Stephen Browning - Energy Strategy Mk XII.

We need an Integrated solution to get the best result as regards Fuel Burn, Emissions and cost with adequate capacity, security and stability of Energy supply to customers (the Trilemma). We also need to maintain diversity of Fuel sourcing.

Noting that Electricity delivery is Unique as an Energy vector. There are no appropriate analogies. It requires that you get it to the Right Place at the Right Time and that will be (Laws of Conservation of Energy) at the Exact Rate (Power) required. Thus tight matching of Generation Power to Expected Demand Power is required. While maintaining Security (MW flow limits), Stability and Voltage (MVAr provision) at all points. While covering for any one of the large number of Credible faults which can occur at any instant.

Bio-Methane is already being increasingly produced from Organic Decomposition. Anaerobic Digestion, Sewage processing and Landfill Emissions capture. This is Low Carbon as it deals with ‘short cycle’ organic material. Not using the large reservoirs of Fossil Energy from organisms ‘crushed’ millions of years ago.

Low and Negative Carbon (Green) Methane can also be produced at large scale from a variety of fuel sources, including Trash. Also incorporating a low cost/low energy CO_2 sequestration process. And actually more efficient than Organic Decomposition capture.

Due to Variability of Output of Wind and Solar Generation, overbuild of Capacity is being promoted. With the excess output being used to produce Electrolytic Hydrogen and Oxygen for use when Renewables output is insufficient to meet Demand.

Better use of Electrolytic Hydrogen (and Oxygen) and Green Methane by proper Integration of Distributed Energy Resources (Demand and Generation) and more efficient combined production of Electricity and Heat is needed... Thus providing the serious flexibility needed to buffer variable renewables. The 'Big + Little' Picture.

With a Heat Anomaly over Siberia threatening to increase the melting of the Permafrost and thus release more Methane (Greenhouse impact 22 times that of CO_2) to the Atmosphere. Also the massive Chinese Coal Burn, which dominates World emissions, is not set to reduce significantly at this time

“We have a need, a need for Speed”

- Establish adequate Electrolysis facilities for production of 'green' Hydrogen, with Oxygen, at Local and Central levels. Noting that the High pressure Gas Grids cannot transit Hydrogen as easily as Methane.

- Resurrect the British Gas Lurgi (BGL) Gasifier and HiCom Methanator mechanism. Eats BioCoal, Biomass and Trash and produces Green Methane (also described as Synthetic Natural Gas (SNG)). The Outputs are Methane and High pressure Carbon Dioxide. The Carbon Dioxide can be easily sequestrated. It can be further processed (Sabatier) with Hydrogen (say from electrolysis using excess Electricity from renewable generation) for more Green Methane.

  This is a Low and Negative Carbon Energy Production process The original BGL-HiCom development was a full production scale system. BGL is in use in Chemical industries today. Johnson Matthey hold the patents for HiCom and manufacture same. For Transport, Compressed Methane in large vehicles is being done.

- Noting that Methane Gas storage and flexibility is awesome - the GB Gas National Transmission System Linepack (Gas in pipes) alone is 3.5TWh and can release and recover up to 30% during a day. Explicit storage has reduced but is still @14TWh. Gas can handle Power movements from @150GWg to @250GWg and back during a day. Even higher rates of Power movement (50GWg to 300GWg) have been presented recently.

- But there is actually a limited amount of Waste and Biomass on a Global scale. So, this production of Low Carbon Methane should be used for applications which still need light High Energy Density Fuels. i.e further processing to Liquid fuels (Methanol) for Transport applications.

- Use the Gas better - Combined Heating Power and Cooling (CHPC) with Heat Stores. Large premises plant room systems (Electricity, Heat and Cooling) and District Power with Heating. With a clutch between the Engine and Alternator and a Heat Pump.

  Also there is now a proposed System for Electro Thermal Energy Storage (ETES - CO2 as the working medium) which can also be added to the Installations. CHP and ETES produce Heat at 90deg to 120 degrees C – same as our Gas Boiler output. So excess Wind and CHP Heat can charge the ETES which can Discharge when more Heat than Elec is needed from Installations. Also for High Temperature Heat which is needed for some Industrial Processes.

- At domestic level (with small commercial where adjacent). Set up Distributed Energy Hub CHP+HP units (up to 500kVA) at Distribution substation level. Heating Flow and Return Water 'Plug compatible' with conventional Radiator systems. Target difficult to heat areas. Especially with bad Air Exchange rates in 'leaky' dwellings where increasing insulation is not effective against the overall heat loss.

- At large non domestic Premises and for larger scale DH set up CHP+C+HP/ETES Units at MW scale.

- This should also justify larger CHP units than the current practice in larger premises where they are sized just to cover minimum Electricity or Heat demand. It does require larger Heat stores - but low tech hot water storage and other systems are well developed and relatively inexpensive technology.

- These CHP(+C)+HP/ETES systems can be configured to be highly flexible with Fast start Engines and Interruptible Heat Pump demand. Flexibility is key to accommodating higher penetrations of variable renewable generation. .

- All these CHP(+C)+HP/ETES systems need to be monitored and ‘managed’ because they will comprise a large amount of Generation and Controllable Demand on the Local systems. Also, cumulatively, on the whole system. This needs to facilitated through communication with Supplier/DSO and, by Aggregation ‘Up’ and Dissemination ‘Down’, the Wholesale Markets and the ESO. To ensure secure and stable operation of the Electricity System at all levels.

- Note that @850000 non Domestic premises in GB, including all Large sites with Peak demand >100kW, all have hhr meters. Each with a dedicated but underutilised comms circuit (usually PSTN) for data collection (usually by daily dial up).

- These non domestic and DH premises with hhr metering (includes Energy Hub DH systems as Gen/Demand >100kW) could take Time based tariffs (FPS 21). First simple Peak/Plateau/Trough, Weekday different Sat and Sun, different Summer to Winter. This encourages demand appliance time shift and running CHP units mainly at high price times. Moving on rapidly to Dynamic Pricing due to Volatile Prices which arise as the result of large scale penetration of Variable renewables.

- Also the GB Smart Meters system (SMETS) for the bulk of the 25 Million Meters, has an Elective Services data route which can be configured for communication from and to Premises. ‘Behind the Meter’ management of Resources.

- Distributed Energy Resources should be managed by (Automatic) ‘Bartering’ with the various Energy and System Services Markets.

- Both Internal Combustion Engines and CCGTs provide Inertia, although that from IC Engines may be low. Hence the addition of a flywheel. IC CHP+C is very efficient (Power and Heat provision) at Full and Part load. While the CCGT GTs are less efficient at low output and also have relatively high Minimum Stable Geneartion

We set up the units thus; Diagram at the end of this Paper.

IC or GT Engine via Self Shifting Synchronous Clutch to Alternator.
With Heat recovery from the Exhaust and the Cooling and Oil Circuits.
With two options for a co-located Heat Pump.
Option 1 – Heat Pump powered through a Slip drive on the outboard side of the Alternator.
Option 2 - Heat Pump as a separate Motor-Pump unit.
Where a DH Unit is adjacent to a Distribution Substation the Alternator can be connected to the LV side. And if the Heat Pump is separate, the Motor can be connected to the HV side. Minimises Distribution losses.

Plus a Heat Store. And, where Cooling is required, an Absorption Chiller and ‘Coolth’ Store.

In addition to the Heat Pump, Electro Thermal Energy Storage can be used to convert and store High and Low temperature Heat. It can also Generate from the High Temperature store and from any premises High Temperature Waste Heat.

IC/GT Engine CHP plus Heat Pump Operating modes

Mode 1 –Engine On with Heat Recovery, Alternator Generating; Heat Pump Off.
Heat direct to Demand or to Heat Storage, Chilling and Cool Storage as required.
Mode 2 –Engine Off, Alternator Motoring (Heat Pump Option 1) or Float (Option 2).
Heat Pump On. Direct to Demand or to Heat Storage, Chilling and Cool Storage as required.
Mode 3 – Engine On, Alternator Generating or Motoring (Heat Pump Option 1) or Generating (HP Option 2). Heat Pump On. Heat Direct to Demand or to Heat Storage, Chilling and Cool Storage as required.
Mode 4 – Engine Off, Alternator Synchronised Float , Heat Pump Off.

In all 4 modes we can provide Inertial Damping, Response (if Engine or Heat Pump running), Reaction and Reserve (Fast start Engine, esp if IC, if not already running).

Noting that the Intake Air of an IC Engine can be enhanced by Oxygen to give more Power Output. However, a very high percentage of Oxygen can caused issues due to precombustion on the Inlet stroke.

With ETES there are more possible modes depending on the Premises and DH Heat and Electricity requirements and the Electricity System Prices. Also by 'bartering' with the Electricity Market, Suppliers and, for Services, the Operators.

The Equipment (CHP+C and HP or ETES) can be set for Reserve operation and instructed in Dispatch, Timing (Sync-Desync) through to Commitment Timescales.

Also, with the Alternator Synchronised we can of course provide MVAr Export and Import to stabilise Local and Grid Voltages.

What we are effectively doing here is using Green Hydrogen (and Oxygen) and Green Methane and the big but relatively inexpensive storage mechanisms of Gas and Heat to provide flexibility to Electricity Supply. With High Efficiency Hybrid energy Production. To enable a Zero Carbon Energy system at reasonable cost

We need to progress from simple tariffs to add Interactive working between Retail Customers, their Supplier and the DSOs and SO (Market and Matching Mechanism Timescales). FPS 21 has some more details on Customer Engagement.

We need a Standard Framework/protocol interface but with Flexible data content (Industry and Customers will be learning how to interact). As noted above, in GB this can be effected by establishing an Industry data route over the comms lines to the Dial up HHR meters and Elective Services across the Smart Meter (SMETS) Interface.
This all also improves visibility of generation, accuracy of SO Matching and of SO and DSO stability and security management. Uncertainty breeds excess cost (and fuel burn and emissions and risk) due to inefficient operation.

This all needs a hierarchical Aggregation/Dissemination data structure to make it manageable - Premises-Microgrid (inc hubs and community systems) to DSO then, aggregated by GSP, to the ESO. With of course the Supplier and ESCO interface at the appropriate level.... Noting that the DSO's obviously have the database of Meter Location (MPANs) and the time based Supplier to Premises assignments.

This enables proper participation of Retail Demand and Generation from Market timescales down. Including the system requirements (reactive power, stability) and the enabling of active participation in Ancillary services provision. As the Information revolution develops this is a major practical application of the Internet of Things.

Note that if, by any method of engagement, we enable large scale customer demand shifting to buffer say Wind variability, we will destroy our current top down forecasting system (my FPS 20, last 2 pages). We will need to rebuild from bottom up ('automatic bartering') using the distributed data framework.

To manage Generation in this way (lots of little plant plus the main Generation) would be the biggest logistical change to operation since 1933 when the Grid was commissioned (12 Areas) and the main plant was scheduled in strict cost order (whoever owned it). Also this 'Big+Little' approach is unique as far as I am aware.

and.... a number of our CCGTs are built on the last of the old Municipal Power Station sites; Peterborough, Rye House (N London), Staythorpe, Corby, Shoreham, etc etc. The old Stations were decommissioned by the late 80's, thus the CCGT developers has a set of ready made sites with Electrical Connection, Cooling Water and Gas (the Gasworks was usually next door).
There has been a heated debate as to whether we could recover the latent heat of condensation from the Steam Turbine exhaust as that is what effectively (via the Cooling water heat exchange) gets 'dumped' in Ocean, River or up the Cooling Towers and is the main part of the 40+% Heat loss on (fully loaded) CCGTs. Heat Extraction rather than a conventional Condensing mechanism is needed; the Danish CHP Turbines run with both and can switch... However, it is a major support structure and plumbing change to an existing Steam turbine installation; new build is easier than retrofit. Lots of heat though which would suit DH.

However, as I principally argue, Distributed IC systems, with and without Heat Recovery are more flexible.

and..... All these Heat systems (Premises/Energy Hubs up to Microgrid up to District Heating), with their large storage, are flexible of course as regards their Sources. Noting that Domestic and Small Commercial scale Heat Pumps will require upgrades to Distribution (100000+ miles of circuits + Transformers, substations, Var compensators etc etc). For the moment the IC/GT CHP+C+HP and CCGT-CHP+C ideas use Gas better - Natural and Low/Negative Carbon SNG (AD and Trash fed +CCS).

Sorry about the length of this but we need an co-ordinated Integrated solution. All the elements need to be progressed together.
If we can get can get this to work the export potential is incredible. The GB Energy Transmission systems can deliver 1000TWh/annum of Gas and 360TWh (sent out) of Electricity per year. We burn @52million tonnes of coal per annum.

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As regards other countries with major Coal based Electricity Production

China's Electricity supply alone is over 7000TWh/annum and they dig up 5+ billion tonnes of Coal per annum. @1100GW of Coal generation producing @4500TWh. They currently also use @350bcm (3500TWh) of Natural Gas/Annum, while importing 100bcm/annum.

Thus there is scope for Elecrolytic Hydrogen and Gasification-Methanation (Synthetic Methane) plus managed CHP+C+HP to deal with the Emissions and other Pollution. China already has some BGL plants for chemicals production and is looking at Coal Gasification.
Noting that the Coal supply from the Northern Province of Nei Mongolia mainly travels via the Grand Canal southwards from Beijing, past the cities of the Eastern Seaboard. Where there should be lots of Trash to combine with it to feed a fleet of Gasifier-Methanators.

The existing Coal fired Stations in South, Central and East China could initially have Gas burners fitted to the boilers (in the bottom Ash hoppers) and also have the Boilers and Coal handling plant replaced by Synthetic Methane fired GTs and Heat Recovery Steam Generators. Such conversion to CCGT mode has already been carried out on one 500MW Unit at Peterhead in Scotland and was proposed for two (currently Coal) 660MW Units at the Drax station in Northern England. The other four Drax units are currently fired by Biomass. They also intend to install BECCS to capture the emissions from the Station and Industrial sites in the area.

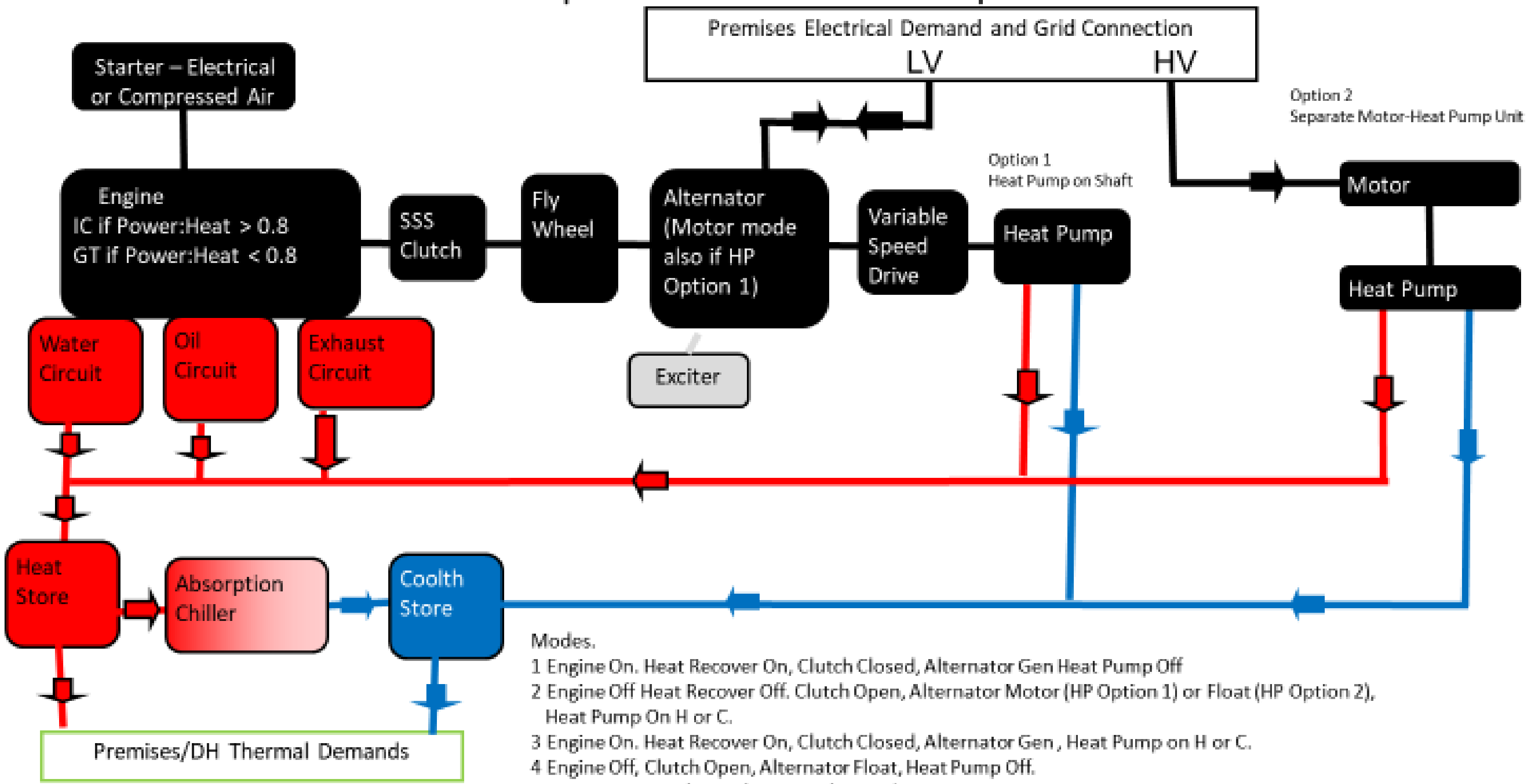
This may be regarded as a 'Get out of jail for the moment' approach as regards Strategy. Hopefully we will get a big jump in material technology as regards Electricity storage (with high speed reaction capability) to enable more serious penetration of Renewables without Fossil 'buffering'.

And of course different solutions are appropriate in different parts of the world, depending on resources available; ‘Once size does not fit all’. We need a ‘Horses for Courses’ approach.

My 22 articles on Future Power Systems are linked at
www.eleceffic.com.

FPS1,2 and 3 have a partly unique analysis of the Balance principle, tightness of the Matching requirement, synchronism and the nature of instantaneous Electrical Power, Generation, Transport and Delivery (each AC system is a giant machine).
FPS 4 covers renewables impact and has a new diagram to show the effect of forecasting uncertainty on the big ramps caused by wind variability (Page 7). This is crucial to demonstrate that these movements are much more difficult (if not impossible) to handle than the regular demand ramps.
FPS 5-7 tackle future distribution (esp active), FPS8-14 the customer to utility interface while FPS15-19 examine customer data and participation issues.
FPS 20 covers the Smart Enterprise with the warning about forecasting methods
FPS 21 covers the Smart Customer with various salient points. Make retail end systems automatic, progress one step at a time, have a fallback in place each time you change the commercial interface, etc
FPS 22 looks at the modelling required to determine Strategy and Value.

CHP+C+HP Two options for the Heat Pump



Modes.
1 Engine On. Heat Recover On, Clutch Closed, Alternator Gen Heat Pump Off
2 Engine Off Heat Recover Off. Clutch Open, Alternator Motor (HP Option 1) or Float (HP Option 2), Heat Pump On H or C.
3 Engine On. Heat Recover On, Clutch Closed, Alternator Gen , Heat Pump on H or C.
4 Engine Off, Clutch Open, Alternator Float, Heat Pump Off.
Sync Comp in Mode 4. Also in Mode 2 with HP Option 2.

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