////**Title: Building Resilience in the Modern Electricity Grid**

////**Standfirst:**

As the electricity generation landscape transforms at a breakneck pace, the techniques engineers use to maintain a high performance in the electricity grid are struggling to keep up. Through a new study, Dr Hashem Nehrir (Hash-em Neh-rear) and several of his former students at Montana State University delve into a variety of potential solutions, which have been presented by global research teams over the past two decades. Through an advanced algorithm, they have now brought together the findings of these studies and present a new grid architecture that could ensure our electricity infrastructures remain resilient well into the future.

////**Main text:**

The global electricity grid is arguably one of the greatest feats of human engineering, connecting systems and devices in virtually every facet of society imaginable. Yet despite its central importance in our everyday lives, the grid is far from invincible. In reality, events ranging from electrical faults to extreme weather can cause severe disruption to the infrastructure. If just one component of an interconnected grid fails, it can cause problems in others to which it is connected. In worst-case scenarios, this creates a cascade of problems, which has led to blackouts across entire nations in the past.

As our world becomes increasingly electrified, it is now more important than ever for researchers and engineers to come up with smart solutions to this issue. Perhaps the most widely agreed-upon technique is to split large, centralised grids into regional, more manageable smart 'microgrids'. By rapidly identifying and isolating any issues that arise, grid operators can temporarily shut down these smaller grids, preventing problems from cascading. Then, 'healthy' parts of the grid neighbouring the affected region can communicate with each other to solve the problem and restore the microgrid's operation.

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Despite the advantages of this system, a new challenge is quickly emerging. Where until recently, electricity was dominated by large, coal-fired powerplants, electricity sources are rapidly becoming more diverse thanks to the rise of renewable energy. With the growing role of smaller-scale wind and solar power facilities, combined with in-built energy storage, today's electricity generation landscape is becoming increasingly dispersed across multiple smaller regions. In addition, the amount of power generated is becoming increasingly variable, depending on factors including the weather, the time of day, and even the time of year.

Currently, the traditional techniques that engineers apply to maintain high performances in the power grids are too cumbersome to allow for their efficient operation. Solving the problem will be no easy task: realistically, the design, development and maintenance of resilient power systems will require exchanges of knowledge between researchers in fields as widely varied as power, communications, control, signal processing, computer science and economics. Unperturbed, Dr Nehrir and his research team at Montana State University have drawn together the numerous findings of numerous studies in these fields into a single, comprehensive solution.

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Each of the studies considered by Dr Nehrir's team offers a different perspective on how modern smart grid performance should be optimised. Because of the diverse energy sources involved in the smart grid era, such as solar, wind and fossil fuels, optimising for factors such as costs, emission of undesired greenhouse gases and limitations of electrical equipment, will have multiple objectives that may be in conflict with each other. This means that any practical measures to optimise one objective could act as a barrier to optimising another.

Dr Nehrir's research team has overcome this multiple-objective challenge with the help of an advanced algorithm, named the 'Nash bargaining solution'. The inner workings of this algorithm are based on the principles of game theory and the strategic interactions that take place between intelligent decision-making agents.

These agents are data processors that are in charge of controlling the diverse energy sources involved, and the grid itself. Using the developed algorithm, agents with competing goals can bargain with each other through peer-to-peer communication. In this case, it allowed them to quantify the impact of each objective on the overall problem, establish a set of trade-off solutions and maximise the desirable outcome, accounting for all objectives.

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Drawing on the outcomes of their algorithm, Dr Nehrir's research team proposes a new architecture for an optimised microgrid-based smart electrical grid. In their design, large-scale, interconnected grids are divided into several smaller, regional grids. These regions are then further divided into several smaller microgrids, which operate autonomously according to the requirements of their local areas.

These localised networks, interconnected under normal condition, can then either import power from their neighbouring parts if they are not meeting demand by themselves, or export power if they are exceeding demand. This means that the architecture can intelligently leverage local renewable resources to maintain power balance across the whole grid and provide continuous energy to all customers.

If there is a fault in another part of the grid, the microgrids described by the team can disconnect from their neighbouring grids in order to prevent any cascading faults – and continue their operation on a smaller scale. Furthermore, if a fault occurs within the microgrid itself, it can isolate itself from the rest of the grid. As soon as the faulty microgrid becomes healthy, it can re-join the larger grid. The same principles can also apply on larger scales, allowing entire problematic regions to isolate themselves until they become healthy again and re-join their neighbours.

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Dr Nehrir believes that this hierarchical structure presents an ideal solution to the growing challenges and vulnerabilities faced by today's increasingly diversified electrical infrastructures. By realising such resilient, self-healing smart grids, any damages brought about by cascading faults can be minimised, and any large-scale blackouts could be prevented. This proposal may sound ambitious, but the researchers argue that their techniques could be integrated into existing power infrastructures without the need for huge system-wide modifications.

Once in place, Dr Nehrir's team shows that the proposed smart microgrids will be able to grow and evolve in smart, adaptable ways as the global electricity grid becomes increasingly diverse and dispersed in the coming years. If their proposed grid architecture becomes adopted more widely, it could ensure that entire nations have sufficiently robust power infrastructures, towards safe and sustainable futures. Further tests will be needed by utilities before putting the proposed proof-of-concept into practice.

This SciPod is a summary of the paper 'A Survey on Smart Agent-Based Microgrids for Resilient/Self-Healing Grids' from *Energies*, https://doi.org/10.3390/en10050620, co-authored by Kaveh Dehghanpour (Kaa-veh Deh-gaan-pour), Christopher Colson, and Hashem Nehrir.

The researchers acknowledge support from the US National Science Foundation, under Award number 1806184.

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