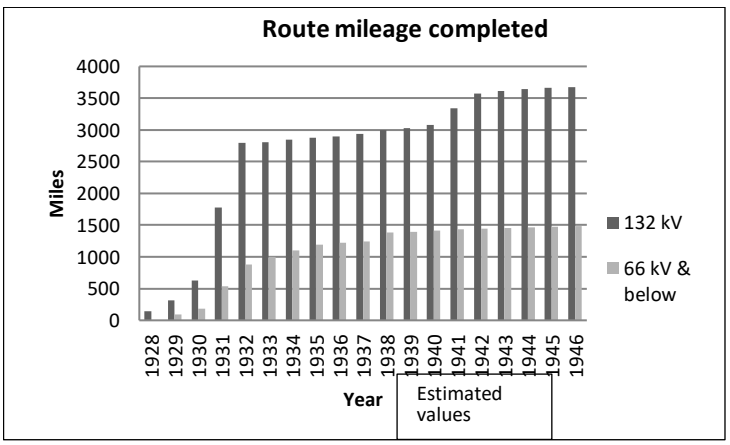


Fig. 16: Route mileage completed v. Year.

Also in 1943 the CEB was considering future development. To minimise delay in post-war construction preliminary consideration of use of voltages higher than 132 kV, e.g. 264 kV was undertaken.

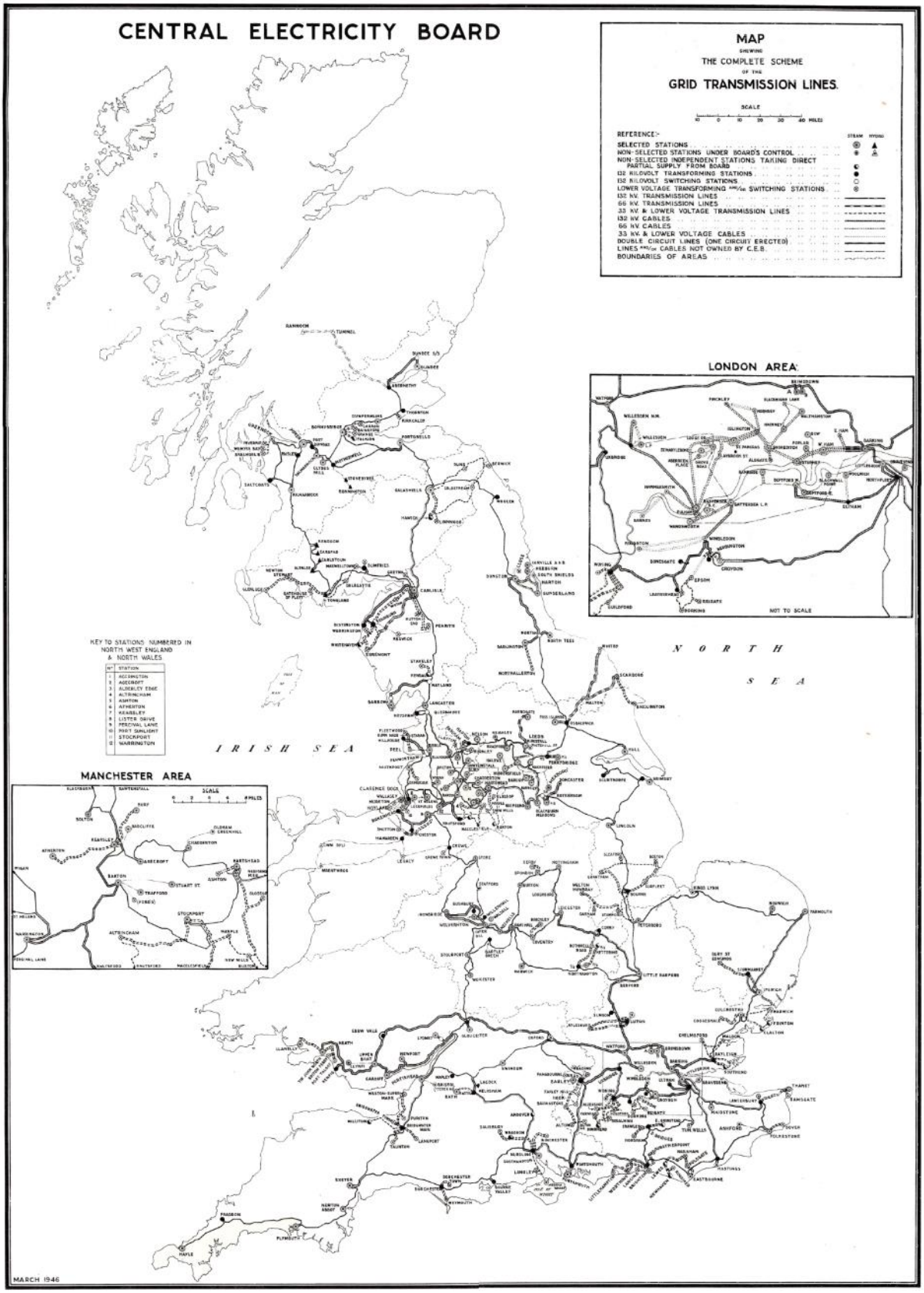


Fig. 17: The Grid at March 1946. ['The Grid']

The war took a considerable toll on the whole supply industry, both in terms of personnel (31st March 1939 – 122,237, 1st Jan.1944 - 91,695) and plant, much needing care beyond its normal life expectation.

This takes us to the end, envisaged at the start, with the establishment of the BEA on 15th August, 1947.

Not all references have footnotes, but data has been drawn from *CEB Annual Reports 1927 – 38*;'*The Grid*', a valedictory publication by the CEB, 1947; the Electricity Council '*Electricity Supply, in the United Kingdom, a Chronology'*1987, '*Power to the People*', Rob Cochrane, CEGB, 1985, and *'War Period Report of the Electricity Commissioners',* HMSO, 1946. Not all agree.