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Senate Select Committee into the Resilience of Electricity Infrastructure in a Warming World

Monday, 20 February 2017

Thermal Energy Storage System (TESS)

Overview Document

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Document Control and Approval

Document Control						
Document Title		Overview Document				
Document ID		TESS-Overview Document		Project ID		
File Name		1414-TESS-Senate Committee Overview Document.docx				
Supplier		1414 Degrees Limited		Supplier Contact		Nigel Gammon
Rev	Date	Revision Details		Author	Reviewer	Approver
1.0	01/02/2017	Initial draft		RR	MJ	MJ
1.1	06/02/2017	Second draft		RR	MJ	MJ
Final	13/02/2017	Final		RR		MJ

Document Approval			
Author Signature		Approver Signature	
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The Proponent

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Details of the Proponent

1414 Degrees Limited is a company that was incorporated in South Australia in 2009 (formerly Latent Heat Storage Ltd) with the mission of commercialising energy storage technology originally developed at the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The Company holds a granted U.S. patent (with patents pending in other jurisdictions) related to the design of silicon based heat storage systems.

Following six years of research and development initiated from its original patent, 1414 Degrees has developed the specification and design for a thermal energy storage system (TESS), which stores electrical energy thermally in molten silicon. The system recovers this heat and converts it back into electrical energy via an energy recovery system (ERS) designed to meet the electrical demand.

The novelty of the TESS is in the use of silicon as the storage medium which gives both a high operating temperature (1,414 degrees C) and high energy density. Heat energy is converted back to electrical energy utilising a heat engine or gas turbine. The melting point of silicon is 1,414 degrees C. Competing thermal energy storage systems typically operate at less than half of this temperature. The heat store is readily scaled up and is of modular construction such that many units can be connected in series or parallel to increase the power output or storage capacity respectively. An illustration of the TESS commercial prototype located in the Tonsley Park Precinct is shown in Figure below.



Figure: TESS Commercial Prototype

The TESS is innovative in that it operates at higher temperatures than competing thermal energy storage systems and it uses the latent heat properties of the storage medium. Operating at high temperature provides efficiency benefits in the conversion of stored energy back to electricity, and in the offering of heat to energy consumers such as district heating and industrial processes to offset expensive gas/LPG heating systems.

As renewable energy sources are added to electricity networks the availability of the power generating sources becomes unpredictable, exacerbating the challenges of designing and maintaining a cost effective energy network. Grid instability of energy networks can be ameliorated by the introduction of strategically positioned energy storage devices. ERS/TESS' scalability provides a solution to grid instability.

A commercial ERS/TESS prototype has been constructed and was commissioned on the 30 September 2016. It is currently operating under test conditions. The prototype has been created to prove the concept and benchmark the underlying design for a commercially scaled system. It consists of the heat store which is the insulated enclosure that contains the molten silicon and a 'Stirling' engine ERS to convert heat to electricity

Alternative Storage Comparison

The competitive advantage of the TESS is its scalability and high energy density. The heat store is constructed from readily available, low cost components and production units will be containerised and modular. A TESS module approximately the size of a 40ft shipping container could house 10MWh_{th} of energy storage and to scale up, modules may be added and to scale down, modules may be removed or smaller ones manufactured. For all sizes of the TESS, the heat store shares a common design principal. The Table below presents a comparison of the ERS/TESS with other storage technologies for both 'behind the meter' (TESS-EC) and 'bulk storage' (TESS-Grid) applications.

The Table also shows the power rating of currently available storage technologies and network benefits of the different power ratings wherein systems less than 10MWh/h are dominated by Lithium Ion (Li ion) batteries and systems greater than 100MWh/h by pumped hydro. Product availability in the mid-sized range of 10MWh/h to 100MWh/h is sparse and it is this size range in which the ERS/TESS cost per MWh/h_{th} is optimum. Having multiple market niches for products based on the same core intellectual property (IP) allows 1414 Degrees to better focus its efforts on developing a defensible technical competitive advantage.

Rating	Technology	Discharge Time	Efficiency	Network Benefits ¹
<10MWh/h	TESS-EC	High hours	Medium	<ul style="list-style-type: none">• Demand management• Peak shaving• Peak shifting• Time of use tariffs• Photovoltaic (PV) self sufficiency• Network augmentation deferral
	Super Capacitors Flywheels	Minutes	High	
	Lithium Ion Advanced Lead Acid Flow Batteries	Low hours	High	
	Sodium Sulphur	High hours		
Between 10MWh/h and 100MWh/h	TESS-Grid	High hours	Medium	<ul style="list-style-type: none">• Network augmentation deferral• Congestion relief• Utilisation of surplus renewables• Frequency regulation• Spinning reserve• Voltage support
	Molten Salt		Medium	
	Compressed Air Energy Storage		Low	
>100MWh/h	Pumped Hydro Storage	High hours	Medium	<ul style="list-style-type: none">• Frequency regulation• Spinning reserve• Voltage support• Arbitrage

Table: TESS Positioning

Additional competitive advantages of the ERS/TESS include:

- The cost is significantly less than current battery technology.
- Constant, high operating temperature that improves overall system efficiency and product durability.
- The ability to simultaneously charge and discharge energy. It should be noted that the ERS discharge, from a grid perspective, will be a rotating generator essentially the same as fitted to current conventional gas or steam turbines.
- The addition of system inertia and the consequential improvement in grid stability.
- The ability to absorb large quantities of energy rapidly in the heating system.
- The ability to generate both electricity and useable heat simultaneously.
- Long life cycle.
- Built with abundant materials (silicon, graphite, steel, etc.)
- Straightforward decommissioning that is environmentally benign.

¹ Garrett Fitzgerald, James Mandel, Jesse Morris, Hervé Touati, Rocky Mountain Institute, The Economics of Battery Energy Storage, How Multi-Use, Customer Sited Batteries Deliver the Most Services and Value to Customers and the Grid, 2014, presents an extensive review and discussion of the multiple benefits that are available from the wide scale deployment of 'behind the meter' and 'grid storage' technologies.

The ERS/TESS offers these advantages over both Li-ion batteries at the low end of the rating scale and pumped hydro at the high end. In the mid-range the ERS/TESS silicon technology betters molten salt or graphite in a number of ways: higher operating temperature; use of the latent phase change; and higher energy density.

The 'behind the meter' TESS-EC (Energy Consumer) is targeted at the commercial installations where consumers have a need for heat as well as electricity. By supplying both, the overall efficiency of TESS-EC is high and consumers very quickly see a reduction in both electricity and gas costs. The primary differentiator of TESS-EC for this market segment is the high discharge time which can be configured to suit the needs of a particular customer site. TESS-EC is branded as 'Energy on Demand'.

The 'bulk storage' TESS-Grid is a cost effective solution in the sparsely occupied niche market of intermediary scale storage applications (i.e. between 10MWh/h_{th} and 100MWh/h_{th}) differentiated from pumped hydro and solar thermal by having minimal site specific requirements: it is a containerised solution for cost effective integration in almost any location. Close proximity to grid interconnects minimises the additional costs of kilometres of high voltage lines and their commensurate energy losses and positioning adjacent to a district heating network does away with the cost of connecting expensive and disruptive infrastructure. TESS-Grid does not try to compete with sub 10MWh/h_{th} storage systems but is positioned as a site-agnostic alternative to larger capacity systems. TESS-Grid benefits over pumped hydro are its cost and location independence, which is its primary point of difference. TESS-Grid is branded as 'Pumped Thermal'.

From the environmental perspective, decommissioning of a TESS is benign in that the waste is solidified silicon that can easily be disposed of or recycled. It does not need to be treated or specially contained and has no damaging chemical impact if it needs to be discarded at the end of its useful life.

Appendix - A List of Acronyms and Abbreviations

1414	1414 Degrees Ltd
\$	dollars Australian
\$k	thousand dollars
\$m	million dollars
°C	Degrees Celsius
AEMC	Australian Energy Market Commission
BOM	Bureau of Meteorology
BOS	Balance of System
CAPEX	Capital Expenditure
CHP	Combined Heat and Power
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EFGT	Externally Fired Gas Turbine
ERS	Energy Recovery System
HRSG	Heat Recovery Steam Generator
kWe	kilowatt electrical
kWt	kilowatt thermal
kWhe	kilowatt hour electrical
kWht	kilowatt hour thermal
kV	kilovolt
L	litre
LHS	Latent Heat Storage
LPG	Liquid Petroleum Gas
MW	megawatt
MWh	megawatt hour
PV	Photovoltaic
OPEX	Operating Expenditure
REC	Renewable Energy Certificate
TESS	Thermal Energy Storage System
TESS-Ind	TESS Industrial Scale Module