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**Program 111 – Liquid Air Batteries**

**As many of you know, I bang on quite a lot about how energy storage is a key to the success of distributed smart grids, and how it’s destined to unlock our sustainable energy future.**

**For most people nowadays, energy storage means one thing – a lithium ion battery. But lithium ion batteries aren’t the only way to store energy.**

**In fact, in very basic terms, if you can find a way to use energy to make something physically happen in a reversible way, then you’ve probably created an energy storage device. If I lift this hammer above my head, I’m using energy in my arm muscles to put potential energy into the hammer by keeping it up here against the pull of gravity. If I let go (and get out of the way, obviously) then that potential energy is released as the hammer falls to the ground. And if you attach a string to the end of the hammer and fix the other end to a little dynamo, then as the hammer falls it’ll turn the dynamo and generate power, albeit very briefly.**

**Engineers all over the world have been using this basic energy conversion principle on electricity grids for decades in the form of pumped hydro.**

**The only snag is that it needs a big height difference between two very large bodies of water, and that means hydroelectric solutions are severely limited by geography.**

**So, what if, instead of deriving our energy needs from moving water up and down mountains, we could just generate it out of the air that surrounds us?**

**Sounds a bit too good to be true doesn’t it.**

**But that’s precisely the principle behind a potentially transformational technology called the Liquid Air Battery.**

**Hello and welcome to Just Have a Think,**

**If energy storage really is destined to transform our electricity grids and move us away from our dependence on fossil fuels, then it needs to satisfy a few fundamental criteria.**

**It needs to be long duration, like 12 hours or so.**

**It needs to deliver enough power to actually plug the gaps in the grid at peak times.**

**It needs to be economically viable.**

**It probably needs to be scaleable and adaptable.**

**And of course, it needs to be environment and climate friendly.**

**Energy storage systems tend to have a trade-off between duration and power.**

**This graph shows two axes, with the vertical axis representing duration and the horizontal axis representing power.**

**Lithium Ion batteries typically deliver their power over a period of up to 4 hours, and the largest plant currently in existence is the Tesla 100 Mega Watt construction down in South Australia.**

**Lithium ion batteries have a really good energy density and they’re instantly responsive, so they’re brilliant at smoothing out temporary spikes in demand. But they’re still relatively expensive, and that upper limit of duration of four hours is generally considered to be the minimum time window of peak operations for most grids.**

**Above lithium ion on the graph sits a technology called flow batteries. We haven’t looked at flow batteries in detail on this channel yet, but that episode is coming soon, so watch this space.**

**Suffice to say that flow batteries can deliver their power for a longer duration but have a lower energy density and so currently only have capacities up to about 50 Megawatts.**

**Then up here we’ve got the behemoth of pumped hydro which, as we’ve already seen, gets great dollops of power from huge reservoirs, easily delivering up to a gigawatt of power for a full 24-hour period if necessary, but with the very obvious limitation of location, and by the way, just to lob in another major caveat with hydro power, where massive dams are built within the more delicate ecosystems around the world like in the Brazilian Amazon or as the Chinese are doing in places like Thailand and Vietnam, then the huge scale of construction and the diversion of water can completely upset the ecological balance of that area and cause great damage or even extinction for vulnerable animal species, not to mention taking away vital water supplies for indigenous human beings further down the river.**

**Anyway, back to the point.**

**The target space on this graph for liquid air batteries is up to 12 hours duration with a power output above 25 megawatts, which puts them somewhere in here.**

**The leading exponent of this fledgling technology is a UK company called Highview Power. Back in January 2020, Highview teamed up with power station developer Carlton Power to commence development of an 85 million pound, 50 megawatt liquid air battery facility in Manchester in the North West of England, backed by a ten million pound grant from the UK government and a 35 million pound investment from the Japanese Sumitomo group.**

**Highview say the this pilot plant will provide enough extra stored energy to power 200,000 homes for five hours at a time. Their design philosophy is heavily based on use existing, off the shelf, components, which means they can buy all the kit from Original Equipment Manufacturers, or OEMs with decades long proven track records of performance in similar industries. That also means they get the benefit of many years of field experience that those manufactures have gained, plus the assurance of warranties and all that good stuff.**

**The components are modular and scaleable, allowing systems to be constructed anywhere in the world at sizes of anywhere between 5 megawatts and many hundreds of megawatts if needed. And the capital start-up costs are very low, which always puts a smile on the faces of Brian and Colin in the corporate spreadsheet department.**

**From an environmental point of view, the system doesn’t use any scarce resources, doesn’t have any toxic components, and doesn’t give off any emissions.**

**All sounds pretty good so far doesn’t it?**

**So how does it work?**

**Well, the first part of the system is a large industrial air liquefier, a technology that’s been used for over a hundred years to produce gas products by distillation.**

**The liquefier draws in ambient air and cleans it up by stripping out moisture and carbon dioxide. Then it’s cooled down to extremely low, cryogenic, temperatures that condense the air into a liquid. That liquid looks and acts quite a lot like liquid nitrogen, because that’s what air is mostly made of. It’s 700 times more dense than the atmospheric air we breathe and it emerges from the process at about 15 times atmospheric pressure, which sounds a lot, but is actually well within operating pressures for existing gas cylinders. LPG gas cylinders for example can handle around 25 times atmospheric pressure.**

**The fluid can then be stored in well insulated, thin walled steel vessels that can be safely kept above ground, avoiding the need for complex and costly underground construction.**

**Then when there’s a demand for power from the grid, the liquid air is released from the containers and pumped up to higher pressure using a cryogenic pump. The surrounding ambient air temperature makes the liquid boil and turn back into gas that can then be passed, at high pressure, across a turbine to drive a synchronous generator and put electricity back onto the grid.**

**So, the basic principle is attractively simple, but to optimise efficiency, the system also recovers the heat of compression on the refrigeration system and uses that to extract more energy from the liquid in the tanks, and then when the air is raised to ambient temperature, the cold is also captured and stored, to be used later to do quite a lot of the cooling back at the initial refrigeration stage.**

**The hot and cold stores are also thin walled steel vessels, so all of the energy storage components are basically just a volume of tankage. Over many years of testing and development, the company has managed to achieve a round trip system efficiency of about 60%.**

**So, we’ve got 3 stand-alone system components that are completely independent from one another. That means if there’s a need in the future to increase the duration of the system, they only really need to add more storage tanks, which are cheap.**

**And if they need to up the power that the system delivers, then the economy of scale they’ve already achieved, means that as a rough rule of thumb, doubling the power output of the system adds only 50% to the system cost, compared to 100% if you were to do the same thing with lithium ion batteries for example.**

**Long Duration energy storage like this have major benefits for modern grids with significant reliance on intermittent power from renewables like wind and solar.**

**Perhaps most significantly, they help alleviate a problem called curtailment – something that represents a constant challenge for grid operators. We won’t dive too deeply into the technicalities here but essentially, because electricity is the movement of electrons, then that movement has to be used to produce power at precisely the time when it’s being generated.**

**With fossil fuels, if you need energy, you burn fuel. And if you don’t need energy, you switch the burners off. But you’ve still got the fuel sitting there in the form of coal or gas, ready for the next time you need it. With renewables like wind and solar, you need to be capturing as much energy as possible when the sun is shining, and the wind is blowing because you know your panels won’t be generating anything when it’s dark and your turbines won’t be turning on a still day.**

**But if the grid doesn’t need power when renewables are generating it, then turbines have to be switched off and solar panels isolated, which means all that free energy goes completely to waste.**

**Systems like Highview’s liquid air battery provide elegant and cheap solutions to the curtailment problem allowing the free energy from the sun and the wind to be captured and stored for very long periods and then released whenever it’s needed for as long as it’s needed, right up to 12 hours or so.**

**This graph shows comparisons between liquid air batteries and lithium ion batteries carried out in a pilot study on New York’s grid system based on projected 2025 prices.**

**The vertical axis on the left-hand side shows the Levelized Cost of Curtailment Avoidance or LCOCA measured in US dollars per Megawatt hour. The horizontal axis shows the amount of curtailment that can be avoided, measured in Terawatt hours, and as a reminder a Terawatt Hour is equal to one million megawatt hours, so it’s a big number.**

**Then over on the right-hand side we’ve got another vertical axis which shows the size of any given storage system, measured in MegaWatts.**

**The Liquid air, or CRYO battery system is represented by blue bars and lithium ion batteries are represented by grey bars, with a trend line running through all the bars.**

**And then there’s this dotted horizontal line which represents the levelized cost of energy from existing Offshore wind, which at about 92 dollars per megawatt hour is the benchmark that the operators used to assess the economic viability of new systems.**

**So, where the trend line and dotted lines cross is the optimal achievable return for the New York model. And that told the operators that they could deploy about 2 gigawatts of energy storage for the same net cost as offshore wind, which meant they would avoid 1400 giga watt hours or 1.4 terawatt hours of curtailment.**

 **The new plant in Manchester, England is due to be operational in 2022 with an expected operational lifespan of 40 years.**

**It’ll employ 200 people, including oil and gas engineers migrating across from the fossil fuel industry.**

**Planning work is already underway on other facilities in Europe and the US including a 400-megawatt hour joint venture with Encore Renewable Energy in Vermont, and design work is in progress on a gigawatt system capable of producing an output of 200 megawatts with a capacity of 1.2 gigawatt hours.**

**This is inexpensive existing technology providing scaleable solutions for future electricity grids that may well be dominated by renewable technologies, but it is by no means the only solution being developed, and we’ll be looking carefully at the various other potential alternatives in future episodes.**

**In the meantime, if you have news or views on this particular technology, then as always, jump down to the comments section below and leave your thoughts there.**

**That’s it for this week though.**

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**As always, thanks very much for watching,**

**Have a great week and remember to just have a think**

**See you next week.**