ENSTORE

Topic …….. A smart flexible energy system a call for evidence with data from Enstore -Q47

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Signed by ……. *E A Lewis* and *P M Lewis* …. Company directors

Anacronyms

- EFR. Enhanced Frequency response.
- ESS. Energy storage system.
- Fast Fault current. The provision of AC current in to an AC fault for a defined time period.
- SBSPM. Second by second performance monitoring.
- SM1 & 2. Meters for recording the SBSPM.
- PM1 & 2. Meters for recording instantaneous and average AC grid power.
- PWM. Pulse Width Modulation
- VSM. Virtual Synchronous Machine implemented in a control system

Contents

47. Innovation.

Can you give specific examples of types of support that would be most effective in bringing forward innovation in these areas?

There are two areas that would benefit from support:

- Development and validation of a Virtual Synchronous machine.

  The Reference in Appendix B has data on possible methods.

  Enstore has data on an alternative VSM design that could provide all the listed **Benefits** from one integrated technology. This new alternative method offers easier integration in to existing systems compared with other proposed VSM designs.

  Enstore does not have the resources to implement the concept but is very willing to work with a funded team to develop and validate the technology.

- Development of a UK based long duration energy storage technology.

  At present to store energy for times up to 4 hours is available from many companies who are developing designs for a four-hour market.

  The most promising technology for very long term storage is the Vanadium Redox flow cell as shown in Figure 47.1.

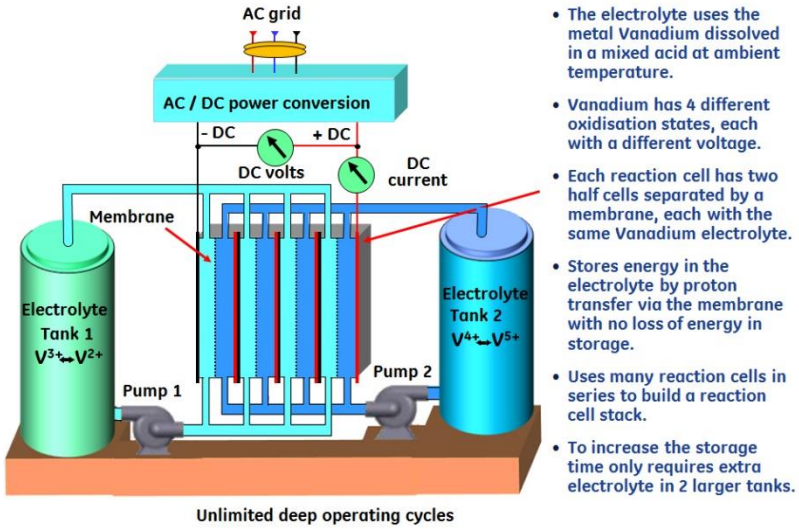

Figure 47.1

The Vanadium Redox flow cell is a viable technology based on using Vanadium as shown on Figure 47.2.

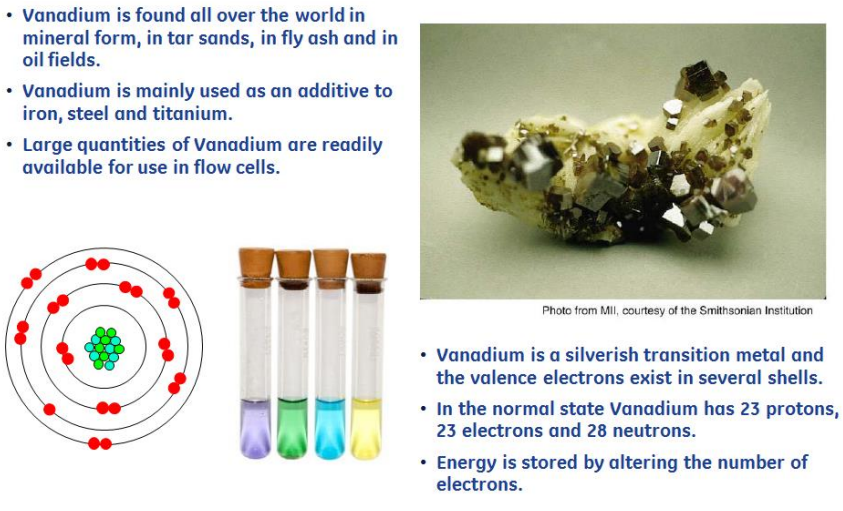

Figure 47.2

There are many advantages of this technology including:

- An electrochemical energy storage system at ambient temperatures.
- Fully reversible chemical process using the different oxidisation states of Vanadium.
- Vanadium is widely available at low cost.
- Unlimited number of deep charge and discharge cycles.
- Over 10 years of cell stack life with a milli second power response.
- The energy storage operates at the molecular level in the fluid that has infinite life.
- The standard modules define the MW rating and the storage tanks define the MWh rating.
- No materials deposited on electrodes so can have very long storage times.
- Standard module built using simple cell stacks for simple repair and servicing.
- Same fluid in both halves of each unit cell so any membrane fault does not corrupt fluids.

One disadvantage of the present designs is that the fluid is electrically conducting and if a high DC voltage is used to feed many reaction cells in series then DC currents circulate in the fluid giving lost power.

The most common way to avoid this is shown on Figure 47.3.

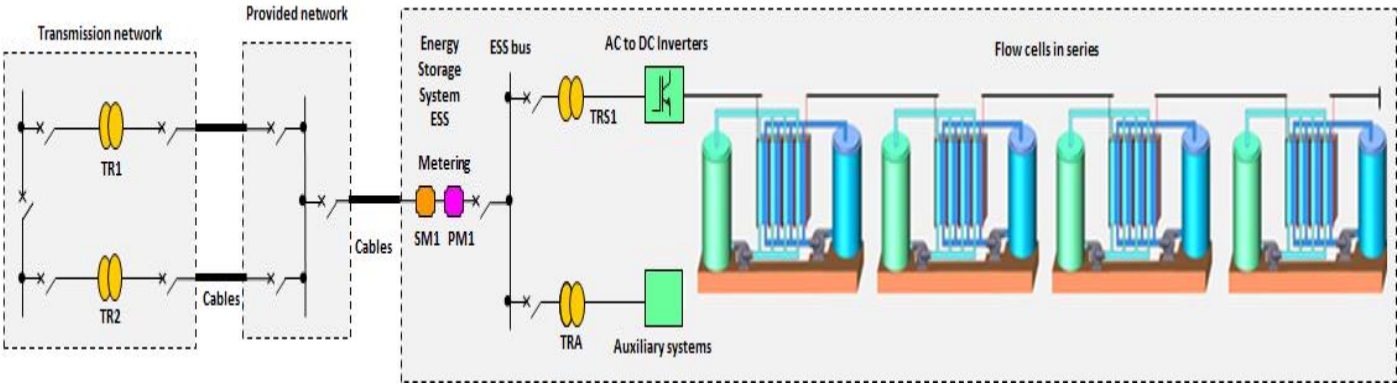

Figure 47.3

The Figure 47.3 uses set of flow cells in series to raise the overall applied DC voltage to a level that is compatible with readily available AC to DC inverters.

The main disadvantage is that this method needs many tanks and pumps all at different DC voltages that makes it very difficult to design the technology for storage times greater than 4 hours.

One way to avoid this is shown on figure 47.4.

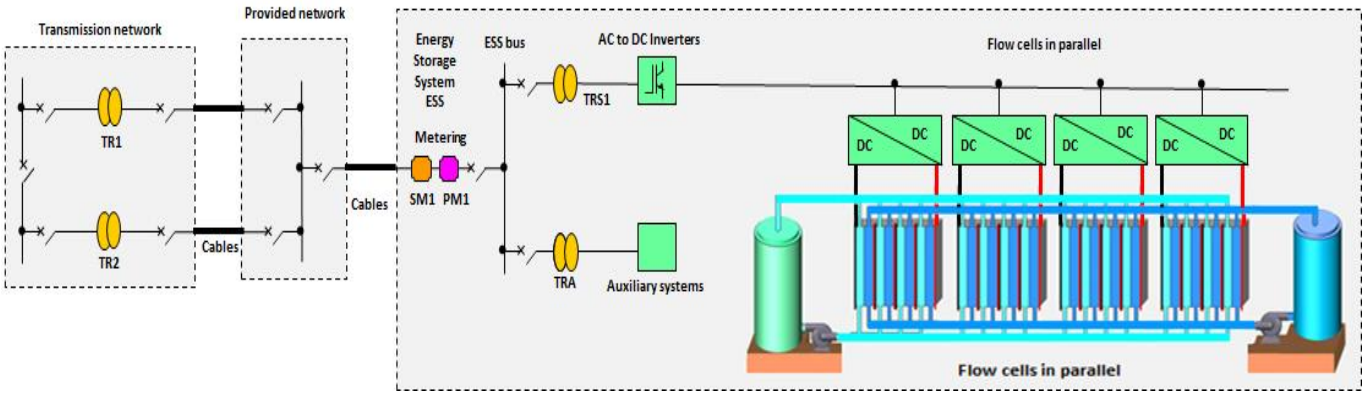

Figure 47.4

The Figure 47.4 can use many flow cells in parallel with one set of pumps and tanks. This requires the use of DC to DC converters that change approximately 50 volts DC to 800 volts DC to give an optimal design.

This concept was first presented at the Vienna Flow cell conference see Appendix B

It is possible to build a flow cell system like the Figure 47.5 that shows the Little Barford design that never went in to operation.

Regenesys' polysulfide-bromine flow battery in Little Barford, UK.

Figure 47.5

Enstore has the knowledge and contacts to implement the concept and is very willing to work with a funded team to develop and validate the technology.

This development would a world class energy storage solution able to store electrical energy for days at a high efficiency.

One possible partner is REDT flow cell suppliers at:

Research & Development
9, The Business Centre,
Molly Millars Lane,
Wokingham,
RG41 2QZ
England

Appendix A. Replacing a rotary synchronous generator

To replace a rotary synchronous generator with either an energy storage system or a renewable energy system it is essential to understand the functions provided by a rotary synchronous generator which include:

1. To provide a continuous output of electrical power in to the AC grid from the input fossil fuel up to a rated level. In most applications, this also involves working in parallel with other rotary synchronous generator by means of a power sharing control system. **Energy storage systems "ESS "can only provide this feature for an agreed duration but Renewable Energy Systems "RES" can provide this feature for as long as their energy source is available.**

2. To provide inertia support by transiently increasing the electrical output power above the fossil fuel power output by taking extra power from the generator's rotary inertia. This occurs when there is a higher load power compared with the fossil fuelled generated power. Taking power from the generator's rotary inertia causes the AC grid frequency to fall. This is an inherent action of the rotary synchronous generator developing a load angle change that typically occurs in 100 milliseconds. **The ESS & RES can theoretically achieve this function which is called Synthetic Inertia and this technology is in the development stage, see question 47.**

3. To provide a primary frequency response by increasing the electrical output power from an increase in the input fossil fuel in proportion to a fall in AC grid frequency. This requires the rotary synchronous generator to be normally operating below rated output power and is achieved in a typical time of 10 seconds by means of a governor control system. This then stops the frequency fall of item 2. **The National Grid EFR 2016 projects are required to achieve this action in 1 second. The ESS & RES can provide this action.**

4. To provide positive damping of oscillations in the AC grid power. This action comes from the currents flowing in the generator's pole face damper windings giving increased losses to damp the oscillations. The currents in the generator's pole face damper windings are zero for steady output conditions. **This is available from the ESS & RES with the VSM developments listed in Question 47.**

5. To provide extra current typically above 300 % of rated currents in to faults in an AC grid to ensure correct discrimination operation of the protective devices in isolating the faulty circuits plus when the AC grid fault has cleared the output power is resumed at the pre-fault value.
   If a high level of fault current is required from an Energy storage system, then this will need a significantly larger AC supply inverter but not a larger battery / power producer for the ESS. For Solar power RES, this Benefit can be supplied as they are ground mounted systems. For Wind power RES this feature will be very difficult to add as the room available in a tower is very limited.

6. To provide either leading or lagging reactive power by and Automatic Voltage Regulation "AVR" control system in response to changes in the AC grid voltage. This is set up to avoid reactive power circulating between rotary synchronous rotary synchronous generator by means of a reactive power sharing system. **To provide reactive power from a ESS & RES may require a power converter de-rating if a high level of reactive power of the phasing to increase the AC grid voltage is required. This does not affect the battery.**

7. There are other options for House load operation and Black start operation. The **ESS and RES can provide these options.**

Appendix B. References

Effects of VSM Convertor Control on Penetration Limits of Non-Synchronous Generation in the GB Power System
Richard Ierna, Jiebei Zhu, National Grid, Warwick, UK.

A VSM (Virtual Synchronous Machine) Convertor Control Model Suitable for RMS Studies for Resolving System Operator / Owner Challenges
Richard Ierna, Jiebei Zhu, National Grid, Warwick, UK.

THE DESIGN AND APPLICATION OF A FLOW CELL SYSTEM
Presented in the 2010 Vienna flow cell conference
Eric Anthony Lewis, CEng MIET, Power Electronic Consultant.