CASE STUDY: COMMONWEALTH FUSION SYSTEMS – RELIABILITY OF HTS WIRES IN FUSION MAGNETS

The case for fusion energy:

Global energy demand is expected to increase by 50% between 2018 and 2050 driven by population growth in Asia and continued industrialisation across developing economies. In addition, the growth of CO_2 emissions and the associated impact on climate change has meant governments and citizens across the world are thinking about new sources of renewable and non-fossil fuel sources of energy.

Fusion energy has long been touted as a way to source clean and carbon free energy. However, for many years, while the concept of fusion power was within scientific possibility, the enabling technologies were not yet ready. That is now changing with the latest development in high temperature superconducting (HTS) materials.

The challenge of fusion:

Fusion occurs when hydrogen nuclei combine to form larger helium nuclei and release vast amount of energy in the process - it is what powers the sun. Fusion has been in the realm of scientific possibility for many years. However, the problem with achieving industrial fusion is two-fold:

1. Fusion can be achieved in a lab but requires more energy input than what is produced. To date, no one has succeeded in making a net gain controlled fusion reactor. This limits the fundamental economics of sustained fusion energy.

2. The reactants of fusion are in the form of hot plasma (ten million to a hundred million degrees) that need to be contained. No container can hold that, so the plasma needs to be confined by a very high magnetic field. Existing materials that can be used as high field magnets are too large or uneconomical for commercial scalability.

Fusion energy – A leap to High Temperature Superconductor

The most common method to confine plasma is in the use of a "tokamak" configuration where the magnet forms the shape of a torus (donut). To get fusion started a very large reactor or a very high magnetic field (for strong confinement) is required. The ITER international project is a global collaboration based in Europe with the aim of building a tokamak and showcasing the feasibility of large scale fusion power by 2035. The ITER tokomak will be 19 metres in diameter, 11 metres high and will weigh over 5,000 tonnes. ITER aims to produce net energy output but will not operate as a power station.

Tokamaks can be made using different materials. Traditional electromagnets such as copper are possible but would consume more energy than they generate. The electromagnets of ITER are made with low-temperature superconductors, which limits the magnetic field available (i.e. < 10 T) within practical constraints.

In the last decade, advances in HTS materials has meant that new small HTS based magnets with high fields are now possible. As a result, the opportunity is now ripe to leapfrog the ITER efforts and build smaller but more powerful/ higher field magnets (i.e. > 10T) that can also enable net-energy gain. The path to commercial fusion is in sight.

Commonwealth Fusion Systems (CFS)- Problems with HTS magnets:

CFS is a US start up spun out of Massachusetts Institute of Technology's (MIT) Plasma Science and Fusion Centre to speed up the development of fusion technologies. Supported by heavyweight industry and investors such as Eni, Khosla Ventures and Breakthrough Energy Ventures (which includes Bill Gates, Jeff Bezos, Jack Ma, Richard Branson and others), CFS aims to build a compact tokomak fusion reactor incorporating HTS wire for the magnets. To create industrial scale magnets, CFS will require hundreds of kilometres of HTS wire. This poses technical challenges.

Firstly, HTS wires generate no heat until a certain "critical current" is reached. After the critical current is reached, there is a large and sudden generation of heat which can be catastrophic for the magnet and the reactor. To induce a high magnetic field, currents are passed through the magnet. Therefore, while the magnetic field depends directly on passing a high current, it is important not to exceed or approach the critical current.

Secondly, HTS wire performance is highly unpredictable. Critical current measurements can vary significantly at different points of the wire. Current quality control systems rely on a cheap and easy methods that can be done with liquid nitrogen (77K) at zero or low magnetic fields. In reality, HTS magnets for fusion will operate at much lower temperatures (4-20K) and much higher magnetic fields (20-30T).

Understanding the performance of wire at extreme operating conditions and understanding the critical current threshold is difficult. HTS wire manufacturers do not have the capability to perform these tests. For CFS, the integrity of their wire is critical to ensure the reliability of their new fusion reactor. A small failure on the wire can impact the whole reactor. With the aim of ensuring appropriate quality control and reliability of their wire, CFS turned to the Robinson Research Institute to help.

HOW THE ROBINSON RESEARCH INSTITUTE HELPED

The Robinson SuperCurrent Facility:

CFS first engaged the Robinson in 2018 to request help in measuring performance of various HTS wires they proposed to use in their reactor. While CFS had the option of choosing other institutes to conduct these measurements, CFS chose the Robinson due to their ability to generate data much quicker than other organisations. CFS made extensive use of the Robinson SuperCurrent Facility by sending samples to NZ and then utilising the Robinson team to conduct measurements. This early work enabled CFS to quickly get results and utilise the Robinson's expertise.

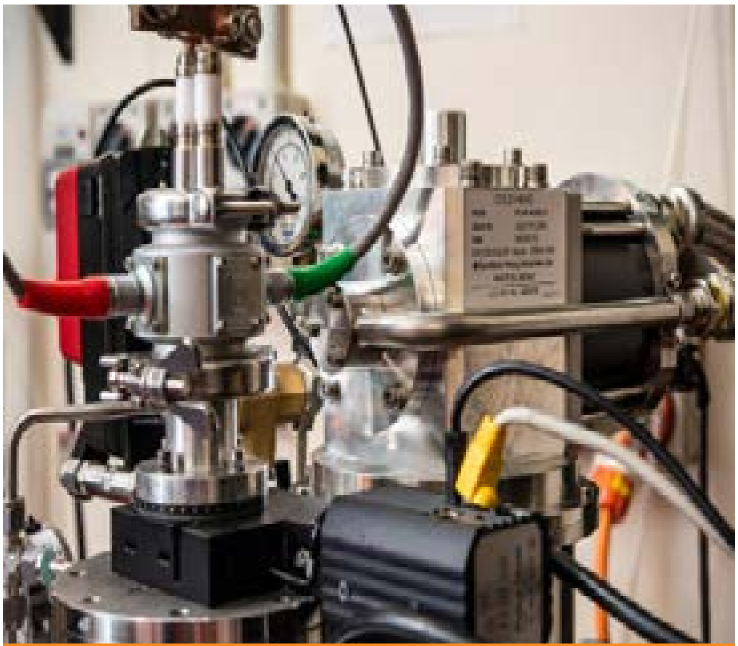
Given the criticality of the wire to the overall fusion project, CFS then opted to send their own teams to the Robinson Institute and work directly with the local Robinson team. By working directly with the Robinson Institute, CFS were able to acquire significantly more data by themselves which helped speed up their decision-making capabilities based on measurement results.

These fast measurements were also used by CFS as quick pre-screening of samples to eliminate underperforming tapes. The ability to measure a large number of different samples quickly enabled CFS to streamline and refine their testing options and better utilise more expensive testing resources.

The Robinson SuperCurrent System:

Once CFS had decided on their proposed HTS wire and begun the scaled development of their fusion reactor, there was a pressing need to increase the throughput of their wire measurements. To ensure ongoing reliability of their proposed wire, CFS needed to ensure that their procured wire had a high level of reliability and needed the ability to screen their chosen wire on a continuous basis.

CFS purchased a custom-made Robinson SuperCurrent System which allowed them to screen multiple samples continuously. Engineered to specific CFS requirements, the Robinson SuperCurrent System enabled CFS to rapidly increase the throughput of their measurements and reduce downtime by reducing the need to send samples from the US to the Robinson facility in New Zealand. For CFS, the ability to continuously measure their wire performance was a critical factor for their ongoing quality assurance.



Outcomes delivered:

Rapid strategic decision making:

The Robinson SuperCurrent Facility offered CFS an opportunity to quickly test multiple wire samples utilising the Robinson expertise and facilities. By utilising the SuperCurrent Facility service, CFS were able to rapidly test their wire options and make strategic development decisions quickly. In addition, the rapid testing also has enabled CFS to focus their internal resources more efficiently and enable them to utilise their investments in a much more focussed manner.

Ongoing reliability:

By enabling CFS with their own custom-made Robinson SuperCurrent System, CFS are able to generate fast, reliable and repeatable measurements themselves. For CFS, this ability to provide their own quality assurance (not provided by manufacturers) means they are able to continue the development of their fusion reactor with a high degree of confidence and minimise the impact of future performance failures.

About the Robinson Research Institute:

The Robinson Research Institute is a world leading research institute focussed on commercialising HTS based applications across the space, energy and healthcare sectors. Located in Wellington, New Zealand and associated with the Victoria University of Wellington, the Robinson has a world class multidisciplinary team of material scientists and engineers with specific expertise in providing high quality engineering solutions related to HTS materials. The Robinson provides a range of services from fundamental research to bespoke HTS engineering solutions.

About Wellington UniVentures:

Wellington UniVentures is the commercialisation company of Victoria University of Wellington and the Robinson Research Institute. Wellington UniVentures provides commercial support to the Robinson and can help connect industry partners to the Robinson expertise and capabilities. On behalf of the Robinson, Wellington UniVentures provides the following services:

- The Robinson SuperCurrent Facility – for organisations looking to identify new application areas, Robinson can provide a wire characterisation service to help clients assess the performance potential of potential HTS wires.

- Robinson SuperCurrent System – for organisations looking for a reliable high-field testing quality assurance solution, the Robinson can offer a bespoke engineered SuperCurrent System that can meet specific client needs. The Robinson already has a 12T solution and can work with clients to tailor make a solution for various magnetic fields.

- Bespoke HTS based research – The Robinson has extensive intellectual property related to HTS technologies. For organisations looking to develop their own research pipeline and access Robinson IP, the Robinson can provide bespoke research services including scoping studies and full end-to-end research services.

PLEASE CONTACT

Hamish Findlay

General Manager Commercialisation

Wellington UniVentures

M: +64 21 618 069

E: hamish.findlay@wellingtonuniventures.nz

For more information

To find out more on how the Robinson can help support your needs please contact Dr Ashwath Sundaresan

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