

PRESS RELEASE

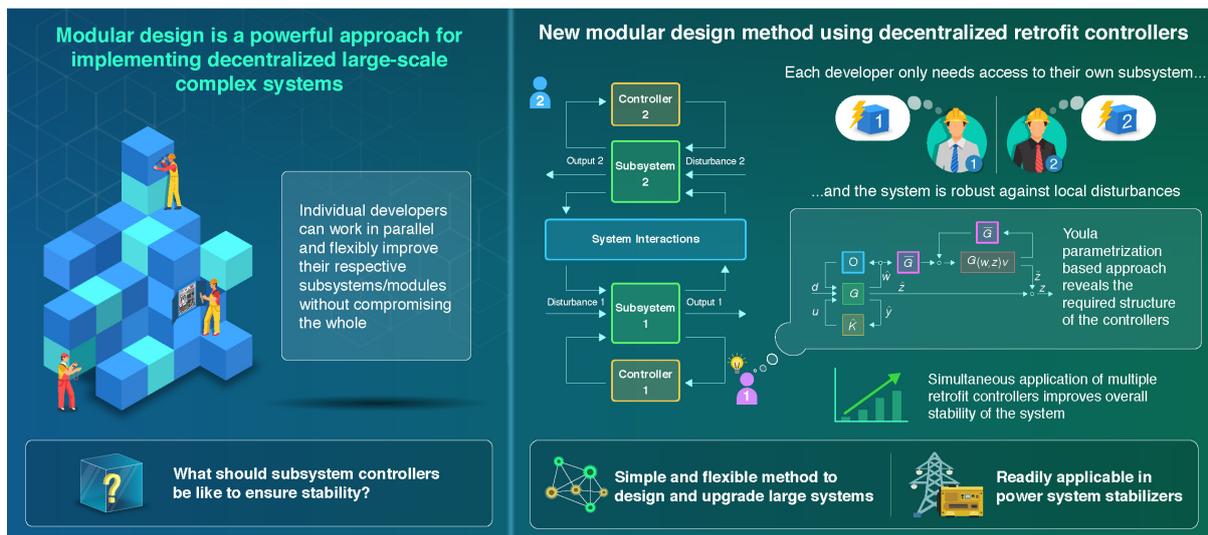
Source: Tokyo Institute of Technology

For immediate release: November 4, 2020

Divide and Conquer—Modular Controller Design Strategy Makes Upgrading Power Grids Easier

(Tokyo, November 4) Scientists at Tokyo Institute of Technology develop a novel approach for the modular design of controllers for large-scale network systems. Their strategy, which provides a completely decentralized method to design controllers for subsystems of a larger whole, could be readily applied in power grids, greatly simplifying the task of sequentially upgrading individual subdivisions while ensuring stability and performance.

Divide and Conquer: New Approach to Modular Design in Large and Complex Systems



Modularity-in-Design of Dynamical Network Systems: Retrofit Control Approach
Ishizaki et al. (2020)
IEEE Transactions on Automatic Control



The control of large-scale dynamic network systems, such as national power grids, is a remarkably challenging topic. In this context, “control” roughly means monitoring relevant output variables to ensure that the system operates stably and within safe margins. The difficulty and necessary considerations associated with the design and implementation of controllers usually skyrocket when dealing with complex networked systems, and theoretical studies to find new approaches to controller design are constantly being carried out.

One common problem that arises in large networked systems is that they’re integrated. So, when a developer changes or upgrades is one subsystem, their actions on their neck of the woods can have unforeseen consequences on the rest of the network unless necessary precautions are taken for all subsystems. Even remote network disturbances caused by local temporary failures, such as the accidental grounding of a line in a power subsystem, can throw

other subsystems off. Consequently, often no change can be made to one subsystem, without needing to alter all others.

However, as demonstrated in a recent study by scientists from Tokyo Institute of Technology (Tokyo Tech), Japan, there is a design paradigm that can prevent such problems: modularity. This term implies working in “modules,” subdivisions of the main system that can be separated, changed, and recombined independently, ideally without compromising each other. Nonetheless, as explained in their article published in *IEEE Transactions on Automatic Control*, achieving this independence between modules through their associated controllers is not straightforward.

In their study, the scientists developed a novel approach for the modular design of subsystem controllers in linear large-scale network systems that enables a number of advantages over existing approaches. In their approach, each developer for a subsystem can independently design and implement their controllers as an add on to the existing system. To do so, they only require knowledge of their subsystem. A decentralized controller designed under such considerations is called a *retrofit* controller.

First, the scientists used a technique called Youla parametrization to formally describe all the relevant parameters of generic retrofit controllers in a networked system. Then, they laid out a unique design for their retrofit controller that required only standard techniques to implement. They also mathematically demonstrated that, given certain reasonable assumptions about the whole, such as a stable system prior to the implementation of the proposed retrofit controller, using their controller guaranteed both local and overall system stability, even in the face of variations in other controllers.

Moreover, through numerical experiments, they showed that simultaneously implementing multiple such uniquely designed controllers in a network translates to performance improvements across the entire system, and adding more such controllers leads to greater power enhancement. As associate Professor Takayuki Ishizaki, lead author of the study, explains “*The proposed modular design method provides a new theoretical basis for sequential system upgrades, such that the stability of the current system is surpassed by its future generations. In short, each designer can individually add, remove, and modify their controller without considering the actions of other designers.*” His team also demonstrated the practical significance of their method through an illustrative example: generator frequency regulation in an IEEE-standard power system model.

The benefits of modularity-in-design are many, as Ishizaki concludes: “*Modular design is a widely accepted strategy that simplifies the design of complex large-scale systems, enables parallel work by multiple independent entities, and enables flexible future modifications of modules.*” Future advances in modular design will hopefully make the control of large-scale network systems more easily tractable and make them more easily upgradeable.

Reference

Authors: Takayuki Ishizaki¹, Hampei Sasahara², Masaki Inoue³, Takahiro Kawaguchi¹, and Jun-ichi Imura¹

Title of original paper: Modularity-in-Design of Dynamical Network Systems: Retrofit Control Approach
Journal: *IEEE Transactions on Automatic Control*
DOI: [10.1109/TAC.2020.3035631](https://doi.org/10.1109/TAC.2020.3035631)
Affiliations: ¹Graduate School of Engineering, Tokyo Institute of Technology
²School of Electrical Engineering and Computer Science, KTH Royal Institute of Technology
³Faculty of Science and Technology, Keio University

*Corresponding author's email: ishizaki@cyb.sc.e.titech.ac.jp

Related Links

[Planning ahead: A new robust approach for minimizing costs in power-distribution networks | Tokyo Tech News](#)

[Symmetry is essential for power network synchronization | Tokyo Tech News](#)

[Takayuki Ishizaki Laboratory](#)

Contact

Emiko Kawaguchi
Public Relations Group,
Tokyo Institute of Technology
media@jim.titech.ac.jp
+81-3-5734-2975

About Tokyo Institute of Technology

Tokyo Tech stands at the forefront of research and higher education as the leading university for science and technology in Japan. Tokyo Tech researchers excel in fields ranging from materials science to biology, computer science, and physics. Founded in 1881, Tokyo Tech hosts over 10,000 undergraduate and graduate students per year, who develop into scientific leaders and some of the most sought-after engineers in industry. Embodying the Japanese philosophy of “monotsukuri,” meaning “technical ingenuity and innovation,” the Tokyo Tech community strives to contribute to society through high-impact research.

<https://www.titech.ac.jp/english/>