New smart grid control decentralizes electricity supply

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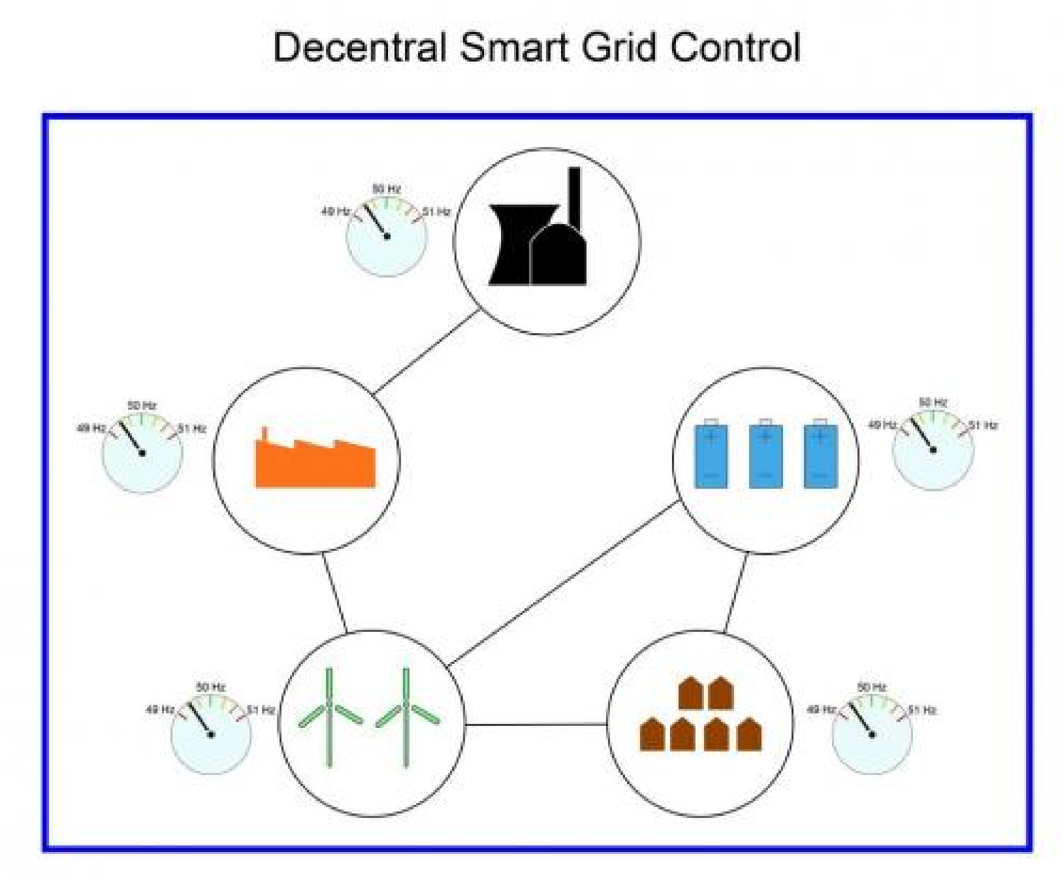


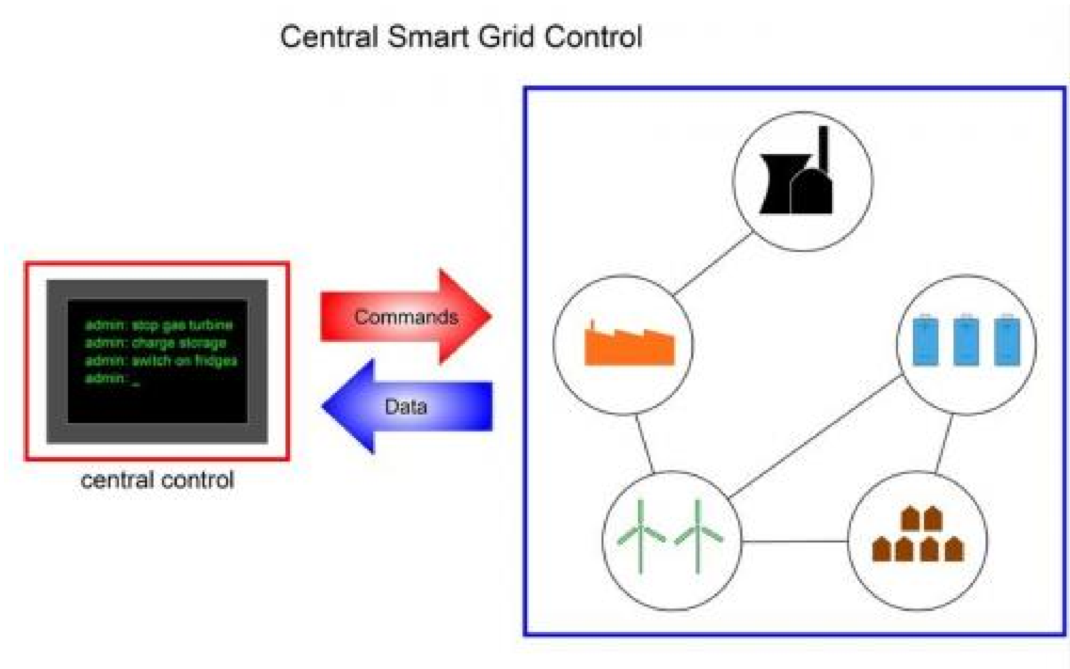
Decentrally organised electricity supply: According to a study carried out by researchers from the Max Planck Institute for Dynamics and Self-Organization, electricity control devices, so-called smart meters, can tailor the electricity supply from nuclear power plants and wind farms to the demand from industry and households based on a self-organised process. The study also takes into account whether the electricity is available in stored form, for example in batteries, or whether it has free storage capacity. Credit: Benjamin Schäfer / MPI for Dynamics and Self-Organization

To improve the management of fluctuations in the electricity supplied by solar and wind installations, the electricity network needs to work more intelligently in the future. Electricity suppliers aim to be able to regulate consumption on the basis of supply with the help of an intelligent electricity network, a smart grid. Intelligent electricity meters developed for such a system would be able to switch electrical devices on and off. Researchers from the Max Planck Institute for Dynamics and Self-Organization have now shown that intelligent electricity meters can match electricity demand and supply decentrally and on an entirely self-organised basis. Up to now, electricity suppliers worked on the assumption that they would need to collect consumption data centrally and also centrally coordinate electricity demand and supply. This makes the electricity supply vulnerable to hacker attacks and also raises data protection issues – problems that do not arise with a fully decentral solution of the Max Planck researchers. Decentral control also relaxes the need for the complex design of the vast communications infrastructure that would be required to connect millions of electricity meters with the major energy suppliers in future.

The use of renewable energy sources is growing rapidly. For instance, since early 2014, the feed-in from renewable energy sources has reached over 28 percent of electricity consumption in Germany – a new, all-time high. However, with the rise of solar and wind installations, fluctuations in the electricity network are also on the rise. When a cloud front covers South Germany, there is an abrupt dip in the amount of electricity supplied by the solar power plants. And when a storm approaches, electricity production in the wind parks increases suddenly and fluctuates even more than usual. Such fluctuations do not arise in the traditional electricity network, as the generators in the coal-fired power stations and remaining nuclear power stations chug along regularly day in day out, providing a constant supply of electricity.

The increasing feed-in fluctuations will have to be balanced out in the future by simultaneous variations in electricity consumption. For example, when the wind and sun provide a lot of energy, the cooling units in computer centres and warehouses, and electric car charging stations should be cranked up; when production dips, they should be put on stand-by. To achieve this, the energy suppliers would like to equip their customers in the future with electricity control devices, so-called smart meters. These would be installed in households or company premises and transmit the data they collect automatically to the energy supplier. Depending on the available supply of electricity, household and industrial devices could then be switched on or off. Customers are more likely to adopt such systems if they are offered excess energy at lower prices. To coordinate the electricity supply and demand, researchers at the Max Planck Institute for Dynamics and Self-Organization in Göttingen have introduced a new concept which focuses on the fully decentral matching of electricity supply and demand.

Hackers could bring a central supply network to a standstill



Centrally organized electricity supply: Today, electricity suppliers would like to operate an intelligent electricity network that regulates consumption on the basis of the current supply by transmitting consumption data from consumers to a central location and coordinating the demand there with the available electricity supply. They also want to control the consumption by different customers centrally. Credit: Benjamin Schäfer / MPI for Dynamics and Self-Organization

The concepts available today for a future intelligent electricity network (smart grid) work on the assumption that the data for all electricity consumers and generators would be collected centrally by the energy supplier. However, according to Benjamin Schäfer, a physicist from the Max Planck Institute for Dynamics and Self-Organization, this approach involves various risks: "This kind of central control is a potential target for hacker attacks." If someone hacks into the control centre via the Internet, they could at worst bring the supply network to a complete standstill. In times of increasing Internet criminality, this scenario must be taken seriously. "Moreover, it remains to be clarified how data protection could be guaranteed if customer consumption data are constantly being transmitted to a central location."

For this reason, Benjamin Schäfer, member of Marc Timme's Research Group, "Network Dynamics" examined whether central control is actually essential. The inspiration for the project was provided by a cooperation partner of the Max Planck researchers, the managing director of the Karlsruhe-based company Easy Smart Grid, Thomas Walter. His company develops system solutions for the operation of decentral energy networks – that is electricity networks, in which the electricity is not provided exclusively by large power plants and is increasingly supplied by numerous small generators. As part of this study, Benjamin Schäfer, together with Marc Timme, his former colleague Dirk Witthaut and Masters' student Moritz Matthiae, examined whether, and how, smart meters installed on customers' premises could regulate consumption directly and decentrally without a detour via a central control system.

For this purpose, the physicists developed a mathematical model in which they simulated the electricity generators and consumers. They wanted to find out whether the entire network remains stable when regulation is carried out decentrally and no longer involves coordination with the central energy supplier. Would the network be able to run itself on a more or less self-organised basis? Basically, network frequency, i.e. the frequency at which the alternating current oscillates in the supply network, is used as a parameter for regulation. It is defined at 50 Hertz and may only deviate from this target value as a result of network fluctuations by a maximum of 0.2 Hertz. If a storm front darkens the skies over a solar park, for example, or an aluminium plant starts up its machinery, less electricity is available the network locally and the frequency falls slightly. If the sun generates more electricity again or major electricity consumers are switched off, more electrical energy is available and the frequency rises. The electricity suppliers must take active measures to maintain the frequency of 50 Hertz and avoid faults in the network.

Smart meters can control the electricity consumption decentrally

Schäfer and his colleagues have now succeeded in demonstrating that such faults can actually be balanced out if the electricity control devices respond directly. The smart meters are thus entirely capable of using frequency changes as a parameter and controlling the electricity consumption of connected electrical devices themselves. Schäfer overcame a particular challenge through his analysis: It is known that many devices have a delayed response to short-term frequency changes in the network, which sometimes arise within a period of milliseconds – for example, a cooling unit has a delayed response when the compressor has to be switched on or off. Schäfer wondered how long such a delay can be and whether it might prevent the direct control of frequency fluctuations through the smart meters installed on the consumers' premises.

His results are very positive. He established that smart meters do not have to react immediately as smaller fluctuations often balance themselves out within a few seconds or fractions of a second. For larger fluctuations, this kind of delay is actually useful. Therefore, it is ideal if the smart meters average out the frequency values over a few seconds, then intervene, and regulate and adapt consumption accordingly. This means, of course, that a sufficient number of smart meters and electrical devices must always be activated so that the impact on the electricity network is adequate. "No previous study analysed in detail whether a smart grid can actually function without central control. Our analysis has shown for the first time that this is possible in principle," says Marc Timme.

A decentral control system of this nature would offer enormous advantages. In particular, it would no longer be necessary to build the vast communications infrastructure that would otherwise be required to connect millions of smart meters to the major energy suppliers.

More information: "Decentral Smart Grid Control" 2015 *New J. Phys.* 17 015002 DOI: 10.1088/1367-2630/17/1/015002

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