RCEA
(SUSSEX)

An Association for Retired Professional Engineers

NEWSLETTER December 2018

President's Message

Welcome to the December Newsletter.

We have started the autumn session with some excellent talks; the most recent on Fusion Power attracted 60 members and visitors which shows the RCEA to be in good health. The full presentation on Fusion Power is now available on our web site to download (see Archive-Newsletters-2018-Fusion). We are very grateful to our speaker for making it available to us.

We have also recently attracted a number of new members, so please keep up the good work in encouraging retired engineers you know to consider joining the RCEA.

Your committee are well ahead with the planning of talks, visits and an outing for 2019, and as usual we are always open to your suggestions. However, for talks we need to be confident of the availability of a speaker and its engineering content.

I wish you all and your families a Merry Christmas and a Happy New Year.

Derek Webb

December 2018

PROGRAMME OF EVENTS December 2018 – April 2019

20th Dec	**Thursday**	**Coffee - at Spotted Cow, Angmering**
27th Dec	**Thursday**	**<u>No Coffee</u> at Swallow's Return**
8th Jan	**Tuesday**	**Talk – "British Tanks in the First World War: an engineering and combat success but a procurement failure?"**
17th Jan	**Thursday**	**Coffee - at Spotted Cow, Angmering**
31st Jan	**Thursday**	**Coffee - with Partners at Swallow's Return**
12th Feb	**Tuesday**	**Talk – "The History of Westland Aircraft Ltd "**
21st Feb	**Thursday**	**Coffee - at Spotted Cow, Angmering**
28th Feb	**Thursday**	**Coffee - with Partners at Swallow's Return**
12th Mar	**Tuesday**	**Talk – "The Loss of MH370 – what do we know; what can we learn?" Note this talk will be held in the Pavilion, not the Chichester room.**
21st Mar	**Thursday**	**Coffee - at Spotted Cow, Angmering**
28th Mar	**Thursday**	**Coffee - with Partners at Swallow's Return**
18th Apr	**Thursday**	**Coffee - at Spotted Cow, Angmering**
25th Apr	**Thursday**	**Coffee - with Partners at Swallow's Return**

The following visits/ outings are also being arranged. Full details and booking slips will be included in the next Newsletter. In the meantime, check the RCEA website and Facebook for updates.

May - Visit – Brookhurst Wood Facility, Horsham (Biffa waste treatment plant)

June - Visit – Culham Centre for Fusion Energy, Abingdon

July - Outing – Weald and Downland Museum, Singleton

All Talks and Meetings will commence at 2.30 pm and be held in the Chichester Room, Field Place, Worthing unless another venue or time is indicated.
Timings for visits and outings will be as printed in the detailed description of the activity.
Coffee mornings commence at 10.30 am.

We apologise for only being able to publish a short list of our forthcoming events. This is simply due to the difficulties we now face in booking speakers and visits far ahead. As you know we sometimes have to cancel/rearrange talks and visits, often at short notice. We suggest that members should increasingly rely upon our website for up to date details of events.

Membership Subscriptions 2018/2019

Our thanks go to all members who have renewed their subscriptions. Those members not renewing should note that their membership will cease on 1/1/2019.

Website of the RCEA

Our website, **<u>www.rceasussex.org.uk</u>** carries the very latest information on all of our events.

New Members and Speakers for Talks

The RCEA needs new members and speakers to ensure that we can continue as a thriving organisation. Please think of appropriate people you know and encourage them to come along to our talks and hopefully join the RCEA.

We also need more speakers to give talks to us on Tuesday afternoons from September to March. We are aware that many members have the knowledge from their working careers to provide interesting talks. If you are willing to give a talk please let us know. Speakers from outside organisations are increasingly harder to find and often seek payment for their services.

New Members

C.Spiller, MSc, B A (Hons), DipTS(London), MCILT, MCIPS, FRGS - Worthing.

T. James, C Eng, MIMechE - Keymer

A.D.Monnery, SIEBE Gorman cert of Commercial Diving - Rustington

J.E.Phipps, C&G, NEBSS, BSc, QMS auditor - Littlehampton

Latest Member's Handbook

Would all members please check their entry in the Members Handbook which has just been issued to ensure that their entry is correct in every detail i.e. address, telephone number, e-mail address, etc.
Similarly if members become aware that a fellow member no longer lives at the address that we publish in the handbook, we would be grateful for the information. Any errors or omissions should be communicated to **Mike Wooldridge, Membership Secretary** so that the appropriate corrections can be made to the master copy ready for printing the next Members Handbook.

RCEA Insurance

Members need to be aware that the insurance policy that the Association holds is solely for the protection for the assets and liabilities for the Association as an entity. The policy does not provide cover for personal injury or loss to individual members. Members attend the Association's events at their own risk; although under some circumstances there may be some cover from the insurance arrangements of the venue owner.

Newsletter Entries

If you would like to provide an article for inclusion in a future newsletter it would be very welcome as we are always looking for new material in addition to reports on previous talks and visits/outings. From feedback from our members we know that the newsletter is particularly appreciated by those who are no longer able to get to our meetings and visits, so if you are able to contribute in this way it would be much appreciated. Articles should preferably be Microsoft Word documents, although we can usually convert both text and pictures (even photographs) into a suitable format. Accompanying pictures are best supplied as separate files which will be embedded within the text during editing.

Brief Detail – Talks, Outings and other activities January – March 2019

Talk.
Tuesday 8th January 2019 - "British Tanks in the First World War: an engineering and combat success but a procurement failure?"

Geoffrey Vesey Holt MBE

The first tank, Mother, first moved in January 1916 and was a remarkable engineering achievement. Her children and grandchildren, the Mark IV and V respectively, enabled the return of surprise and success to the British Army at the Battles of Cambrai (November 1917) and Amiens (August 1918). The later battle inflicted a decisive defeat on the Germans.
The successful development of the first tank was due to a combination of leadership and engineering skills. Winston Churchill played a key role as did three engineers: d'Eyncourt, the Director of Naval Construction, Tritton and Wilson. However by the end of the war the British Army had almost run out of tanks due to a failure to maintain production.
Our speaker, Lieutenant Colonel (Retired) Geoffrey Vesey Holt, was educated at the Lycée Français de Londres and is a graduate of Durham University. He was commissioned into the Royal Tank Regiment in 1974.

Talk

Tuesday 12th February 2019 – "The History of Westland Aircraft Ltd"

Bill McNaught

The history of Westland Aircraft covers the 70 years from its inception by 'ironmongers' Ernest and Percival Petter in 1915, though its fixed wing design and production period ending around 1948, and finally its far sighted decision to initiate helicopter production. It concludes with the infamous 'Westland Affair' of 1986 which has led to major changes in ownership. The talk will also include some of Bill's own reminisces from 25 years with the company.

Talk

Tuesday 12th March 2019 – The Loss of MH370 – what do we know; what can we learn?

Ian Gilbert, Avionics Consultant

On 08 March 2014, a scheduled passenger flight from Kuala Lumpur to Beijing, operated by Malaysia Airlines (MAS) and designated flight MH370, went missing soon after a routine handover from the Malaysian Air Traffic Control to Viet Nam Air Traffic Control. The aircraft operating the flight was a Boeing 777-200 ER, registered as 9M-MRO. On board the aircraft were 12 crew and 227 passengers. Despite an extensive air and sea search, the location of the aircraft and occupants remains unknown. However, some debris has been recovered consistent with having drifted over nearly two years from the area in which impact is thought to have occurred.

The disappearance of Flight 370 has been dubbed one of the greatest aviation mysteries of all time. Since the time of the disappearance various scenarios have been proposed to explain the loss. Possible theories proposed include hijacking, crew involvement, and suspicion of the airplane's cargo manifest; many unofficial theories have also been proposed by the media – most of which are fanciful.

The Malaysian Ministry of Transport's final report from July 2018 was inconclusive, but highlighted Malaysian air traffic controllers' failures to attempt to communicate with the aircraft shortly after its disappearance. In the absence of a definitive cause of the disappearance, safety recommendations and regulations of the air transport industry have been changed to prevent a repetition of the circumstances associated with the loss.

For many, the question remains: 'how could an advanced passenger aircraft simply disappear in an era of instant, world-wide communications'?

This talk will try to explain the facts of what we know about the disappearance of MH370, as of today, and try to interpret those facts to give an indication of what might have happened to MH370. Inevitably, the audience may leave with more questions than answers.

Reports

Talk

Tuesday, 18th September 2018 – "We Plough the Fields and Clatter – a personal account of a life with a couple of Fowler Ploughing Engines".

Sally Watts

Sally is the daughter of Ray and Sheila Parsons, so grew up in close proximity to Ray's 5 inch railway engines and was taught to drive one from an early age – see picture opposite. This was the start of her love of steam machinery; although she has no formal qualification in engineering, she has lived with a Fowler Ploughing Engine for a number of years.

Sally explained that, for ploughing, horses were slow, there was a limit to the depth they could plough, they compacted the ground, and they needed feeding and caring for. With the advent of the steam age, a number of different plough designs were tried, but the system developed by Fowler won the Royal Agricultural Society's £500 prize in 1858 and his final design eventually cornered the market. It consisted of two ploughing engines, one at either side of a field, hauling the plough from one side to the other.

Each engine (see opposite) was fitted with a windlass mounted under the engine boiler, carrying the cable (600-800 yards long on this type of engine) which hauled the plough.
The plough was double ended, multi bladed, and could be tilted like a seesaw, rotating around the central pair of wheels so that the appropriate set of shares could be selected, depending on the direction of travel.

The picture opposite shows a six furrow anti-balance plough of this type. It may just be seen that one wheel is of a slightly larger diameter than the other; this allows for the fact that it travels in the groove formed by the newly cut outer furrow from the previous haul.

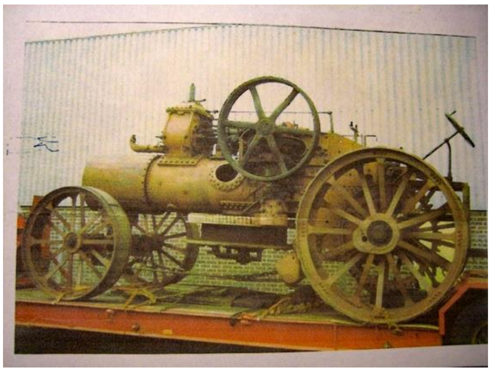
This technique had the great advantage that the engines did not have to go on the field, so the soil was not compacted; it was much more powerful than horses, so could plough deeper and more quickly, including ploughing a greater number of furrows simultaneously: a pair of steam ploughs could plough up to 20 acres a day using about a quarter of a ton of coal, compared with 1 acre for horses. Ploughing engines were used mainly between 1870 and 1919, with some sets still in use during the Second World War. However, by the 1950s they were no longer in use for ploughing, having been replaced by tractors.

Ploughing engines were used mainly for pulling ploughs and cultivators, but could also be used for dredging lakes.

The Fowler engines were very well designed – over-engineered – so that they were extremely reliable. They were exported across the world, including to Africa, India and Argentina. Each ploughing engine came with a detailed set of drawings with each part identified so that, when a part did need replacing, the factory could easily provide the relevant spare part. Similar machines were manufactured in the USA by Case but were of inferior quality – one consequence of which was that they sold more engines than Fowler because they had to be replaced more frequently!

Sally moved on from her father's miniature locomotives to large traction engines and met her husband Bob, who owned a steam roller shown opposite. As she said, very useful if you want to get rid of moles!

However, a steam roller was not enough, and he decided that it would be a good idea to get a ploughing engine as well. They saw a Fowler advertised that included its original living van.



This looked interesting – see left, so they went to South London to view the engine. Unfortunately, it was not quite as pictured and consisted of several heaps of bits – see right and below left!

Also, the owner said that the platform for the driver, together with the coal bunker and water tank, had been sent to a firm in Wales for restoration. A number of other bits seemed to be missing, including all the brass work. Nevertheless, they felt that there was enough to work on, so they shook hands on a deal.

The owner then explained that the living van was in Essex, so they drove out to see it – see right. It was in good condition – and contained a number of the missing parts! Finally, the owner said that there were a few other parts down in Somerset.

The magical mystery tour continued and there they discovered the missing brass-work, amongst other things. They came back in a VERY overloaded VW Passat.
Ultimately all the bits were delivered and you can see that the space for Sally to dry her washing was somewhat restricted – see opposite!
They were now the proud owners of a Fowler Class BB 16HP Ploughing Engine, although also having use of a friend 's ploughing engine named Wilbur (its partner, Orville had not survived) at shows and to find out where the various 'bits' fitted.

They were able to see their engine's history in the original factory order book, held at the University of Reading Fowler Archive, which showed that it had been ordered in October 1916 and delivered in April 1917. The living van was delivered on the same date; sadly, the original plough and cultivator have not survived, although her sister engine is in preservation. The factory archives also include blueprints for the engines and the van. These were updated to reflect developments in the design and include comments such as "Do not drill this hole for engines after 1916". The van blueprints are also very detailed and specify items such as the positions of 5 coat hooks, and the provision of two sets of sheets.

In 1917 Fowlers produced 70 sets of the BB Series engines, responding to a need to increase food production in the face of the food shortages resulting from U-Boat attacks. Experienced operators were even recalled from the Western front to man them.

Sally said that the gearing system and clutches were quite complicated to operate smoothly (and needed a fair amount of strength): to see it done well was quite impressive. She also noted that the steersman had to stand on top of the toolbox to drive the engine. If the box hadn't been shut properly, the lid tended to bounce up and down, and combined with the steering wheel 'kicking' on rough ground the steersman could be thrown off! The chain steering takes quite a lot of strength to operate, but the regulator for the compound engine is very easy to operate (easier than that on their steam engine). The combination of high and low pressure cylinders makes the engines smoother when starting. It is also easier to start from a TDC position by bleeding off a little steam via the 'high top' valve (a small lever by the regulator)- which helps to nudge the cranks out of line. However when a single cylinder engine stops at TDC, there is no option other than to turn the flywheel a few degrees by hand.

The living van was made of wood, varnished inside and out, with sawdust insulation (see opposite). The area around the stove was tiled or tin sheeted to reduce the fire hazard.

Renovation of the ploughing engine was complicated by the fact that the Welsh steel works had no idea if they had the bits of the tender etc – eventually they were re-made from scratch.

Importantly, the crankshaft had been stored upright and so was still true and fit for re-use as shown right.

As part of the restoration, the boiler was re-tubed (see right) and the firebox remade.

When moving the engines, one can use a low loader as shown opposite or, if an agricultural implement is included, they can legally haul an impressive road train as they class as agricultural vehicles. However, driving these engines any distance on tarmac is not good for the driver, the tarmac, or the following traffic!

Wilbur's boiler operates at 80psi and the action is beautiful – it will tick over all day. When ploughing, the operator tries to bring the plough up as close to the engine as possible, to plough the maximum amount of the field. Sometimes they get too close, as evidenced by dents on the cylinder block casing or boiler sheets! The ploughing machinery has no brakes so, if anything goes wrong, the operator has to whistle for the other engine to stop.

All the surviving engines in this area are left-hand designs, which mean that, when ploughing together, one of them has to go backwards. Sally's husband plans to remedy this problem and has bought a second, right hand engine (also called Bob). It is now in the process of being restored, which means there is even less space in the back garden – see over page!

The engines weigh 22 tons, which means that they can sink rapidly in soft ground. Additional bars (spuds), are attached to the metal tyres, hooked over the inner circumference and bolted loosely at the outer , to improve traction on muddy ground (see right) and Fowler did invent some other designs to cope with soft ground, but Sally is not sure how effective they were.

You can see and hear two of these engines in operation at https://www.youtube.com/watch?v=Wc0QNh0P_0k.

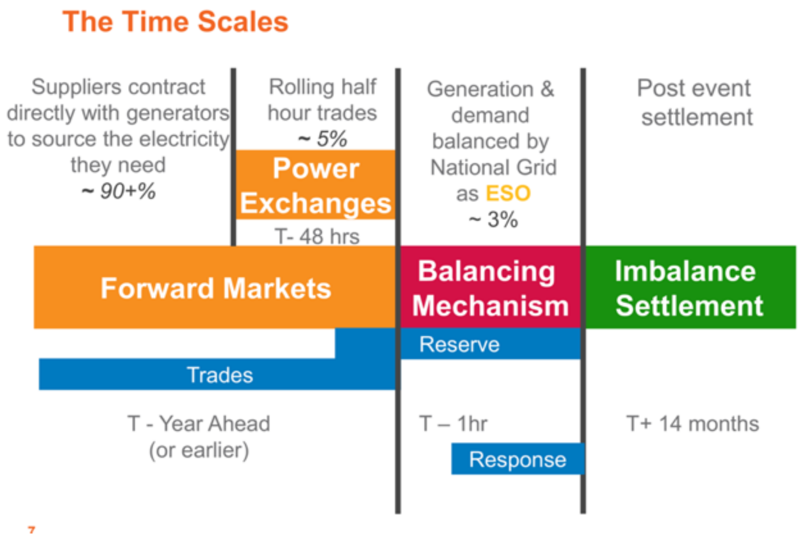
Visit
Tuesday 25 September 2018 - the Electricity National Control Centre (ENCC)

Our visit to the ENCC was arranged for us by Dr Tianyu Luo, who had previously delivered a talk to us in February describing the work of the ENCC. This visit was subsequently planned to show us the control centre in operation, and to give us some more detail on the National Grid's work.
The ENCC is housed in a modern building set in impressive grounds just outside Wokingham. We were met on arrival by Tianyu, who introduced two colleagues, Jian Sun and Murray Yelland, who would be speaking to us before we visited the viewing gallery and would be with us to answer questions both in the gallery and over a buffet lunch provided by ENCC.

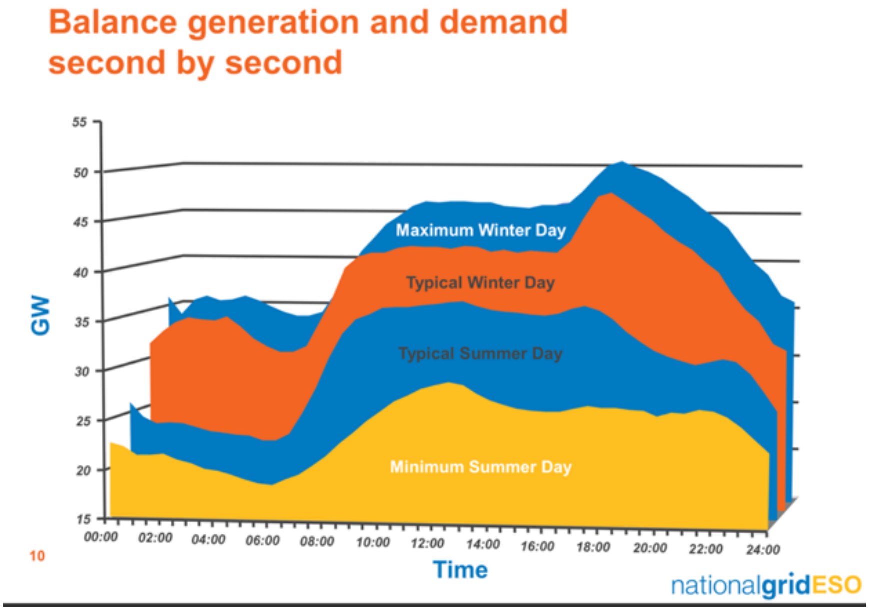
Commercial operation and challenges. Jian Sun

Jian started his talk by summarising the role of the National Grid, which includes balancing the GB system, configuring the GB transmission system, operational planning and managing Connection and Use of System Agreements with generators, suppliers and distribution companies.

He explained that they work with two main markets: the Retail Market manages the sale and purchase of electricity between consumers (customers) and retailers (suppliers) while the Wholesale Market deals with the sale and purchase of electricity between suppliers and generators, and is designed to encourage competition. The timescales for trading electricity are shown opposite.



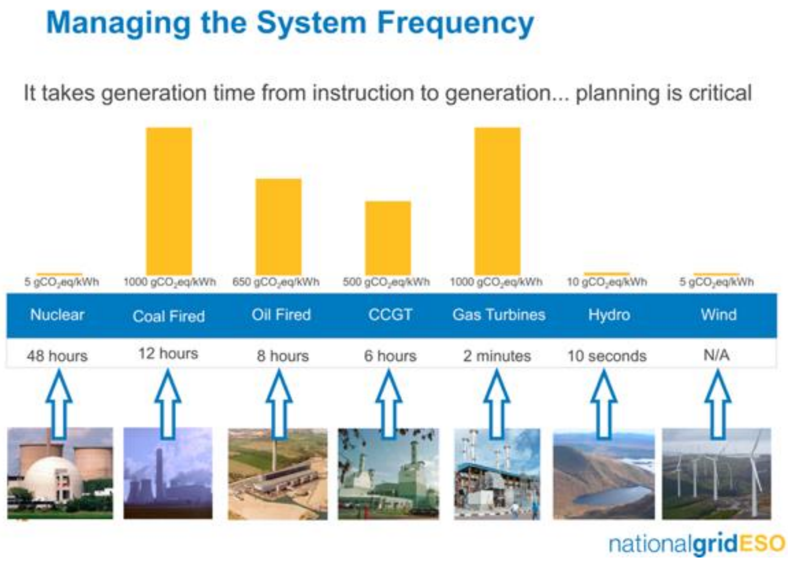
The National Grid's role as Electricity System Operator requires it to ensure that generation and demand are aligned in the short term (energy balancing); to ensure that sufficient generation is available to meet likely demand (margin, foot room); to ensure that the balance of generation and demand will remain within acceptable boundaries following unexpected changes (response/ fast reserve); and to contain the flow of energy around the system within the limits of the in-service transmission equipment (constraints).

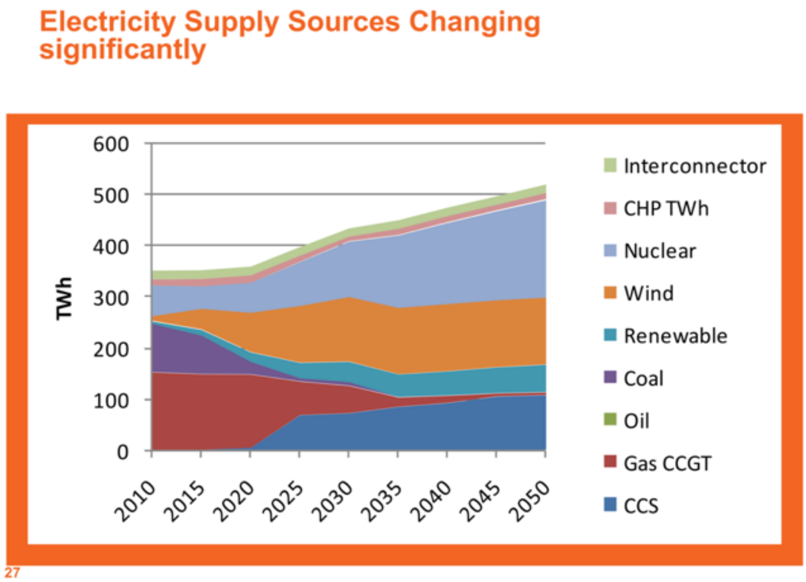


The system operator has two key roles: managing electricity flows across networks, and balancing generation and demand. If the two are not in balance, the frequency will be affected: the target is to maintain a frequency of 50Hz +/- 0.5Hz. This requires the ENCC to balance generation and demand ideally 'second by second', as shown opposite. In practice, sudden changes in supply capability such as the loss of an interconnector link, large generator or converter unit will take the frequency near to the lower limit.

If significant changes in generating capacity are required, this can take time to bring on line. The diagram opposite shows the lead times for different types of power generation – advance planning to meet expected levels of demand is vital.

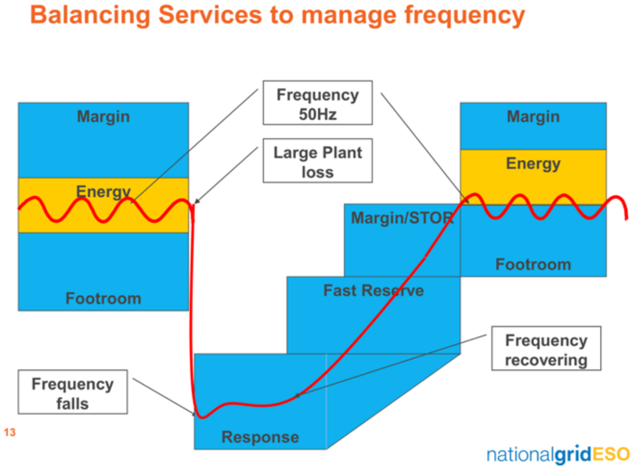
Given more time we would have liked to learn exactly how the inherent unpredictability of wind and solar power (likely to be 40% of annual energy provision in 12 years' time – see below) fits in with this plan.

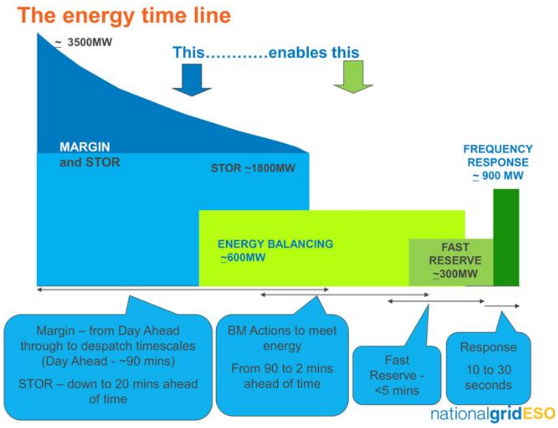




He produced an interesting chart showing the projected changes in sources of electricity (opposite). This appears to have some remarkable assumptions, including the growth in nuclear power generation and the significant adoption of CCS (carbon capture and storage) – not in itself a means of power generation, but enabling the continuing use of generators burning fossil fuels, as well as the continuing expansion of wind farms. It will be interesting to see how accurate these forecasts prove.

If a main generator fails, the frequency will fall dramatically and rapid action is needed to recover the position, as shown below left. The timelines for the different types of energy management are shown below right. Note that STOR= Short Term Operating Reserve.

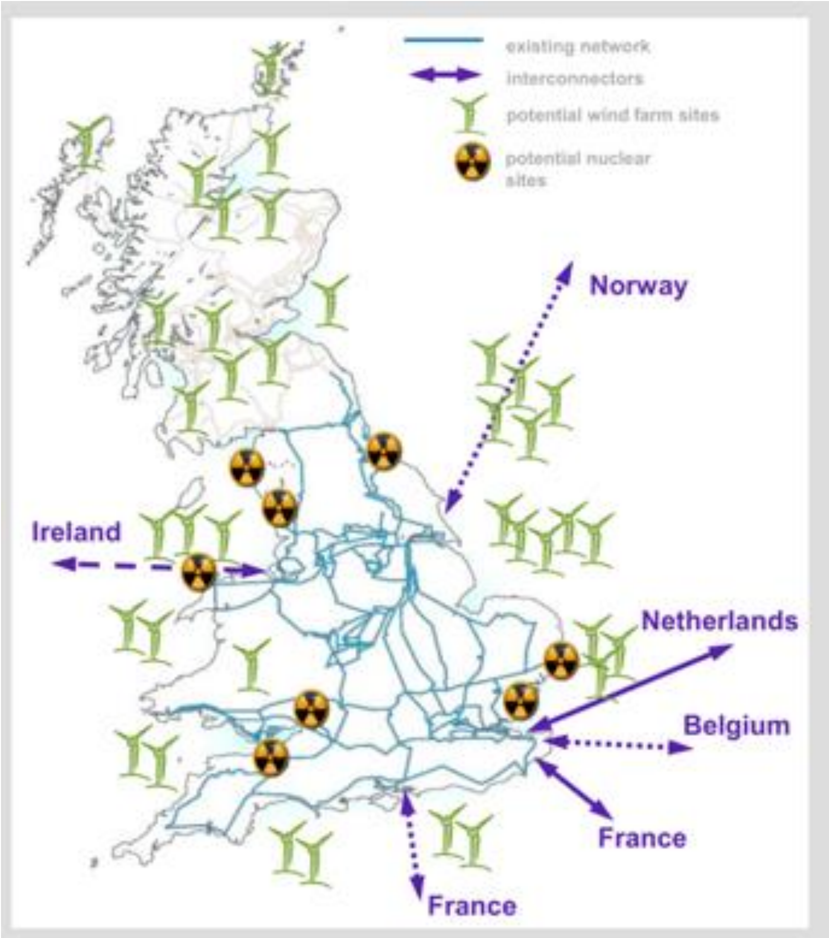




The control centre also has to manage electricity flows across the national networks, taking account of constraints such as: thermal; voltage; stability; fault level limits (limit on number of machines in an area that can be synchronised without overstressing switchgear); response and reserve limits (limits on generation in a localised are due to potential for simultaneous loss of power infeed from a likely fault).

It is interesting to note that the main parameter used for load balancing is keeping the frequency within 50 +/- 0.5Hz, with generation capacity/ load shedding being marshalled accordingly.

Finally he discussed the role of interconnectors enabling electricity to be imported to/ exported from Great Britain. These are shown opposite, together with the sites of potential wind farms and nuclear reactors.



ENCC Viewing Gallery

These pictures illustrate our visit to the Grid Control Room taken from the viewing gallery.

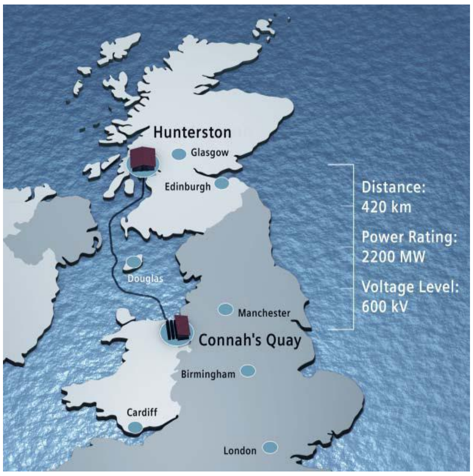
Our hosts were on hand to field the large numbers of questions arising.

High Voltage Direct Current (HVDC) links

Murray Yelland then gave us a presentation on the Grid's HVDC links, principally concentrating on the Scottish links. He started by outlining the two links that have been/are being installed to carry excess renewable power generated in Scotland. One of these is the 'Western link' installed between Hunterston (in Ayrshire) and Flintshire Bridge (North Wales), and the other is the Caithness to Moray link.

Western Link HVDC

- Increased Wind Generation in Scotland.
- Scottish export limit to be improved by Series Compensation of AC lines and addition of submarine HVDC. (West and East)
- NGET and SPT formed joint venture NGET/SPT Upgrades Ltd., to develop the project "Western HVDC Link". (Bootstrap)
- Converter Stations at Hunterston and Kelsterton
- Connah's Quay 400 to replace Deeside.



The Western Link (opposite) is 422km long (of which 385km is underwater), can carry 2200MW at +&-600kV dc relative to earth and uses thyristor LCC technology. It went operational in December 2017 initially carrying 900MW. It was supplied by Siemens at a cost of £1.2b including the undersea cable supplied by Prysmian.

Caithness – Moray (Route)

The Caithness to Moray link is much shorter with 160km underwater, and uses VSC/IGBT technology at + & - 320kV dc . It is scheduled for live operation at the end of 2018 and is being supplied by ABB for £500m. A further £600m is being spent to enhance the associated supply networks, substations etc.

Why HVDC?

It is interesting to note that AC was originally chosen for HV transmission (125 years ago), because it was easy and efficient to step the voltage up and down at each end of the link. With the advent of power electronic devices, it is now feasible to use HVDC. This has the following advantages:-

a)Enables different networks operating at different frequencies to be inter-connected

b)Overcomes problems with phase and stability of independent national networks

These two advantages are not relevant for links within the UK, but the following are

c)More efficient use of a given size cable (peak to peak voltage of AC = 2.8 times RMS)

d)No impedance due to Capacitance (and inductance). This is significant for long transmission lines

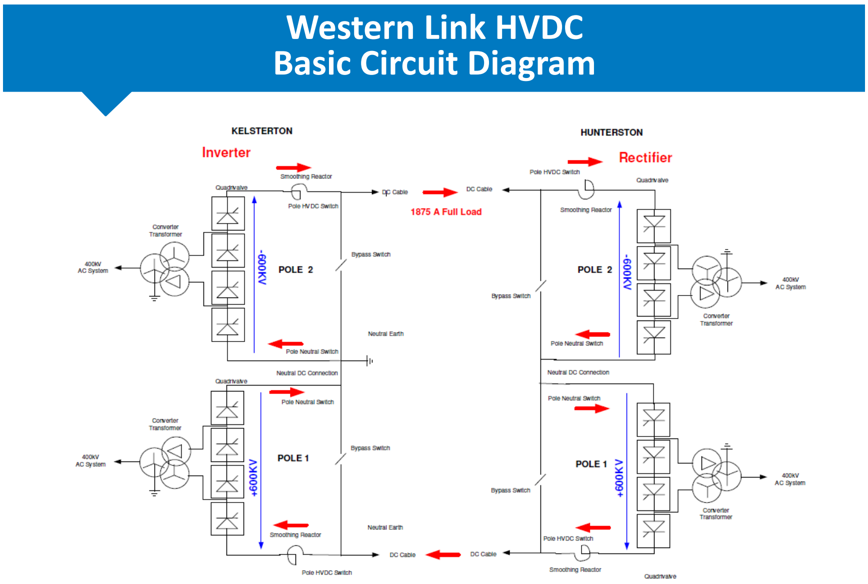
e)No skin effect or corona losses

Advantages c, d,and e imply that, ignoring the terminal electronics, HVDC transmission lines are cheaper. ABB quote an example of a 1200MW overhead line running at 400kV. AC would need two sets of 3 cables at 1200 mm^2, whereas the DC equivalent only needs 2 cables at 1620 mm^2 - a saving of more than half in metal conductor material. The pylons are also smaller, and fewer. However because of the cost of the electronic converters, there is a break-even distance that must be exceeded before DC becomes cheaper – 600km for overhead, but for underground/ underwater cables this falls to 50km.

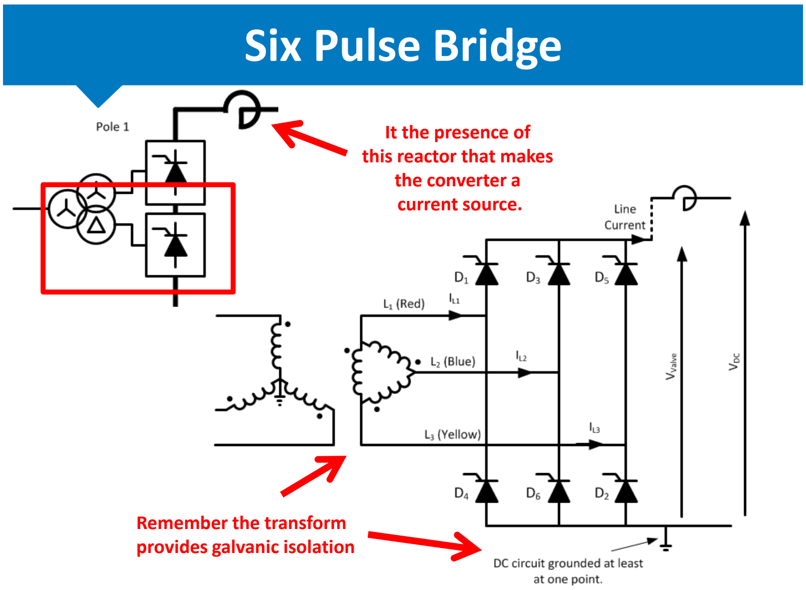
f)Easier to control short circuit currents by (instant) electronic means.

The choice of overhead or underground/underwater is also partly determined by visual intrusion arguments.

Electronic convertor technology

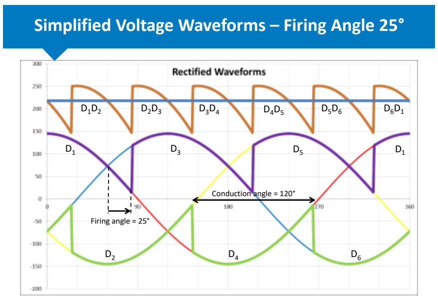


The Western Link uses Thyristor bridges – see opposite. These are simplified diagrams, in that each thyristor symbol represents stacks of hundreds of thyristors,

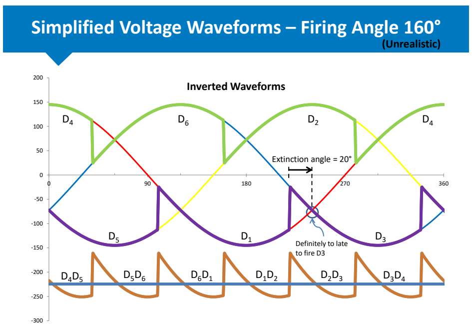


The thyristors are connected in 3 phase (6 pulse bridges) as shown opposite.

Note the presence of the large reactor on the DC output side turning the convertor into a current source.



These two diagrams show the rectified DC voltage waveform containing significant harmonic content. However the distant inverter effectively sees a steady current smoothed by the series reactors in the main DC loop.



The distant inverter is connected (via transformers) to a ‘stiff’ AC supply system (presumably 400 or 275kV?) enabling it to be line commutated. An alternative system is being used for the Caithness to Moray link – see later.

The above description attempts to simplify things. In practice the following extra observations should also be noted:

a)The transformers feeding the rectifier have associated leakage impedances which will delay the transfer of current from one pair of thyristors to the next.
b)The AC current waveform approximates to a series of square waves, which by definition have a very high harmonic content (which is bad news for many externally connected devices) so a given amount of these harmonics have to be absorbed by an extensive local network of filters mounted in the AC yard.
c)In order to take some of the load off the filters, the AC is supplied to its respective bridge via a transformer with 2 sets of windings connected with one in Star and one in Delta, thus splitting the square wave into 2 portions with a 60 degree phase shift.
d)Because the firing angle represents a phase delay in the current waveform, there is appreciable reactive current.

Voltage Source Converters/ Insulated Gate Bipolar Transistor (IGBT) technology

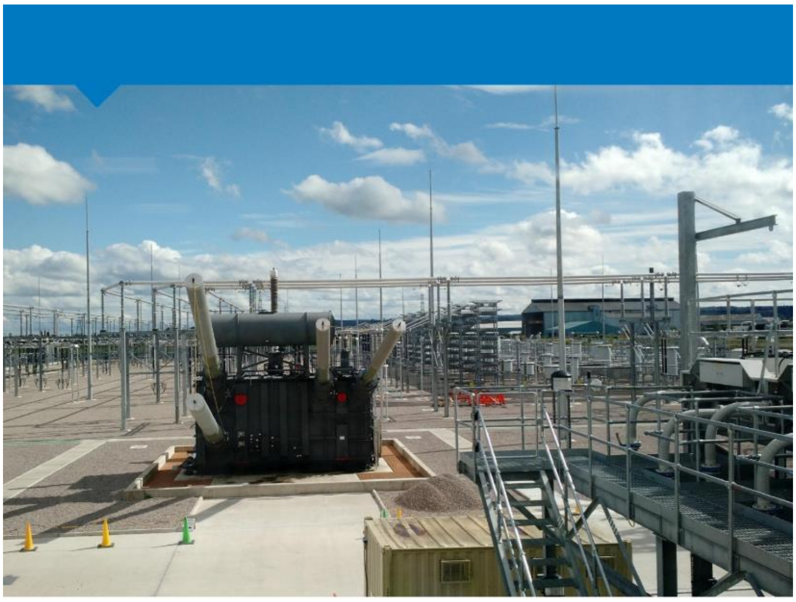
IGBT technology has been chosen for the Caithness to Moray link. It was not fully discussed during our visit, but essentially uses high voltage power transistors capable of rapid switching to both on and off states. These did not exist when thyristors first came into existence. The rapid switching makes it possible to synthesize a voltage waveform that approximates more nearly to a sine wave (hence lower harmonic content) and additionally does not rely upon an externally provided AC waveform to feed into.

Operating experience of the Western link.

The terminal equipment itself is well proven technology and so far has not given any real problems, (although there has been one occasion when a fault in the inverter effectively presented a short circuit to the rectifier, causing a brief but heavy network overload, before the fault current was cleared.)

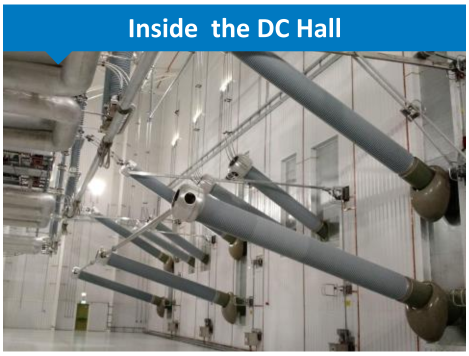
The main faults seen so far have been associated with the cable, which represents cutting edge technology. There have been two underwater faults near the southern end of one of the cables. Apparently a technician on the cable laying ship actually noticed a residue on the cable as it was being laid! But the cable laying ship continued on its journey, and it was only when made live that the fault was confirmed. There has also been a mechanical fault in the other cable – but this was due to an unfortunate hitch in the laying operation.

Another observation relating to the cable is the remnant charge that can be left in the cable when the DC source is disconnected. The capacitance in the cable can retain several kV, and steps have to be taken to safely discharge this before the cable can be worked on.



The AC yard for one of the Western Link converters is shown opposite.

Left is shown one of the DC reactors and right the transformer bushings for one of the star delta transformers; the star point can clearly be seen in the form of the short horizontal rod nearest the floor.



Our thanks go to Tianyu, Jian and Murray for being such welcoming and enthusiastic hosts.

Perry Eastaugh and Mike Wooldridge

Talk
Tuesday 9th October 2018 – "Artificial Intelligence and the Two Singularities"

Calum Chace

Our presenter is a best-selling author of fiction and non-fiction books, focusing on the subject of artificial intelligence. His work includes two non-fiction books about the promise and the challenges of AI ("The Economic Singularity" and "Surviving AI"), and a techno-thriller novel about the first superintelligence ("Pandora's Brain"). Calum is a regular speaker on artificial intelligence and related technologies and runs a blog on the subject at www.pandoras-brain.com. Before becoming a full-time writer, he had a 30-year career in journalism and business, in which he was a marketer, a strategy consultant and a CEO. He maintains his interest in business by serving as chairman and coach for a selection of growing companies.

The following text is a short synopsis of Calum's talk. He began by describing the two singularities:-

The technological singularity is the moment when (and if) we create an artificial general intelligence which continues to improve its cognitive performance and becomes a superintelligence. Ensuring that we survive that event is probably the single most important task facing the next generation or two of humans – along with making sure we don't blow ourselves up with nuclear weapons, or unleash a pathogen which kills everyone.

If we secure the good outcome to the technological singularity, the future of humanity is glorious almost beyond imagination. As DeepMind co-founder Demis Hassabis likes to say, humanity's plan for the future should consist of two steps: first, solve artificial general intelligence, and second, use that to solve everything else. "Everything else" includes poverty, illness, war and even death itself.

The stakes in the economic singularity are not so high. If we find ourselves in the "gods and the useless" scenario, or if our societies collapse as we fail to transition from modern capitalism to something more suitable for the new world, it is unlikely that every human will die. (Not impossible, though, as someone might initiate a catastrophic nuclear war.) Civilisation would presumably regress, perhaps drastically, but our species would survive to try again. Trying again is something we are good at.

On the other hand, if it is coming at all, the economic singularity is coming sooner than the technological singularity. No-one knows how long it will take to build an artificial general intelligence, but it looks tremendously hard. It is probably only a matter of time, but that time may well be quite a few decades. The economic singularity is likely to be with us in two or three decades, and it is likely that large numbers of people will understand that it is coming in around a decade or so, when they see fully autonomous vehicles displacing human drivers. That could lead to a panic, and to some very dangerous populist politics, or worse.

Relatively speaking, then, the technological singularity is more important but less urgent, while the economic singularity is less important but more urgent.

There are many reasons to be excited about artificial intelligence and what it will do for us and to us. In particular, people are concerned about privacy, transparency, security, bias, inequality, isolation, killer robots, oligopoly and algocracy. But none of these concerns refer to phenomena which could, if mis-handled, throw our civilisations into reverse gear, or even destroy us completely. The economic and technological singularities could do that if we are foolish and unlucky.

Relinquishment won't work

Impressed by the dangers attending the two singularities, you might think it would be a good idea to call a halt to further development of artificial intelligence research, either permanently, or simply for long enough to allow us to work out how to ensure that both events are beneficial. Unfortunately this is impossible.

First, we would not know what research to pause. Improvements in the performance of AI comes from many directions: chip design and manufacture, algorithm development, the accumulation and statistical analysis of data, to name but three. Unless we could arrest pretty much all scientific and technological research, we could not be sure that someone, somewhere, was not working on something which will advance AI.

Second, the incentive to develop and deploy a better AI than the competition is literally irresistible. For companies like Google and Facebook, who are leading the way in AI research, it is a matter of critical commercial performance in the short term, and of economic survival in the medium and long term. For military commanders it is quite literally a matter of life and death. Even if by some miracle all the world's leading politicians could be gathered together and persuaded to sign a joint declaration that all AI research will stop, they would not abide by it. We can all agree that North Korea would cheat, but who would be so naïve as to think that their own government would not do the same?

If it is possible to create an artificial general intelligence, it will be created – and it will be created as soon as it becomes possible.

The same applies to the technologies required to render most humans unemployable.

The role of the tech giants

Google, Facebook, Amazon, Microsoft, IBM and Apple are shaping the new world we are moving into, along with their Chinese counterparts Baidu, Alibaba and Tencent. Their motivation is partly commercial: they understood sooner than anyone else that artificial intelligence and related technologies will increasingly provide most of the world's economic value. They are moving aggressively to dominate the AI space, and competing fiercely with each other for talent and market positions.

Although I have no privileged access, it seems to me that many of the leading figures in this industry are also motivated by something else: a belief that the future will be better than today, and an impatience to make it arrive faster.

The idea that artificial intelligence is improving quickly is now firmly in the public mind. When self-driving cars become common, smartphones are capable of sensible conversations, and domestic robots can carry out many of our domestic chores, people will increasingly ask where it is all heading. In the absence of optimistic answers, they will gravitate towards the bad ones, and Hollywood has given us plenty of those.

We need potent new memes, illustrating the current benefits and the future promise of AI. The tech giants are creating this new world; even if only for their own self-preservation, it would be a good idea for them to explain how it is capable of being a glorious new world.

What should I study?

The question that young people (and their parents) naturally ask about the economic singularity is, how can I best prepare for the economy that we are moving towards? It's an important question for me, too: at the time of writing my son is 16.

The obvious answer is to study computing. Computers are at the heart of the changes sweeping the world in the information revolution, so it has to be valuable to understand how they work and what they can and cannot do. If possible, study machine learning, and in particular, deep learning. It seems a safe bet that these powerful techniques will remain important for years to come. Carrying out maintenance, supervision or development of hardware or software may keep you in a job for longer than most.

In the long run, however, if the argument of this book is correct, a majority of us are likely to be unemployed. It may well be an advantage for a while to be rich, but if we manage the transition successfully, that may become less important and less worthwhile. And if we don't … well, let's just say we have to.

Beyond the economic singularity you're going to want to have as rich an interior life as possible, so give yourself as broad an education as you can. Studying your own and other people's languages will give you insights into how our minds work. Studying sciences will give you insights into how the world works. And studying the humanities will give you insights into how societies work. All of these should make what could be a very long life an interesting one.

The most important generations

Every generation thinks the challenges it faces are more important than what has gone before. They can't all be correct. American journalist Tom Brokaw bestowed the name "the greatest generation" on the people who grew up in the Great Depression and went on to fight in the Second World War. As a "baby boomer" myself, I certainly take my hat off to that generation.

Speaking at the United Nations in 1963, John F Kennedy said something which would not sound out of place today: "Never before has man had such capacity to control his own environment, to end thirst and hunger, to conquer poverty and disease, to banish illiteracy and massive human misery. We have the power to make this the best generation of mankind in the history of the world – or make it the last!

Today's rising generation is the Millennials, born between the early 1980s and the early 2000s. They are also known as Generation Y, and the one after them, born from the early 2000s to the early 2020s, is provisionally called Generation Z. Let's hope that is not prophetic in a bad way.

The Millennials and Generation Z have been born at the best time ever to be a human, in terms of life expectancy, health, wealth, access to education information and entertainment. They have also been born at the most interesting time, and the most important. Whether they like it or not, they have the task of navigating us through the economic singularity of mass unemployment, and then the technological singularity of super-intelligence. If they succeed, humanity's future is almost incredibly good. If not, it could be bleak. It will fall largely to them to plot the course, adjust it where necessary, avoid the rocks and the cries of the Sirens, and bring the ship safely home.

Following a short break for refreshments, Calum fielded a multitude of questions that his talk had provoked on subjects as diverse as population growth, machine learning, the practicalities of a universal basic income, transition to a low priced economy and the historical inability of man to forecast the future to any degree of accuracy.

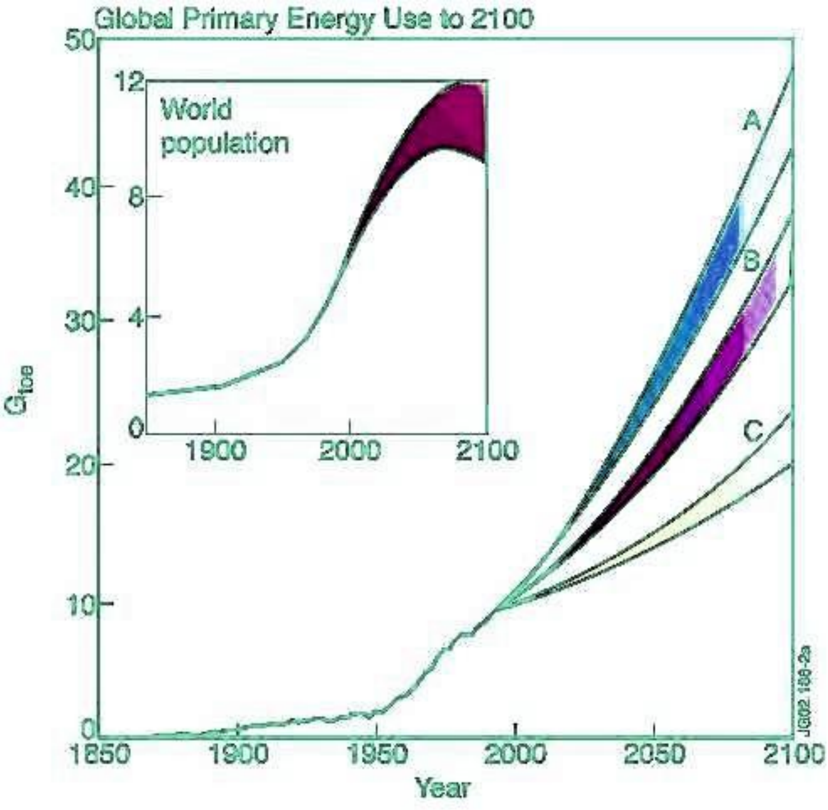
From the turnout that this talk had achieved, it was clear that this topic was of considerable interest to our members.

Talk

Tuesday 13th November 2018 – "Fusion Power – within our grasp?"

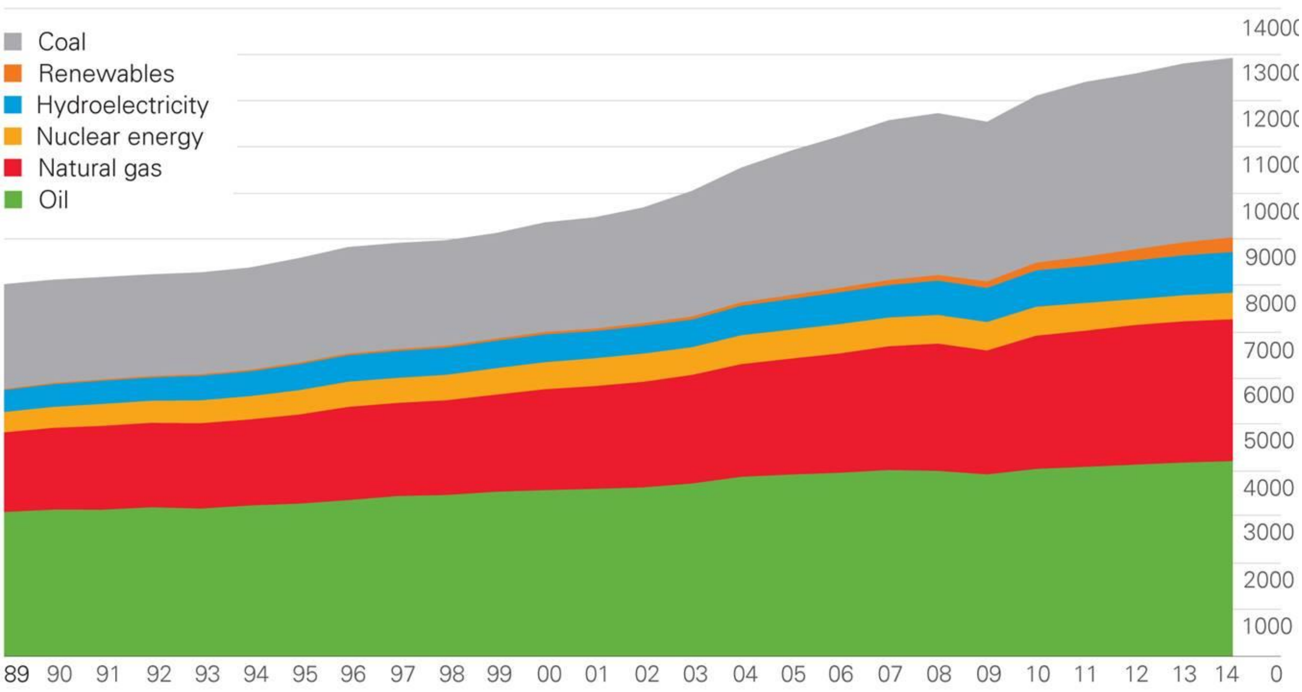
Cooch memorial lecture by Robin Stafford Allen.

Our speaker , Robin, started his talk by showing projections for world population growth over the next 80 years (shown opposite), and more worryingly, energy use per capita over the same period, which could triple (the three curves labelled A, B &C represent most pessimistic, mean and most optimistic estimates respectively).

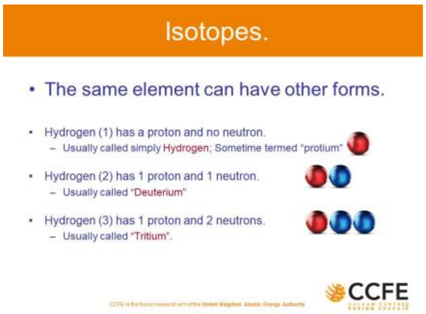


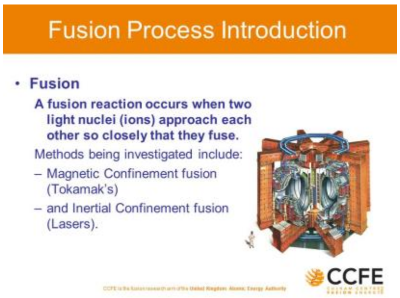
This was followed by a slide (below) showing where this energy has come from up until 2014 – predominantly fossil based. However the days of fossil fuels are limited, as also are the days of easily-accessible uranium for fission power.

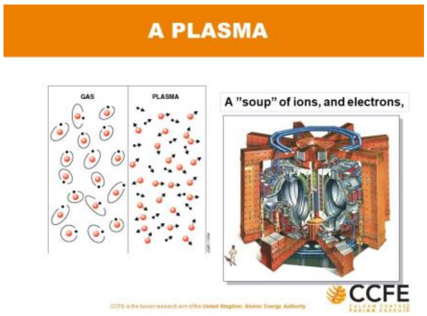
Robin also believes that renewables are a distraction, and hence predictably is a strong supporter of nuclear fusion power – the process used by the sun. It's also clean. (Interestingly after the lecture, Robin strongly recommended us to read 'Without Hot Air' by David Mackay. Subsequent reading of the book's synopsis available as a free download, does however identify a strong future role for desert solar pv).



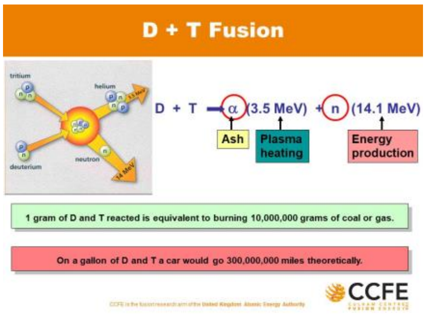
Our speaker then gave us a short tutorial on the fusion process, which is shown in the next three sets of illustrations.

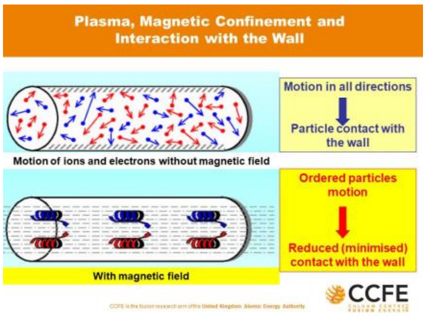


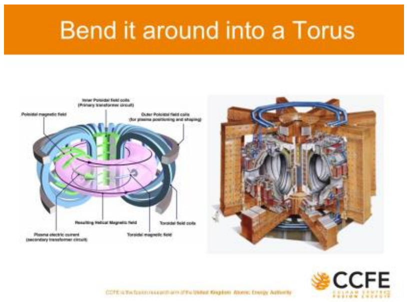




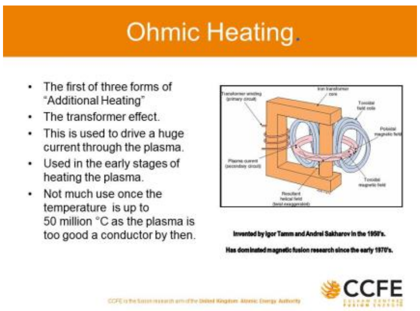
The fusion process starts with hydrogen, or more accurately, its' isotopes. Not all isotopes are stable and some, such as Tritium, decay or change during their life. Tritium has a radioactive half-life of 12 years, as compared to Plutonium at 24,500 years. All gasses become plasmas above 6000º C, and cold plasmas can be seen in fluorescent lights and the like. For Fusion to occur, the speed, and therefore "temperature" of the nuclei, must be very high to allow impact of the material and a fusion reaction. The neutrons released during fusion must be stopped in Lithium blankets to create usable heat energy (and more Tritium).

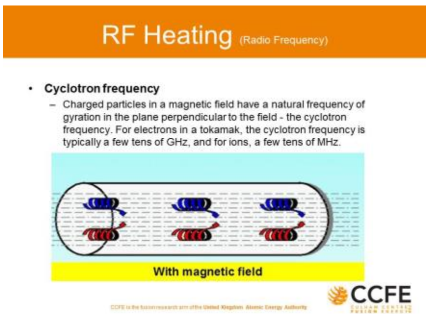


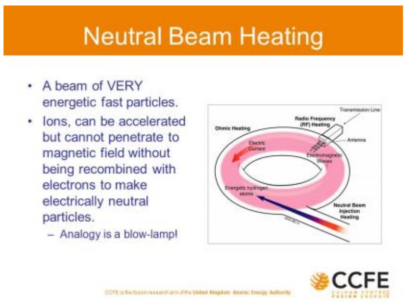




It will be noted that a key component is deuterium- extracted from heavy water, of which the world oceans have a 'limitless supply'.
A fusion reaction is about four million times more energetic than a chemical reaction such as the burning of coal, oil or gas. While a 1,000 MW coal-fired power plant requires 2.7 million tons of coal per year, a fusion plant of the kind envisioned for the second half of this century will only require 250 kilos of fuel per year, half of it Deuterium, half of it Tritium.
There are two approaches to the fusion process; one features a plasma contained in a magnetic field contained in a torus (Tokamak reactor) and the other (inertial confinement) uses a burst of laser beams focussed on a series of fuel pellets– each of which is the size of a peppercorn. The USA has put a lot of effort into the latter, but although it works, the time taken to recharge the capacitors to drive the required 192 lasers currently takes far too long to make the process commercially viable.

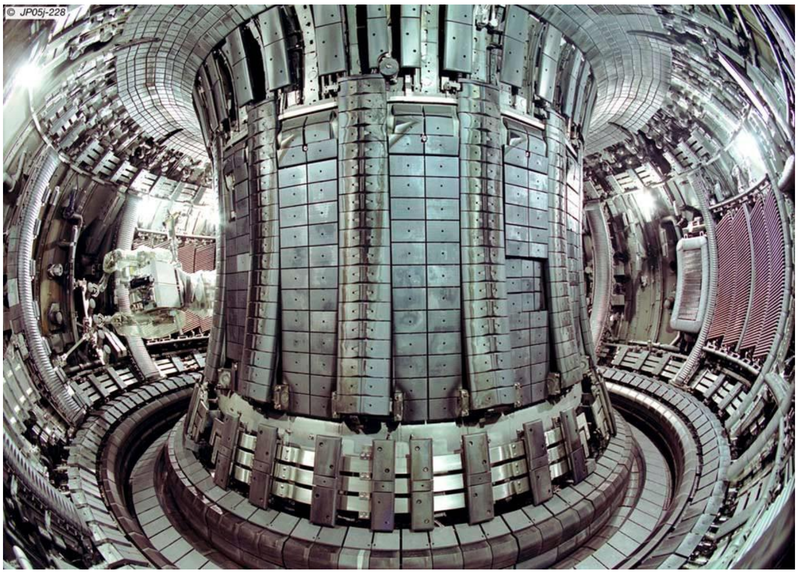






The above diagrams illustrate the different approaches to heating the plasma.

From the foregoing it can be seen that the Tokamak reactor is currently the best bet, which brings us neatly on to JET, the largest Tokamak based in Culham.



The picture opposite shows the inside (working part) of JET.

Over the first 20 years of JET, progress was amazing to the peak of the Tritium experiment in 1997. A peak power of 16 MW of fusion power was generated for 2 seconds, a record that still stands today. 16MW of power pulse had a neutron yield of 5×10^{18} for the whole pulse and every sq cm of the tiles saw 2.5×10^{12} neutrons, that's 2.5 million x million impacts per sq. cm.

On the wall of the torus hall, about 10 times further from the centre of the device, the bombardment was around 2.5 thousand million per sq. cm.

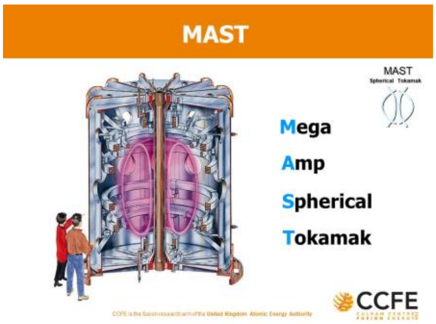
At the peak of a pulse the JET site can draw 1000MW from the 400 kV grid. This would brown-out Oxfordshire so we have an energy collection system in the form of 2 flywheel generators.

Each is nearly 10 metres in diameter and weighs in at 775 tons. These are spun up to 225 r.p.m. in the 10 minutes just before the pulse and then together give around 400-600 MW for the duration of the pulse (one minute or so) powering the TF and PF coils with controlled DC in particular.
Even so we have to alert the National Grid Control Room and get permission just before each pulse, and several times a year they inhibit our operation, usually because it is the commercial break in a TV soap, or one of their power stations is off-line, so they do not have spare capacity.

If you monitor the frequency of the mains, the change during each pulse is observable.

The pony-motors that spin the flywheels are each rated at 8 MW and to keep a flywheel spinning at 225 r.p.m. takes 3 MW mainly due to air resistance.

Although JET has, and still is, a useful step in the development of fusion, a major group of nations reflecting over half the world's population (China, EU, India, Japan, South Korea and USA) are now funding ITER – a larger experimental Tokamak being built in France, with a design aim of routinely releasing 500MW of fusion power.



The Tokamak path started with JET at Culham, then MAST (a more efficient so-called spherical Tokamak – ie it is not such a spread-out doughnut shape as JET) show on the left, and finally ITER shown under construction on the right.

Before leaving the subject of funding, it is worth noting some politics. Firstly there was a very long delay (years) whilst politicians agreed the funding and location for ITER. Robin bemoaned the fact that politicians tend to think not much further than the next election; this can lead to a tragic delay in what must surely be a key technology for providing future energy for the World. Secondly we were told that Trump, in response to the oil lobby, wants to withdraw USA ITER funding. But thankfully, it seems that the original agreement was sufficiently well worded to make this impractical.

There have been various technical challenges along the way. The three main ones seem to have been:

1. Instability of the plasma ring. This can lead to sudden collapses within the torus called 'disruptions' (cf sun-spots). This produces enormous forces which make a 'loud bang', and can lead to the local seismic recording station north of Oxford, having to re-calibrate its instruments! Amazingly, the events do not seem to cause damage to the torus itself, and in any case the process is better understood now and is (nearly?) fully under control by the use of fast acting (milliseconds) control circuits coupled to very large circular conductors in the same plane as the toroid and producing a strong magnetic control field.

2. The challenge of getting enough power to a) produce and maintain a large magnetic field to contain the plasma and b) produce enough heating to form and maintain the plasma itself. The aim is to reach self sustaining 'ignition'). Superconductors were not discovered/sufficiently developed when JET was built, and so copper was used. Culham only has a 400MW Grid supply, so, in order to provide the necessary power, albeit for a relatively short period two large flywheel generators were installed as described above.

3. The need for suitable materials to line the torus. This has to withstand the radiation from the plasma, which gets worse as the reactor gets larger. Currently replaceable tiles are used – initially made of carbon, then beryllium was tried, and then carbon plus carbon fibre. These are open to the criticism that they have to be replaced too often.

Intensive research into new materials is being carried out at Culham, and sintered materials using metal oxides are showing promise. In addition to the tiles there is a lithium blanket which absorbs the heat energy and thus produces steam for turbines.

Robin was keen to stress his optimistic outlook for Fusion power, and, by way of example, quoted what has happened to aircraft and engine development since the Wright brothers made their first flight. Of course, in the case of fusion power, incremental developmental steps cost more and can be spaced out in years or decades – but the observation was surely well made.

During questions, Robin was asked whether there were any potential 'show stoppers'. He thought not, though it would be nice to get longer lasting tiles to line the Torus. He re-iterated that the only radio-active waste is tritium with a half life of 12 years; hence it becomes relatively harmless after say 100 years. The other potential show stopper, or slower-downer, is funding/ lack of political drive. Robin talks about 'the world paying lip-service to fusion power development' and quotes, by way of example, investment in the Manhattan war time project (atomic bomb development). At its peak this used 0.4% of USA GDP. If the UK alone invested 0.4% of our GDP in nuclear fusion we could have 4 ITERs in 10 years.

Other observations noted during the talk:

a)Hydrogen can easily be produced from the process, and is therefore of interest to a potential 'hydrogen economy' where hydrogen is used as the energy transmission medium.

b)ITER uses low temperature (2°K) superconductors, requiring liquid helium cooling. The conductors are 1.5mm diameter and carry 350A. They still possess a small resistance of a few nano-ohms over their length of 30Km! There ae now superconductors which work with liquid nitrogen cooling.

c)Robin has also been involved with superconducting magnets for MRI scanners. Apparently the design spec uses the term 'field half life' (normally used for decay of nuclear radiation) to demand a current that only decays to half after a 1000 years. It has to be this stable in order to enable the scanning components to operate without re-calibration during a given patient scan.

d)We were shown a spectacular picture (below) of a self-propelled vehicle that operates (at night) between Marseille and the ITER site – about 30 km away at Cadarache. It has 352 wheels on 88 axles and can carry 900 tons.

e)Unlike fission, fusion research is amazingly open. This seems to have stemmed from a frank and amazingly open meeting between scientists and engineers when Russia's President Kruschev visited the UK in 1956. The meeting was followed up by UK scientists visiting Russia to measure some high temperatures (11.5million°C); apparently we were better at this than Russia. This openness has persisted in the development of fusion power.

Overall, it was an excellent talk, from someone who, though now retired, has in depth and current experience of the fusion power scene.

Mike Wooldbridge

End of Newsletter