Robust Lifecycle Design and Health Monitoring for Fuel Cell Extended Performance (RESILIENCE)

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Overview

- Overview of project.
- More detail on meeting the project objectives.
- Project to date.
- Related work.
Overview of Project
- Area of focus

- Reliability of Fuel Cell System to maximise life.
  - Achieved by:
    - better system integration
    - design optimisation
    - effective health management

- Multidisciplinary approach, including the areas of mathematics, information science and engineering.

  fuel cell power sources at the forefront of future UK energy provision.
Overview of Project
- Current limitations

- The area of reliability assessment for the fuel cell system is still in its infancy.
  - Many of these applications relate to single cells or subsystems.
  - Understanding the behaviour at a system level is critical.

- Requirement of maximal performance over its life, producing commercial viability.
  - An effective asset management strategy is required to fill a current gap in the research.

- Managing and understanding the large amounts of data to make informed decisions.
Overview of Project
- Research Vision & Aim

- The **vision** of this project is to improve:
  - The understanding of the cell/stack/system.
  - The ability to deal with data in an informed manner.
  - The support and decision making throughout the lifecycle.

- The overall **aim** of this research is to produce:
  - an intelligent and dynamic infrastructure to support the fuel cell system design and operation to achieve optimal reliability throughout its life, in a given market with specified limitations on the available resources.
Overview of Project - Objectives

1. **Achieve the most robust design**
   - Initial design process.
   - Limitations on resources and functional requirements.

2. **Establish a ‘dynamic’ asset management strategy**
   - Understanding the degradation of the system elements.
   - Performing maintenance on a predict and avoid strategy.

3. **Establish a diagnostic capability**
   - To identify the causes of failed or degraded system performance.

4. **Establish a real-time dynamic and adaptive intelligent infrastructure**
   - To manage large terse data sets.
   - Enable interrogation of the information for system level informed decisions.
Overview of Project - Integrated Units

Objective 1: Robust Design
Objective 2: Dynamic Asset Management
Objective 3: Diagnostic Capability
Objective 4: Intelligent Infrastructure

Intelligent Health Monitoring Tool
Meeting the Objectives

- **Initial Requirement: Establish the Fuel Cell System Functional Description**
  - Commercial viability.
  - Industrial collaborator, Intelligent Energy.
  - Knowledge will be gained of the overall functionality of the fuel cell and system structure.
  - A failure analysis (FMEA) of the system modules will be used.
  - The relationship between potential design variations and the functional requirements, environmental conditions and practical implementation issues would also be established.
  - Initial reference models will be constructed.
Meeting the Objectives

- **Obj.1: Robust Design**
  - **Fuel Cell Module Failure Model Generation**
    - Fault Tree Analysis and Binary Decision Diagrams.
    - Data for the component failure rates would be imported from the data store where the latest, continually updated, values are available.
  - **Fuel Cell System Design Optimisation**
    - Genetic Algorithm multi-objective framework.
    - Enable setting the component selection, the redundancy allocation and the servicing requirements in the fuel cell system design.
Meeting the Objectives

- **Obj. 2: Dynamic Asset Management Strategy**
  - **Component Degradation Model Development**
    - Establish probabilistic models.
    - Utilisation and environment data.
    - Component lifetime data.
  - **Asset Management Strategy Development**
    - Control the risk of in-service failure to an acceptable limit.
    - System structure considerations (redundancies).
    - Replacement intervals and setting of renewal conditions.
    - Constant updating of the strategy as the data quantity increases, and operating or environmental conditions change.
Meeting the Objectives

- **Obj. 3: Diagnostic Capability**

  - **Prognostics Model Development**
    - Predict the symptoms which will be observed for every potential component level fault condition.
    - A dynamical model of each sub-system.
    - Development of simulation software will use the Petri Net approach.

  - **Sensor Type and Location Selection**
    - Determination of the value of the sensor information - information indices.

  - **Fault Diagnostics**
    - Bayesian Network.
    - Adapted for Dynamics and *The time duration between the occurrence of multiple faults* - a pattern recognition approach.
Meeting the Objectives

- **Obj. 4: Adaptive Intelligent Infrastructure**
  - **Data Hub Infrastructure**
    - Ontology will form the foundations.
    - Semi-automated node and linking.
    - Use a layered approach providing direct mapping to data stores.
  - **Integrated System Optimisation**
    - Interrogation of ontology to yield critical quantifiable lifecycle process parameters.
    - A further layer for prediction of areas for optimisation for the lifetime strategy.
    - The environment created will enable a dynamic or ‘living’ capability.
  - **Dynamic Health Monitoring Visualiser**
    - Visual system to quickly interpret results.
Project to Date

~ Intelligent Health Monitoring Tool

- Not yet started.

- First two RAs due to start imminently (next month).

- PhD student support – 2 hopefully starting in October (currently in recruitment).
Related work

- Other fuel cell work currently on going:
  - Fuel cell integration into an unmanned aerial vehicle.
  - Control system work for fuel cell/battery hybrid.
  - Thermal management of evaporatively cooled fuel cell vehicles.
  - Structural integration of PEMFC into existing aircraft wing components.
  - Social acceptance analysis of PEMFC technology (vehicles).
  - Gas diffusion layer degradation analysis.
  - Reliability modelling of fuel cells.
  - SOFC
Thank you for your time.

Any questions?