Stephen Browning - ESI History Mk X.

Googling Edison Holborn Viaduct and Ferranti Deptford finds all sorts of useful stuff.
Also the "CEGB story' booklet is up on an AboutBlyth site and Glyn England's musings from 1982 (view from my Window) are on a South Western historical electricity site.
Plus the main Electricity timeline document produced by the Electricity Council in 1987, Rob Cochrane's books Power to the People and the CEGB Story and various other sources.

Looking at the current difficult situation we appear to be in, I've been digging around how Electricity delivery has progressed in GB. I thought you find this interesting.....
There is a salutory lesson re excess capacity which really held us back until 1933, albeit at that time also with serious supply type diversity.

Following on from Michael Faraday's experiments, James Clerk Maxwell wrote his treatise on Electricity and Magnetism which was a bit hard to follow. However John Ambrose Fleming, the one student who sat through all of Clerk Maxwell's lectures realised what was needed and came up with the Right Hand (Generation) and Left hand (Motor) rules. Motion at Right angles to Magnetic field with Electric field at 90 degrees to both. Hence the development of Dynamos (Constant Voltage driving Direct Current - DC), Alternators (Alternating Voltage driving Alternating Current - AC) and Motors (DC and AC)

Much new Electricity Generation and Supply equipment was on show at the 1881 Paris Electrical Exposition and the 1882 Crystal Palace Exhibition. Edison and Swan displayed the new incandescent lamp. Edison had by far the largest exhibit in Paris powered by 'Jumbo', the 125hp monster generator which could run 1000 16 Candle power bulbs. This really kick started the Electricity revolution. Up to that time there had been individual systems, including in stately homes such as Cragside with Ponds constructed for Hydro Generation. In towns their monopoly on digging up the streets was jealously guarded by the Gas Companies.

In 1882, Edison set up Holborn Viaduct power station (DC, using 'Jumbo'), positioned so as to use the Sewer (Sir Joseph Bazalgette), which crossed underneath the Viaduct and up to Newgate Street, to run the wires as he could not 'dig up the streets'. Then branching into buildings along the way to supply lighting. Where the Sewer ended he had to run cables up the side of a pub (Holborn Tavern) and overhead to supply a feed to the Telegraphs building of the General Post Office. Although the head of the GPO Telegraphs and Edison had an professional animosity which had to be resolved first. Edison went back to New York and opened Pearl Street Generating station in September 1882. Then other DC stations dotted across the Big Apple. He also started the New York Steam company to use the excess heat produced to ensure the Generator could be quickly increased or decreased to meet the varying demand. Holborn Viaduct closed in 1884; limited expansion blamed on the 1882 Act preventing systems crossing Local Area boundaries (see next page).

Lord Crawford went to the 1881 Paris exhibition and on his return suggested to his cousin Sir Coutts Lindsay that the new Incandescent light bulbs would work well in the latter's Grosvenor Gallery in Bond Street. Coutts Lindsay installed a small generating unit. The neighbours were impressed with the new lighting and asked if he could add some more plant as they would take 'all the spare current'; thus he expanded the station in 1885.

In 1886 Coutts Lindsay hired Sebastian Zian de Ferranti who realised a big solution was needed. He proposed giant Steam driven Alternators (10000HP) at Deptford, down the river to enable large volume cheap coal supply (Northumbrian by sea) and cooling. Then AC cables at the (unheard of) voltage of 10kV running along the huge viaduct of the London and Greenwich Railway to London Bridge and then Charing Cross. So, Lord Crawford and Sir Coutts Lindsay started the London Electricity Supply Corporation (LESCo).

Ferranti could only manufacture cable in 20' lengths so there were 8000 joints from Deptford to Charing Cross, only 15 of which faulted in 40 years of operation.... Up to the 1882 Electricity Act, a Private bill in Parliament was required to set up an Electricity undertaking. The new Act permitted the Board of Trade to licence Electricity Utilities and permitted the breaking up of streets and stringing of overhead lines for Electricity supply, with the consent of the Local Authorities. However, licences would only last 7 years and the Authorities could take over the supply company assets after 21 years (later increased to 42). They could also prevent companies from crossing authority boundaries. This hindered the development of Electricity in the UK.

Thus, LESCo had to apply to the Board of Trade for a multi-Authority block licence to dig the streets in Central London for distribution. However, there were a lot of competing requests for orders in each Area and customers could demand a supply and choose type (AC or DC,, voltage etc!!). The Board of Trade tried to restrict the number of suppliers in each Area but the inefficient small Area based station model prevailed. This restricted the supply area for the larger LESCo undertaking and the customers were initially reticent to select it. However, some common sense then prevailed, customers came back 'in droves' and Deptford grew rapidly. In 1892 the first Oil circuit breaker was installed to deal with increased current levels and the station even had to be taken out of service in early 1906 for complete replanting..... Note that the sending end voltage at Deptford had to be raised to 11kV to maintain 10kV in the West End of London. 11kV is still in use today as 'second level' distribution.

In 1889 Nicola Tesla, working for George Westinghouse, promoted Polyphase AC systems in the USA for distance transmission which needed High Voltage. A two phase 25Hz system was put in place to connect Niagara Generation to New York. Tesla then defined the principles of 3 phase AC Generation and Distribution.
The last of Edison's New York Public DC supplies was 'spiked' in 1981.

Note that Reciprocating Steam engines are only in the order of 9% efficient under varying load. The ‘sealed steam circuit’ Turbo Alternator designed by Sir Charles Parsons was adopted from the start of the 20th Century. Enabled Larger and more efficient units.

In 1901 Charles Merz and William McLellan built the first 3 phase Generating Station at Neptune Bank, Newcastle, then the first Alternator with an electromagnetic rotor in 1903.
In 1904 Merz and McLellan built Carville A, being the first Turbo-Alternator station of the modern (Unit) type. Also claimed as the cheapest Electricity In the World at that time.
Other developments, including Mertz-Price protection for Alternators was also developed for the Newcastle-upon-Tyne Electric Supply Co. By 1912 they had the largest integrated system in Europe.

In 1910/11 Ferranti, as President of the Institution of Electrical Engineers, proposed full scale National Electrification with 100 stations at 250MW each to conserve Coal, improve efficiency and reduce costs.

In 1916 Charles Merz proposed the National Trunk Distribution systems. A Government review in 1918 identified the need for a more centralised system but the Act of 1919 did little to resolve the issues with multiple undertakings still dominating the field.

In 1921 Merz and McClellan opened North Tees Power Station, the first to use high temperature and pressure steam conditions, with boiler reheat between the High and Low pressure Cylinders. They also set up the first Grid system at 40Hz in the North East; again the largest single system in the World at that time but with no HV circuit breakers!!. They therefore commissioned Alphonse Reyrolle to come up with a suitable device.

But, by the early 1920's we had over 500 Electricity undertakings in the country with over 50 different combinations of AC/DC, voltage and frequency in the Capital alone. In fact you couldn't move across London and be sure you could take your appliances with you. Because of serious excess capacity (75%), with the resultant costs and charges, running five light bulbs cost a labouring wage and the GB demand was only about the same as that of Manhattan!!
Gas was cheaper than Electricity for Energy delivery.

The 1925 Weir committee (including Charles Merz) led to the 1926 Electricity Act which finally got the monster by the tail. A standard supply was defined - AC 3 phase 50Hz. Voltage levels were defined; 132kV grid with some 66kV sections plus distribution at 33kV then 11kV and finally 415V (Phase to Phase) to smaller premises (240V Phase to Neutral). The 122 most efficient major stations connected to it were to be operated in strict cost order, whoever owned them. Some 22kV, 6kV, 3.3kV, 2.2kV systems were also used where appropriate.

It is notable that Stanley Baldwin, as a Conservative Prime Minister, pushed through the 1926 act which is classed as 'one of the most Socialist pieces of legislation on the statute book'. The Act became law on 15 December 1926.

The Grid was built in 12 Area sections (around the main demand centres) with Emergency Interconnection; all in all 4000miles of 132kV circuits. A useful infrastructure project during the depression then the war. National then War Governments from 1931 to 1945; James Ramsay-Macdonald, Stanley Baldwin, Neville Chamberlain and Winston Churchill.

The 12 sections were
North Scotland, Central Scotland, South Scotland,
North-East England, North-West England and North Wales,
Mid- East England, Central England, East England,
South-East England, South-West England and South Wales.

The Grid and the new Control structure was implemented in 1933. The level of excess plant plummeted, prices dropped dramatically and demand rocketed. From 750000 customers in 1920 to 9 million in 1937; the fasted growing system in the World.

And in 1937 on the October 29 night shift an enterprising National Control Engineer closed up all the Grid interconnectors (instructing stations at the end of each Interconnector line up and down to achieve Synchronism) and it held. From October 1938 it ran solid across the country which of course helped considerably during the Second World War.

The (mainly municipal) utilities found the demand was now increasing at an alarming rate... For example, in 1923 the Croydon (A) Station capacity was 15MW with a Max demand of 8.6MW. In 1936 when they commissioned the No 7 30MW turbine the capacity came up to 58MW with the Demand at 39MW. But the demand rise was such that in 1939 the Corporation designed (and piled the site) for a brand new 300MW B station - 12 * 33MW boilers; 9 would be needed steaming for full load from the 6 * 52.5MW sets.
Construction of all new plant was halted by the war.

Immediately after the war the municipals started building plant again but, especially by the time of Nationalisation in 1948, it was realised the units were too small. Croydon B was 'truncated' to 200MW which 'unbalanced' the already slow Coal to Bunker plant (station designed to look 'pretty') and thus it could never base load at full load.

Also, in 1952 the Clean Air Act was passed. From that time you start to see more 1,2 and 3 bar Electric fires being bought. The new Ring main wiring (30 amp circuits) was introduced in domestic premises to replace the old 15 Amp radially connected sockets. This all caused another boost to the Demand which was already increasing at an alarming rate.
In 1950 the Peak Demand estimate for 1970 was 30GW; that was actually surpassed in 1960. The Generation and Transmission part of the Industry in England and Wales was reorganised as the Central Electricity Generating Board in 1958.

From Nationalisation there was a rapid move to 120MW then 250-350MW generators. It was also realised that the scale of overland coal transport needed for much larger stations near Demand centres would be untenable. Thus the CEGB opted for 500MW then 660MW unit stations near the fuel sources (Coal at the pits and Oil at the Refineries) with the 275kV then 400kV Supergrid going in for Bulk Power Transmission (Coal and Oil by Wire).
There was also a move to convert some of the Municipal stations to Oil Firing where Fuel transport was an issue.

And in 1963 the first of the Nuclear Magnox Stations was commissioned, followed by 11 more. The CEGB then planned the next stage of development; five AGR stations.

The long established seabourne route from the Northumbrian coalfields to the Thames Estuary facilitated supply to large stations below Tower Bridge. Including Kingsnorth dual fired adjacent to the Grain refineries and with a large Coal unloading jetty. Also by ‘low height’ barges to the Stations further up the Thames.

In the early 1960’s the Gas Board introduced the new ICI plant which produced Manufactured (Town) Gas from Naptha Distillate rather than in Coal fed Retorts. This dropped the price of Gas considerably and Gas heating became more economic than Electric fires. Therefore, by the late 1960’s Gas Fired Central Heating was being extensively installed.

Up to the end of the 60's the older (Municipal) Generating plant was still running hard to meet the Winter demands - Coal fired units running Weekday base load and even the OCGTs being thrashed for 16 hours a day. However, due to even lower Gas prices as North Sea Methane arrived from 1967, then the Oil Price ‘shocks’ of the early 70’s, recession set in and the Electricity Demand rise ‘stalled’.

After the 1972/3 miners strike the margin situation eased and the older plant went to Two shift or Peak only manning. By the middle/late 1970's ancient Municipal stations, some of which had started life as Private undertakings 1890-1900, had shut down. And after the Oil price shocks the municipal Coal stations built after the war which had been converted to Oil also ceased operation. The remainder of the last municipal build (Coal fired) plant went in the early 1980's. The plants were demolished and the sites cleared.

The Control Framework comprised National, with 12 Area centres who actually instructed the large numbers of units. National Control was established behind the Bankside (Southwark) by 1938 but moved into the redundant lift shafts of the St Pauls Underground station during the war. It was then moved to temporary accommodation on Paternoster (by St Pauls) before going back to Bankside House and then to the purpose built centre with advanced facilities on Park Street (2 blocks behind where the New Globe Theatre now stands) in 1971. By that time there were 8, reduced shortly afterwards to 7, Area centres in England and Wales..

An Inter-Area transfer system allowed for a distributed Instruction of Generation (Telephone and Telegraph) and a degree of Area based correction for forecast demand and generation errors. Strict National optimisation of plant running in On Load cost Merit Order was carried out at Peaks and Troughs with Transfers Interpolated in between. To ensure that Generation is matched to required Demand at all times, without incurring excess costs for reserve provision, accurate prediction of demand is required at all forward timescales. More sophisticated models for analysis of demand against actual weather, then application of same with forecast weather to give forecast demand, were developed.

From the early 70's, Merit Order derivation (System Marginal Costing), Fuel planning and Generation planning down to day ahead used a heuristic computerised scheduler. For Fuel Allocation and Merit Order determination, annual simulations iterating with the Cost Optimised Fuel Allocation program were used. These Generation-Fuel simulations determined the right Merit order, with matching Fuel allocation, to use the fuel and generate in an optimal overall manner, allowing for scarcity of each source as well as individual source prices and transport costs. 500 individual fuel pit/coal type and refinery oil sources, 2500 routes between those sources and the 150 or so Power Stations.

CEGB System Operation System Control Development, National Control and the Computing Centre worked on getting a better computerised scheduler into service, to optimise generation at every schedule point (not just Peaks and Troughs) and account for Start up costs and impact of generator dynamic parameters (Maximum Run Up/Down rates, Minimum Generation levels, Minimum On/Off times etc).

The new mechanism first replaced the old scheduler in the Generation Planning and System-Fuel simulations (1980 and 1983), and was then implemented in Control in 1985. It tightened up plant running to reduce Costs, Fuel burn and emissions. Saved a few billion.

In 1975, as Natural Gas was being produced in bulk from the North Sea, the EEC issued directive 1975-404 restricting the use of Gas (as a Premium Fuel) for Electricity Generation.

But, for a time up to 1980 the CEGB did burn Gas in two Coal stations, West Thurrock on the Thames Estuary (1240MW) and Hams Hall in Birmingham (366MW), overnight, to help smooth the Gas flows from the Supply infeeds and through the developing National Gas Transmission System. However, that ceased when the Gas Board tried to up the price to that of Oil.

The Nuclear AGRs arrived between 1976 and 1984. In 1984 we also get the 1800MW Dinorwig Pumped Storage Station and the 2000MW French link. The Sizewell B PWR arrives in 1995. Demand increase was slow and then nearly levelled out. Peak Demand passed 50GW (GB) in 1976 but didn’t get to 60GW until 2002.

So, as noted above, through the 80’s the CEGB closed and demolished the last of the pre-Nationalisation ‘Municipal Authority design’ Coal and Oil Power Stations.

Then we get to Privatisation in 1989 and 1990. By EEC directive 1991-148 the EU Energy Commissioner, Antonio Jose Caroso e Cunha, repealed EEC 1975-404 thus lifting the restriction on the use of Gas for Electricity Generation. Note that Leon Britain (previously a UK Minister) was the Competition Commissioner at that time. Both Commissioners were active together in promoting the Single Energy Market.

The Power Producers could now build high efficiency Gas fired Combined Cycle Gas Turbines. Most of the Independent Producers used the sites of those old Municipal Coal Power Stations which were ideal; Roosecote, Barking, Little Barford, Peterborough, Corby, Staythorpe, Shoreham, Marchwood, Plymouth etc etc.

The ‘footprint’ of each CCGT station was much smaller than the area of each such site and Electrical (usually 132kV) and Cooling Water connections were in place. The Gas supply was usually adjacent on the site of an old Gasworks. In other cases CCGTs were built on riverside/seaside sites near the Gas National Transmission system and the Supergrid.

Thus began the dash for gas which would increase the Gas demand by 50% and advance the demise of UK Continental Shelf production. However, in 1992 the Government cancelled the British Gas Lurgi Gasifier + HiCom Methanator project, designed to produce Synthetic Natural Gas from Coal, Biomass and Trash. This was intended to cover the eventual rundown of UK Continental Shelf Gas supply (now brought closer by the CCGTs), while maintaining diversity of primary fuel supply.

In May 1993 National Control moved to its new centre in Wokingham with new Computer systems. New matching facilities were put in place in the remaining 4 Area Control centres. Then we progressed to National Central control based on two centres, with the operational functions split between them. Either centre can take on all vital Control activities, if needed, at a moment's notice.

All customer demands were now being either metered (1994 - all premises over 100kW) or synthesised (1998 - profiling) to Half hours for Wholesale Market Settlement Reconciliation. A Wholesale Trading and Matching Operation was now put in place for Electricity (New Electricity Trading Arrangements). Multi party Bi-Lateral trading with the Operator making Unilateral adjustments for Major Generation-Demand mismatch (Market Timescales) and to secure the system Transmission Constraints and ensure pre and post fault stability. Instructing the Generation fleet (and participating retail customer sites) explicitly at near real time. Unfortunately this will not achieve overall efficient operation.

Then from 2003 (ROCs – Wind) and 2010 (FiTs – PV) we get the flat rate Incentives for Variable renewables. A significant capacity has been built with considerable impact. We do not now have the right plant mix to handle this; please see my Strategy as regards a robust way to move forward.

With a fleet that is capable of producing nearly 500TWh but with a demand of only 360TWh (Station Sent out)........

"There are an infinite number of ways of running an Electricity system badly!!"

Central management of the system, with hierarchical aggregation/dissemination of Distributed resources data and trading/instruction data to make participation manageable would facilitate a much better approach. The unbundling of the major ESI elements - Generation, Supply, Transmission, Distribution and System Operation gives a fragmented approach to cost-income application. Also, to get the 'meaning of time' across to the Customer you need top to bottom (Generator to Customer) analysis.
Hence the US Vertically Integrated Utilities are more successful at effectively engaging the retail customers. However, demographic differences dictate that a number of approaches are required.

And Customer Engagement, to change the times at which they run Appliances (especially for the increasing Demand from Electric Vehicle charging), will constitute one of the biggest changes in principle to Electricity Delivery since the birth of the Industry.

Careful time series and time sequence modelling is needed to evaluate the best plant mix and control logistics for Energy - Electricity, Gas, Heat and Transport.

Please see my associated notes on Future and Fast Action and Strategy and the Future Power Systems articles (Basics through to Brave New World) via the links at.....
www.eleceffic.com
FPS 20, 21 and 22 are relevant to the Customer Engagement and overall modelling requirements.