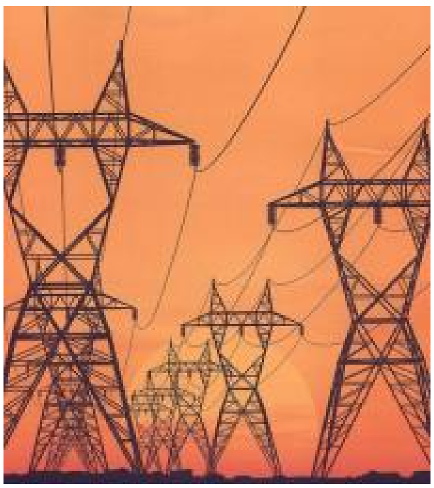
From power grids to heartbeat: Using mathematics to restore rhythm

July 15 2015



Credit: Argonne National Laboratory

When a rhythm stalls, the effect can be fatal - in a power grid it can mean a blackout, and in the human heart even death. An international team of scientists has now developed a new approach for revoking these undesired quenching states. They use an advanced mathematical methodology, building on complex networks analysis, and demonstrate it in experiments with chemical reactions.

This could one day help to stabilize the flow of electricity in power grids challenged by the variable input from renewable energy sources. Future research could apply it to other complex networks, including processes within body cells and even the human cardiovascular system.

"Many systems rely on tiny movements back and forth, in a certain rhythm, like in music - we call this oscillation," says Juergen Kurths of the Potsdam Institute for Climate Impact Research (PIK) in Germany, head of the research team. "Now if the rhythm gets disturbed, the system cannot continue working properly. Hence the interest in finding ways to restore the rhythm." The findings will publish in the eminent journal *Nature Communications*.

Fluctuating renewable energy generation enhances power grid stress

Power grid stability was the point of departure for the scientists. The alternating current transmitted in power lines swings at a certain frequency, for instance 50 Hertz in Europe and 60 in the US. This regular behaviour can get disturbed when the power input changes from one moment to another - this can happen, for instance, with electricity generated by windmills when a storm or a calm period occurs, while coal-fired power plants produce a steady flow of energy. Yet more and more renewable energy is being fed into power grids, since burning fossil fuels emits greenhouse gases which are the main cause of dangerous climate change.

To avoid power grid stress, and eventually blackouts, new approaches to stabilize current frequency are much desired. The method the scientists now found is just one of a number of approaches, many of them already under discussion. Yet it is an unprecedentedly innovative one. "The principle is fairly simple, but the mathematics behind it are not", says István Kiss of Saint Louis University in the USA. "We demonstrated that the theory applies to an experiment in which the rhythmicity can be restored in a small network of current generating chemical reactions. These reactions involve an ensemble of complex physical and chemical processes with many variables and uncertainties, so it is really surprising how well the purely mathematically derived approach proves to work here. This indicates a remarkable generality."

Two organ-pipes of similar pitch can mutually suppress their vibration

The scientists studied the interaction of coupled oscillating systems. Already in the 19th century it was observed that two organ-pipes of similar pitch standing side by side can mutually suppress their vibration. Related phenomena are known from neuroscience, chemical reactions, and electronic circuits. Up to now, no solution for restoring the rhythm had been found.

The team of researchers involved comprises experts from China, India, Russia, the US, UK, Macedonia, and Germany. Several of the international scientists have been working on the study during their stay as guest scientists at PIK, so this is where they developed a good part of the analysis.

"We show that subtly delaying the impulse which goes from one element of the system to another, for instance in a power grid, can efficiently restore the previously disrupted oscillations," says Wei Zou of Huazhong University of Science and Technology in China, lead author of the study. "Even a feeble deviation can make a huge difference here - I have to admit we have been surprised how simple and robust our method is. Now we hope it will open a door for future research in the field of complex systems science, and invoke eventually applications in many areas ranging from biology via engineering to social sciences."

More information: Zou, W., Senthilkumar, D.V., Nagao, R., Kiss, I.Z., Tang, Y., Koseska, A., Duan, J., Kurths, J. (2015): Restoration of rhythmicity in diffusively coupled dynamical networks. *Nature*

Communications doi:10.1038NCOMMS8709

Provided by Potsdam Institute for Climate Impact Research