Increasing the penetration of renewables by stabilizing the grid through the use of energy storage; fuel cell technologies.

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Increasing the penetration of renewables by stabilising the grid through the use of energy storage - fuel cell technologies

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Introduction

Environmental pressures to reduce CO_2 emission has led to the rapid expansion of electricity generation from renewable energy sources. Electrical power grids used around the world today must become much more robust as they integrate larger quantities of fluctuating renewable power sources and a growing number of small, decentralised power producers. Electrical networks must also have the ability to store excess power fed into the grid from fluctuating power sources. Hydrogen is seen by many industry leaders as an energy vector that has the potential to provide essential energy stores required to facilitate the wide spread connection of renewable energy inputs. The use of hydrogen technologies to develop fast acting energy stores is an area of research that requires much greater depth of work. This is to define what existing hydrogen technology is capable of achieving and what areas critical developments requiring focus to allow their cost-effective adoption into the energy market.

Background

To date renewable energy represents just a small fraction of the total power generation profile. However, most recent global climate change policies targeted to substantially reduce CO_2 emission has lead to significant increases of electricity generation from Renewable Energy Sources (RES). It has been indicated that as much as 46% of global electricity would be from RES by 2050 [1]. Within Scotland alone, ambitious national targets are focused on achieving renewable generation of 80% by the year 2020 [2]. Traditional modelling suggests that the maximum stable renewable energy mix with conventional centralised power stations is up to 20%. 40 to 80% renewable penetration can only be achieved through the parallel integration of large scale, high energy density energy storage mechanisms within the electrical grid infrastructure.

Reference Energy System

Simulation and modelling works will be compared to the reference system described below.

The electricity generated from the wind turbine directly provides for the electrical needs of the Hydrogen Office. Surplus electricity is used to generate hydrogen through the process of electrolysis. The hydrogen generated is stored for periods where there is insufficient energy from the wind to meet the demands of the Hydrogen Office Demonstration Centre. During calm periods a fuel cell provides the electricity for the Demonstration Centre in a process whose only by-products are heat and water.

Aims & Objectives

It is crucial to the wide spread and economic adoption of energy storage technologies to be able to simulate their impacts when proposing to integrate them into existing electrical infrastructure

This research project will focus on analysing and investigating the consequent dynamics of electrical grid infrastructure in the presence of distributed energy storage utilising hydrogen technologies. The work will focus on the effects of using hydrogen as an energy storage mechanism, where water (H_2O) is split into H_2 and O_2 when excess renewable energy is available through the use of electrolysis technology. H_2 will be stored as fuel and O_2 vented or used in other processes. Fuel Cells (FC) would then be used to convert the stored H_2 to generate and supply electrical infrastructure with electrical power when demand exceeds renewable supply.   Hydrogen production through electrolysis is an independent energy storage mechanism from the fuel cell technology that is to be utilised for releasing stored energy on demand. Due to this it is possible to site strategic energy storage reserves in a more flexible manor than traditional electrochemical energy storage technologies. This research will seek to simulate and model solutions for electrical grid problems that can arise when using storage technologies in conjunction with renewable and the network. Simulation and modelling works will then be compared to the summarised reference system described. formally opened by the first minister of Scotland on the 18 January 2011. The reference system is installed as part of the Hydrogen Office project in Methil, Fife, Scotalnd.

Additionally this work will aim to investigate solutions for grid stability problems that can arise when using storage technologies in conjunction with renewable and the network. It is also intended to investigate the techno-economics of a hydrogen Fuel Cell energy storage system on the grid, and to define the break-even point where such technology is viable.

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Introduction

Environmental pressures to reduce CO2 emission has led to the rapid expansion of electricity generation from renewable energy sources. Electrical power grids used around the world today must now become much more robust as they integrate larger quantities of fluctuating renewable power sources and a growing number of small, decentralised power producers. Electrical networks must also have the ability to store excess power fed into the grid from fluctuating power sources. It is crucial to the economic wide spread adoption of energy storage technologies to be able to simulate their impacts when proposing there integration into existing electrical infrastructure.

Hydrogen is seen by many industry leaders as an energy vector that has the potential to provide essential energy stores required to facilitate the wide spread connection of renewable energy inputs. The use of hydrogen technologies to develop fast acting energy stores is an area of research that requires much greater depth of work. This is to define what existing hydrogen technology is capable of achieving, and what areas critical developments require focus to allow their cost-effective adoption into the energy market.

This research project will therefore focus on analysing and investigating the consequent dynamics of electrical grid infrastructure in the presence of distributed energy storage utilising hydrogen technologies. The work will focus on the effects of using hydrogen as an energy storage mechanism, where water (H_2O) is split into H2 and O2 when excess renewable energy is available through the use of electrolysis technology as shown in figure 1. H2 will be stored and O2 vented or used in other processes. Fuel Cells (FC) as shown in figure 2 would then be used to convert the stored H2 to generate and supply electrical infrastructure with electrical power when demand exceeds renewable supply.

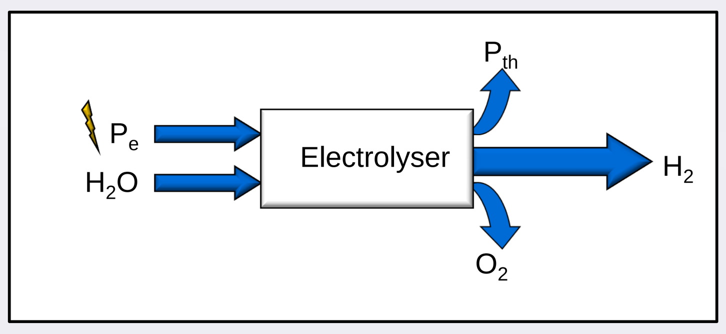

Figure 1: Simplified Electrolysis Overview

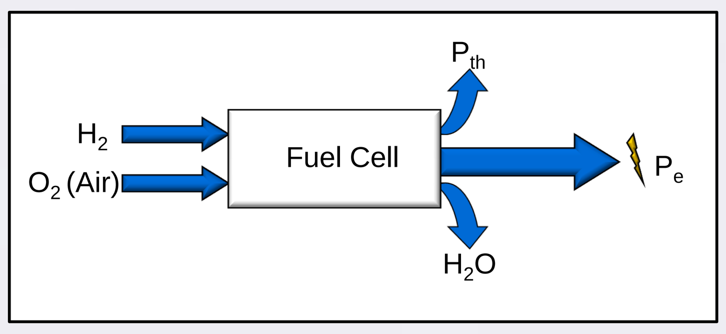

Figure 2: Simplified Fuel Cell Overview

Background

To date renewable energy represents just a small fraction of the total power generation profile. However, most recent global climate change policies targeted to substantially reduce CO2 emission has lead to significant increases of electricity generation from Renewable Energy Sources (RES). It has been indicated that as much as 46% of global electricity would be from RES by 2050 [1]. In addition BPs 2011 energy forecast predict Fossil fuel energy source growth to fall from 83% to 64% of market share in favour of renewable energy sources in their 2030 energy outlook.

Within Scotland alone, ambitious national targets are focused on achieving renewable generation of 80% by the year 2020 [2]. Traditional modelling suggests that the maximum stable renewable energy mix with conventional centralised power stations is up to 20%. In addition the United States Energy Information Administration (EIA) predict global renewable energy output to increase by over 50% (excluding bio-fuels) between 2010 and 2035 [3].

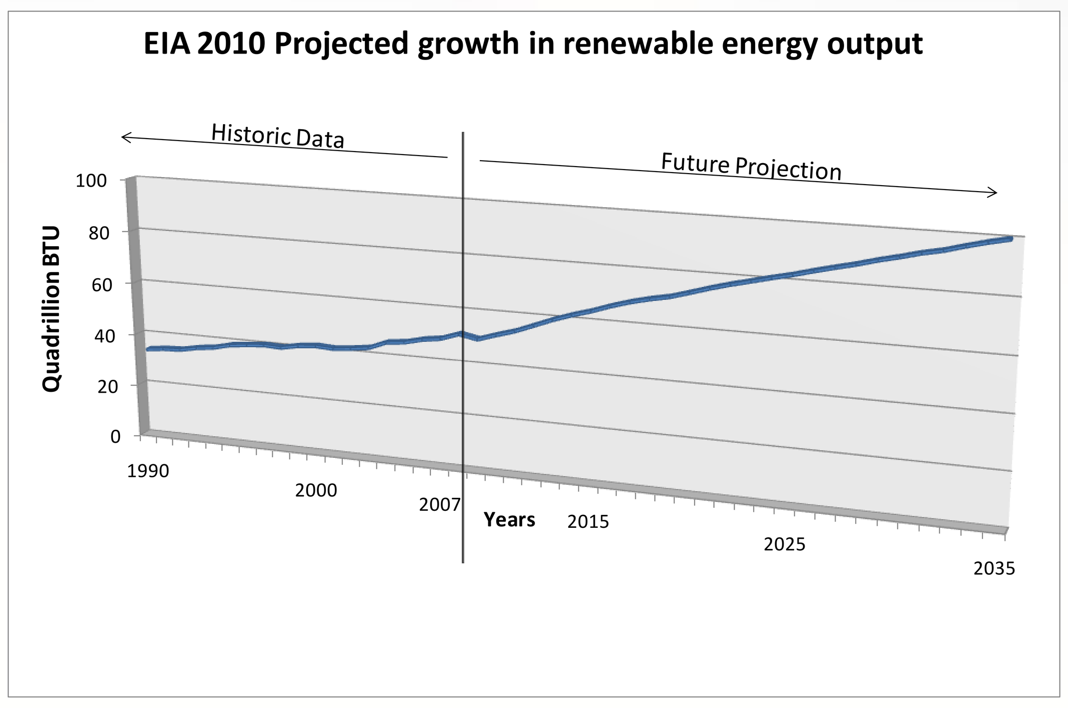

Figure 3: EIA data indicates a predicted doubling of renewable output

An increased renewable penetration of between 40 to 80% can only be achieved through the parallel integration of large scale, high energy density energy storage mechanisms within the electrical grid infrastructure.

Hydrogen Office - Case Study

The Hydrogen Office will be the case study energy system which is pictured in figure 4. An overview of the Hydrogen Office Energy system can also be seen in figure 5. The electricity generated from the wind turbine directly provides for the electrical needs of the Hydrogen Office. Surplus electricity is used to generate hydrogen through the process of electrolysis. The hydrogen generated is stored for periods where there is insufficient energy from the wind to meet the demands of the Hydrogen Office Demonstration Centre. During calm periods a fuel cell provides the electricity for the Demonstration Centre in a process whose only by-products are heat and water.

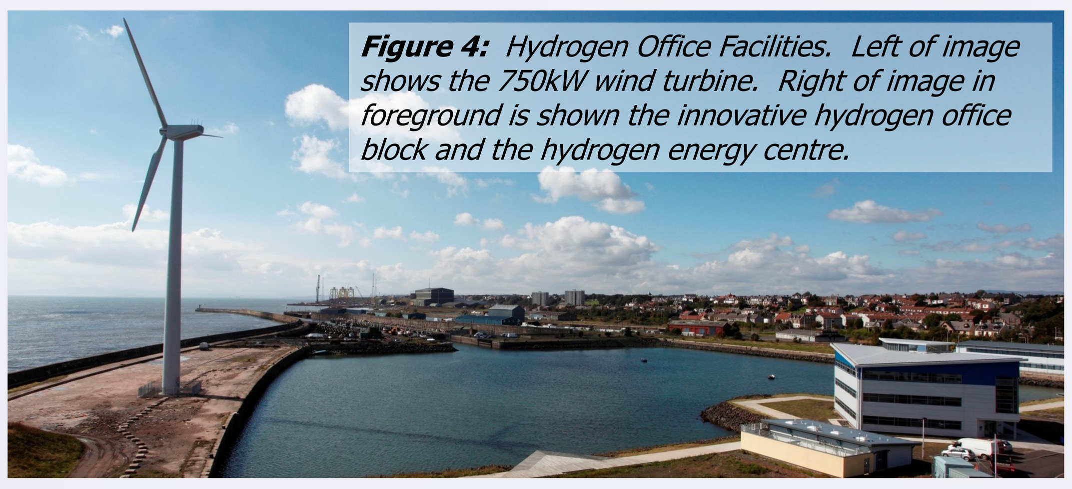

***Figure 4:** Hydrogen Office Facilities. Left of image shows the 750kW wind turbine. Right of image in foreground is shown the innovative hydrogen office block and the hydrogen energy centre.*

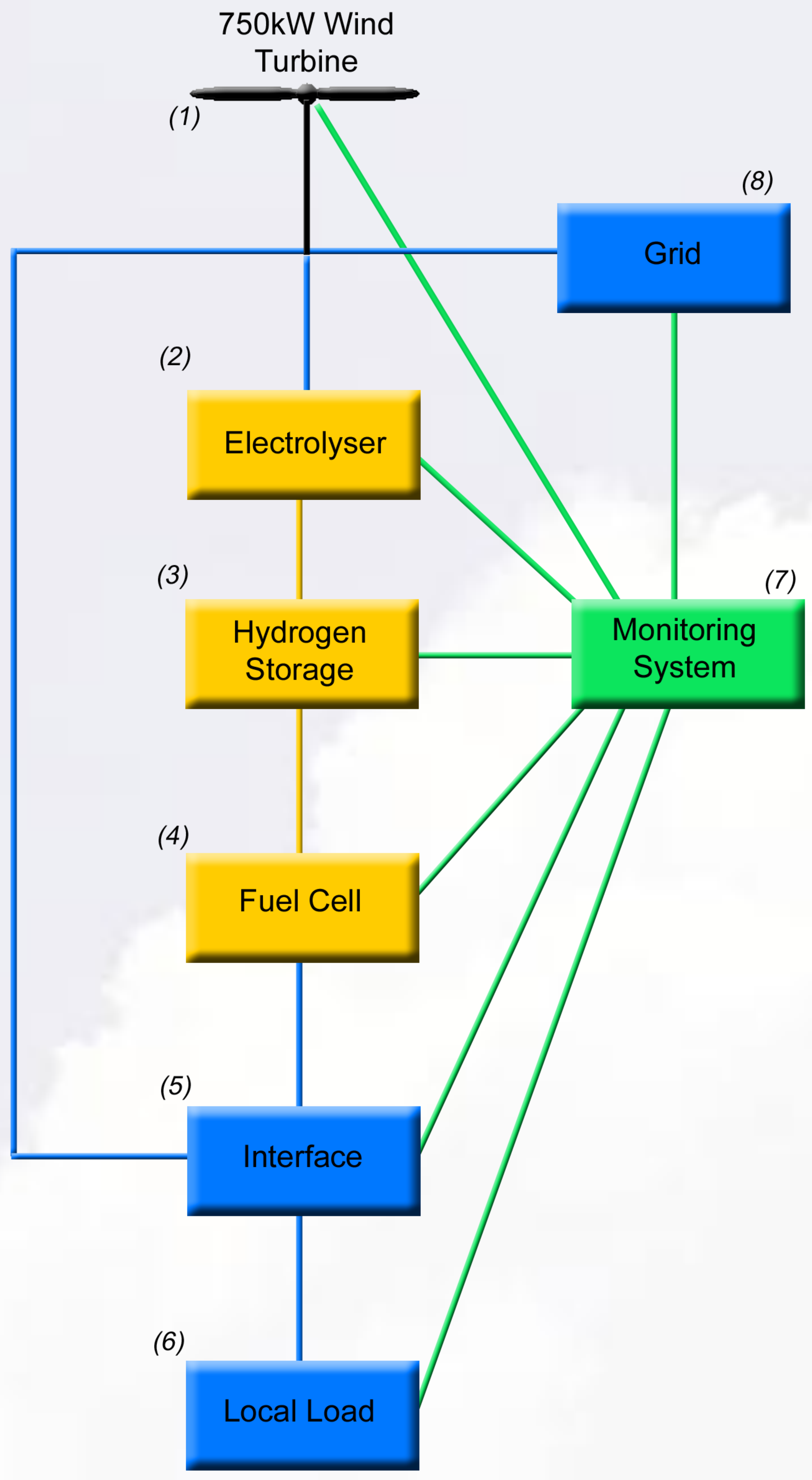

Figure 5: Simplified Overview of Hydrogen Office Energy System

(1) 750 kW grid connected synchronous induction machine
Active stall regulation
47m rotor diameter

(2) 30 kW alkaline electrolysis system
Variable production output

(3) 126Nm³ gaseous hydrogen storage
12 bar operating pressure

(4) 10kW Proton Exchange Membrane (PEM) Fuel Cell
Modular stack solution

(5) Power factor correcting power electronic interface
200% Integrated surge capacity
Intelligent control and protection

(6) Hydrogen Office and demonstration centre
Variable reactive load

(7) System wide monitoring and automatic control
Comprehensive data logging & Visualisation

(8) Export/Import Grid connection
Connection into local network distribution

Aims & Objectives

Hydrogen production through electrolysis is an independent energy storage mechanism from the fuel cell technology that is to be utilised for releasing stored energy on demand. Due to this it is possible to site strategic energy storage reserves in a more flexible manor than traditional electrochemical energy storage technologies.

This research will seek to simulate and model solutions for electrical grid problems that can arise when using storage technologies in conjunction with renewable energy and electrical distribution networks.

Simulation and modelling results will then be verified by comparison to the case study Hydrogen Office energy system. The case study system is installed as part of the Hydrogen Office project in Methil, Fife, Scotland and was formally opened by the first minister of Scotland on the 18 January 2011. The people shown in figure 6 are photographed in front of the hydrogen storage system used in the case study Hydrogen Office energy system, one of the largest storage tanks of its type in Scotland.

Figure 6: First Minister of Scotland Alex Salmond, Derek Mitchell of Hydrogen Office Ltd, Adrian Gillespie of Scottish Enterprise and Dr. Daniel Aklil of Pure Energy® Centre at the Hydrogen Office opening

Additionally this work will aim to investigate solutions for grid stability problems that can arise when using storage technologies in conjunction with renewable and the network. It is also intended to investigate the techno-economics of a hydrogen Fuel Cell energy storage system on the grid, and to define the break-even point where such technology is viable.

Research Development Steps

Steps towards developing the modelling tool described will be to:

- Conduct a full literature review to identify:
  - Ability of existing modelling tools and platforms
  - Operational characteristics of electrolysis and fuel cells
  - Electrical effects of grid connecting electrolysis and fuel cells
  - Most appropriate rout for modelling system using state of the art tools and techniques
- Develop component models
- Integrate component models into system model
- Simulate system performance with developed model
- Compare to reference system

References

[1] International Energy Agency, Energy Technology Perspectives 2008 – Scenarios and Perspectives to 2050, (Paris, 2008), 643 pp. (2010 edition now in print)

[2] First Minister for Scotland announcement, Target for renewable energy now 80 per cent, 23-09-10, http://www.scotland.gov.uk/News/Releases/2010/09/23134359

[3] International Energy Outlook 2010, DOE/EIA-0484(2010), July 2010, U.S. Energy Information Administration Office of Integrated Analysis and Forecasting

Further Information

www.rgu.ac.uk/ideas

www.pureenergycentre.com

www.hydrogenoffice.com

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energy technology partnership