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Optimal control of PEMFC system based on Genetic Algorithm

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Abstract

PEM fuel cell is a non-linear dynamic energy system that transforms chemical energy to electrical energy without any carbon based emissions.

Efficient maintenance of this process require an integrative control strategy, encompassing transducers (sensor and actuators) and the communication network in a flexible, optimum, adaptive and efficient manner. The final objective is to obtain the maximum available power from the system. Unfortunately, the involved variables makes it very difficult to accurately calculate the optimum current to be drawn from the stack in order to achieve this goal.

In this paper we solve this optimization challenge using a Genetic Algorithm (GA) framework to efficiently control a 15 watts PEM fuel cell system. Genetic algorithms use operations inspired from Genetics and Evolution (reproduction, cross over, mutations and natural selection) to find optimum solution and variables (fitness function and fitness space). A simulation model using the GA is created and a physical experiment is conducted in order to validate the proposed model.

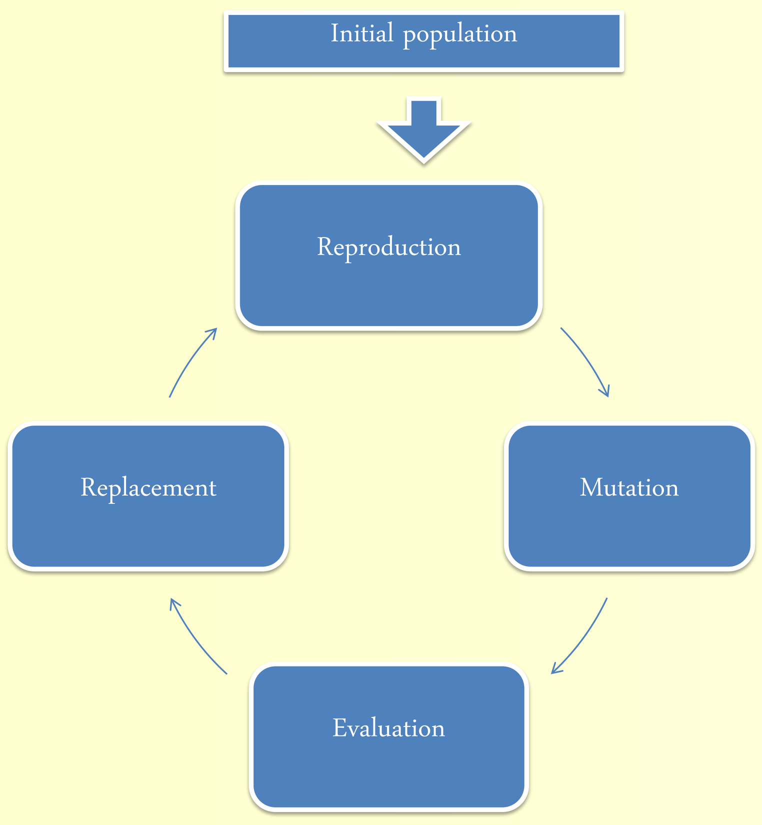
The validation of the control strategy is done using the PEM fuel cell system under laboratory conditions. Our work underscores the importance of Global optimization techniques like GA to real world problem of control optimization of PEM fuel cell.

Material and methods

Genetic algorithms:

Genetic algorithms were defined by Goldberg [1] as: "Genetic algorithms are search algorithms based on the mechanics of natural selection and natural genetics". Genetic algorithms are a branch, along with the "evolution strategies" and "Evolutionary Programming [2].

"The algorithm starts from an existing population of individuals candidate solutions.

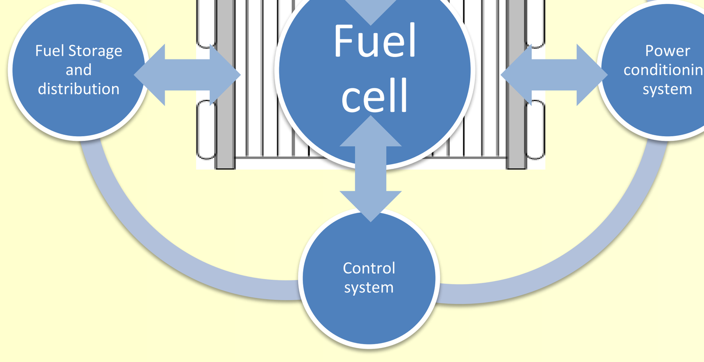


Selection strategies (replacement) can be:

- Random: the new insert into place either population (randomly replacing one of the individuals in the original population),
- Replacement of parents: the new substitute for same number of parents,
- Replacement similar: they replace the original population which present similar performance (fitness) that offspring,
- Replacement of the worst: the worst of the population are selected at random the necessary to be replaced by the new generation.

PEM fuel cell setup:

The model used for the study has been a PEM fuel cell up to 15W at rated. This fuel cell consists of 12 cells, weighs 650 grams (including casing and fans) and the cooling is performed by air through a fan which drives air. The output voltage of the fuel cell is between 6 and 14Vdc, given that if it goes down, the system will shut down as a safety measure. Overall Integrative fuel cell system comprises of following subsystems:



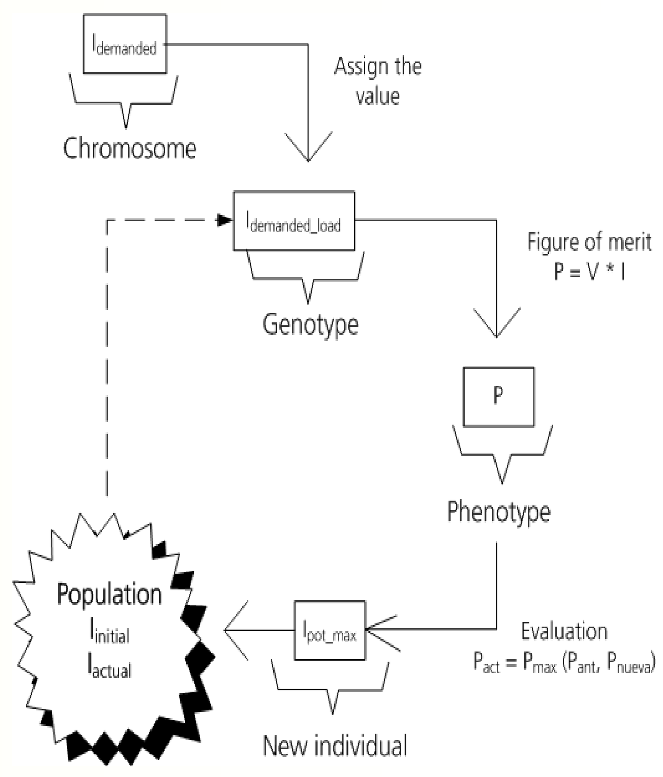
Implementation:

The control system is programmed in LabVIEW (LV) and genetic algorithm is programmed in C. Access from LV to C code was performed using dynamic link libraries (DLL). Thus, from LV we can call the required functions.

The genetic algorithm is employed on the fuel cell being studied. Testing operation of the control algorithm was conducted using the following equipment:

- Electronic load : The electronic load allow to control the current of fuel cell at all times and variable depending on the outcome of the algorithm.
- Control algorithms (genetic algorithm) is programmed using LV.
- Analog interface: USB cDAQ. Modules used: NI9263 and NI9205

The genetic algorithm programmed, based on the foregoing description works in the following manner:



Results and Discussion

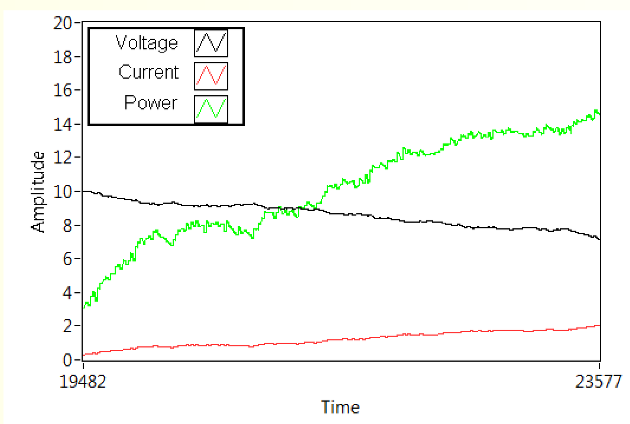


Figure a) operation of the fuel cell system control based on genetic algorithms.

This figure shows the startup behavior of the algorithm. As time passes are exploring solutions with statistical variability and the population of individuals (each solution) evolves towards higher values of power.

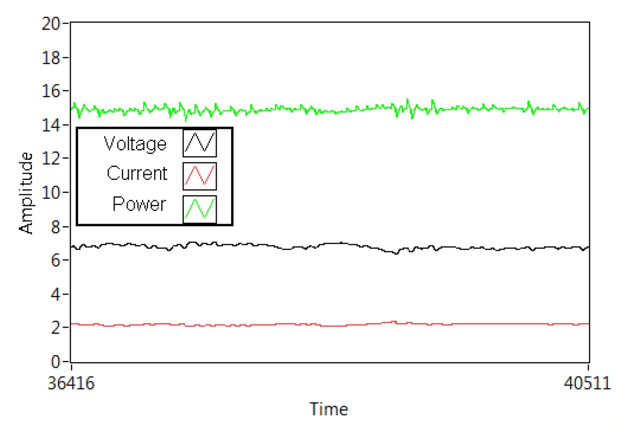


Figure b) Steady state of the system. As expected, even when on the point of greatest power, the algorithm continues looking for solutions that can lead to better fits. Thus, changes in any of the variables that determine the performance of the fuel cell (humidity, temperature, press, ...) do not preclude that the algorithm reach the best solution.

Conclusions

We applied a genetic algorithm for controlling a fuel cell system. This type of control is used in order to optimize the power produced by the fuel cell regardless of the boundary conditions of the BOP. Experimental tests were conducted to obtain the desired behavior. Thus it has been demonstrated the feasibility of controlling the fuel cell system automatically generating maximum power output. Next step would be to use multiple gene based control which will be especially relevant for control of medium and high temperature PEM fuel cells.

References:

[1] Goldberg, *Genetic Algorithms in Search, Optimization, and Machine Learning*, 2007.

[2] Tomassini, M. 'A survey of genetic algorithms ". Annual Reviews of Computational Physics, III: 87-118, 1995.

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