Modelling and Analysis of Hydrogen-based Wind Energy Transmission and Storage Systems:

HyLink System at Totara Valley

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Abstract

Distributed generation has the potential to reduce the supply-demand gap emerging in New Zealand's electricity market. Thereby it can improve the overall network efficiency, harness renewable energy resources and reduce the need for upgrading of existing distribution lines.

A typical New Zealand rural community consisting of three adjacent farms at Totara Valley near Woodville represents a demonstration site on distributed generation for Massey University and Industrial Research Limited. Local renewable energy resources are being used for the purpose of sustainable development. Alternative micro-scale technologies are being combined to achieve a valuable network support.

This paper is an in-depth report on the implementation process of the HyLink system; a system which utilises hydrogen as an energy carrier to balance and transport the fluctuating wind power. The report documents its development from the laboratory stage to commissioning at Totara Valley, which was carried out under direction of Industrial Research Limited.

The PEM electrolyser's performance at different stack temperatures was investigated. It was found that hydrogen production increases at the same voltage with a higher stack temperature. This is due to the improved kinetics of the electrochemical reactions and decreased thermodynamic energy requirement for water electrolysis. The electrolyser efficiency measurement at the half of its maximal power input (247 W) resulted in 65.3 %. Thereby the stack temperature attained less than half of the allowed limit of 80°C. The capture of the excess heat by insulation can improve the electrolyser's efficiency.

Pressure tests were performed on the 2 km long pipeline at Totara Valley using hydrogen and natural gas in order to test their permeability. The results were compared with previous studies at Massey University and with data obtained from the industry. The hydrogen permeability was measured to be $5.5 * 10^{-16}$ mol m m^{-2} s^{-1} Pa^{-1} for a 2 km MDPE pipe. This is about half the result obtained from previous studies on

hydrogen permeability through MDPE at Massey University which was undertaken at room temperature. The reason for this discrepancy is likely to be the lower ambient temperature during the measurement at Totara Valley, which can be supported with the Arrhenius equation. It was furthermore measured that the power loss due to hydrogen diffusion through the pipeline walls during the fuel cell operation is about 1.5 W at the current system operation mode.

A techno-economic analysis of the system was undertaken applying the micro-power optimisation software HOMER as a simulation tool. Two operation modes of the system were investigated, the load following and the peak demand compensating. The simulation results reveal that the durability and the cost of the electrochemical energy conversion devices; electrolyser and fuel cell, are the main hurdles which need to be overcome on the path in introducing hydrogen based energy systems like HyLink.

Finally, economic optimisation modelling of the small-scale system by best component alignment was performed. It was found that the electrolyser capacity down-rating of 80% in relation to the wind turbine capacity, leads to a minimal system levelised cost. In addition to this, the impact of various wind turbine/electrolyser subsystems and pipeline storage capacities on the fuel cell capacity factor and on the system levelised cost in the load following operation mode was analysed. The outcomes can be useful for further HyLink related energy system planning.

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