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# Multi-objective network planning tool for the optimal integration of electric vehicles as responsive demand and dispatchable storage

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# Overview

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# Decentralised Energy System

- The research programme is structured by the features considered essential in a sustainable and resilient highly distributed energy future.
- The Supergen Highly Distributed Energy Future (HiDEF) programme which is supported by EPSRC will research the essential elements of a decentralised energy system that could be implemented over the period 2025 & 2050.
- The research vision is one of:
  - Decentralised resources (Electric Vehicles, PV panels, Wind turbine)
  - Control
  - Market participation to include end users at system extremities
- Electric Vehicles as a responsive demand and dispatchable storage

# Problem Statement

Extend an existing network planning tool to analyse the integration of Electric Vehicles into the distribution network at Low Voltage when used as a responsive demand and dispatchable storage. Responsive EV charging can meet multiple stakeholder objectives.

## Objectives:

Maximise revenue

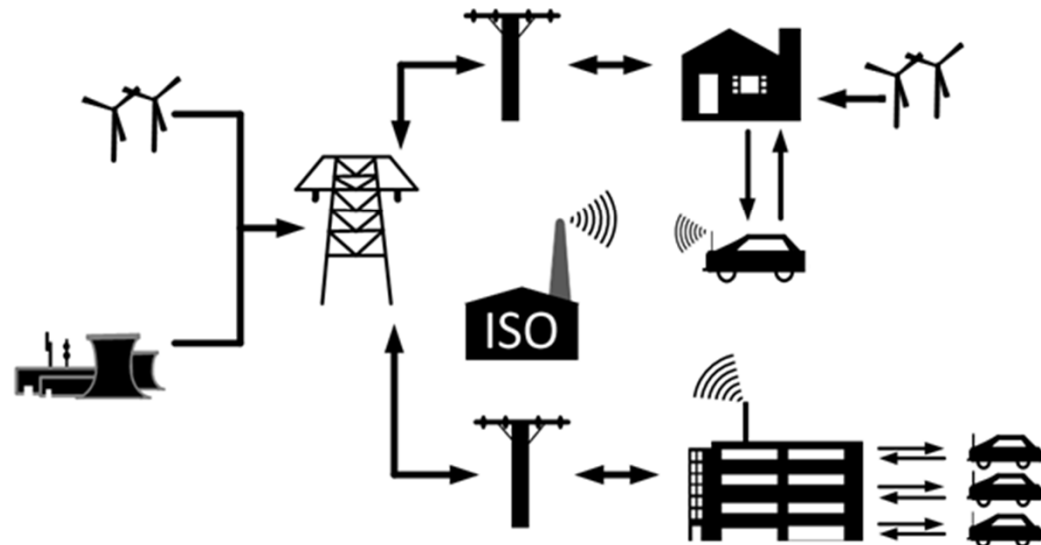
Minimise costs

Minimise power losses

Maximise renewable uptake

Therefore,

Optimisation is required





# Optimisation

Traditional optimisation methods are for single objectives or multiple objectives coded as a single objective > loss of accuracy

The optimisation method chosen must be equipped to handle:

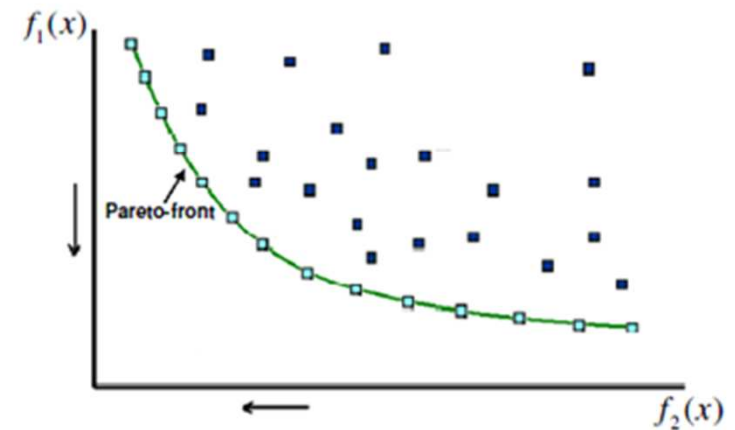
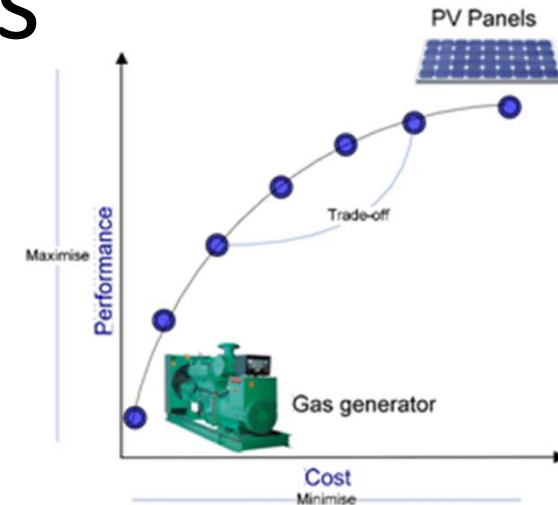
- Multiple (and conflicting) objectives
  - Minimise losses
  - Maximise revenue
  - Minimise cost
- Any type and number of constraints (technical) and objectives
- Integer and discrete variables

Traditional Methods e.g. Linear Programming or Integer Programming not suitable so new family of techniques to be used > MOEA



# Genetic Algorithms

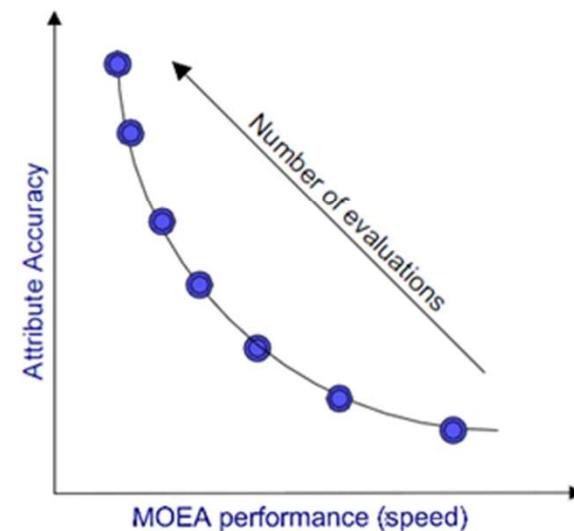
- Based on Evolutionary Theory & simple concepts
- Most popular Evolutionary Algorithm
- GAs are a family of powerful search techniques.
- Genetic Algorithms can be used with:
  - non-differentiable objective and
  - constraint functions and
  - non-convex objective functions.
- Pareto set  
A solution belongs to the Pareto set if it cannot improve in one objective without detriment to other objectives.





# Multi Objective Evolutionary Algorithms

- Multi-objective techniques which are based upon the principles of Genetic Algorithms have the ability to produce several solutions of the Pareto set simultaneously
  - Evaluating hundreds of chromosomes over hundreds of generations means tens of thousands of evaluations
- MOEA can effectively and efficiently offer a variety of solutions to DER planning problems specifically
  - the number & location of Electric Vehicles
  - used as dispatchable storage
  - on the distribution networks which have
  - multiple objectives of interest.
    - Minimise losses
    - Maximise revenue
    - Minimise cost

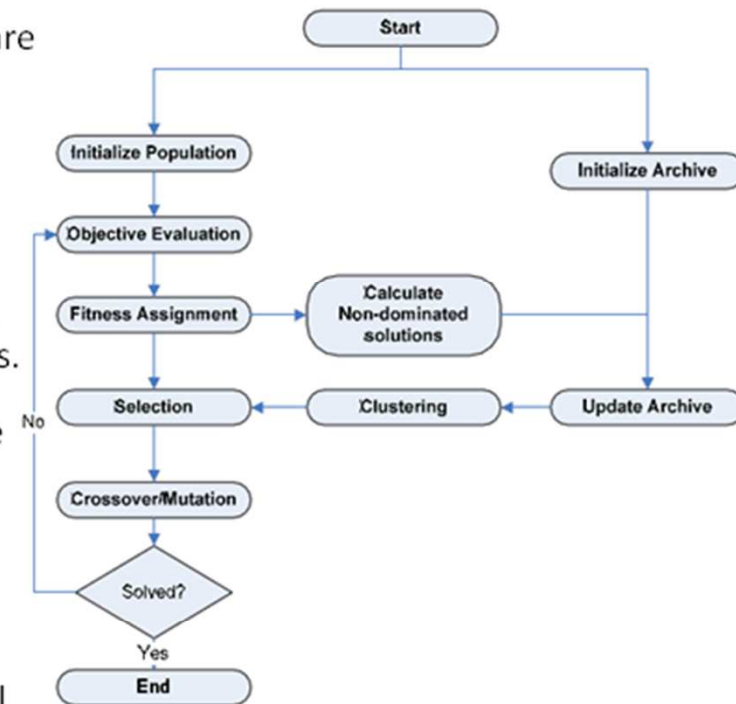




# Strength Pareto Evolutionary Algorithm 2

- The goals of MOEA in general and SPEA2 specifically are
  - Accuracy
  - diversity and
  - spread
- SPEA2 achieves these by implementing an enhanced fitness assignment procedure that increases selective pressure where the fitness of each individual solution is modified according to the distance to its neighbours.
- Another feature of SPEA2 is that only members of the elite archive participate in the reproduction step. This ensures that only 'fit' solutions are kept to reproduce to the next generation.

SPEA2 is more accurate, computationally faster and outperforms other MOEA in both theoretical and practical applications and is the most efficient, even in a small number of generations [1]





# Electric Vehicles as Storage Units

- The inclusion of EV technology on the distribution network will mean that bi-directional energy storage can be exploited to meet grid requirements at various times of need
- The stored battery energy could provide backup during periods of peak energy demand, and also provide reserve, constraint management and other frequency and voltage regulation services when connected to the grid.
- Location and size of the storage unit can be optimised but also the role of management/control of the storage device can also be optimised[2]
- It has been shown that privately owned cars are utilised only 5.2% of the time of transportation thus making them, in principle available for the remaining 94.8% of the time as a secondary source of power generation or flexible demand [3]

[2] C.E.T. Foote, et al., "Ubiquitous Energy Storage," Proceedings of the 2005 FPS International Conference on Future Power Systems, 16-18 Nov, Amsterdam, The Netherlands, 2005

[3] S Huang and D Infield, "The Potential of Domestic Electric Vehicles to Contribute to Power System Operation through Vehicle to Grid Technology," The 44th International Universities' Power Engineering Conference 1-4 September, 2009

# Responsive EV Charging

- The current planning tool which is based upon the SPEA2 algorithm will be adapted and used to manage and schedule the (smart) charging of electric vehicles on the LV distribution network
- The precise formulation of the network planning problem can offer network planners low cost solutions to diverse planning problems that may include;
  - Minimise network investment costs (by managing constraints and capping peaks in demand)
  - Maximise wind energy utilisation
  - Minimise losses
  - Maximise renewable DER network access
- The penetration of renewable wind energy will be maximised (in balance with the other optimization objectives) with the use of electric vehicles as a responsive load in this method.

# Expected Results

- The problem of integrating EVs into the distribution network and optimally scheduling the managed charging of these will be approached by extending a network planning tool that uses SPEA2 to size and site EVs on the simulated distribution network.
- EVs are added (to the simulated test network in blocks of ten to each node) so that the optimisation of the scheduling in operation
  - and siting and sizing can be conducted
  - while addressing the overall impact on the network
  - whilst being limited by thermal constraints and
  - voltage constraints and
  - also a fixed battery capacity.
- A multi-objective planning method will obtain a set of Pareto Optimal DER and EV integrations and network configurations
- The best charging strategies will be identified and correlations with EV availability for scheduled charging and times of high penetration of renewables will be shown and results similar to those above will be presented



# Conclusion & Further Work

- A Multi-Objective Evolutionary Algorithm specifically SPEA2 will be used to optimise the inclusion of Electric Vehicles in the distribution network when used as dispatchable storage and responsive demand.
- The use of the presented network planning tool will identify smart charging strategies of electric vehicles (based on the chosen multi objectives and with respect to constraints)
- These will assist in mitigating the intermittency of wind, and the accompanying benefits that this will provide.
- The identified optimal EV charging and storage control is expected to be pushed towards test in a managed network demonstration
- Discussions are underway with network operators to identify and develop case studies to represent typical DER integration in the UK distribution network incorporating EVs.



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Thank you,

Questions?