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(FRS) FUTURE RESILIENT SYSTEMS 未来 韧性 系统

Building Composite Indicators to Quantify Electricity Supply Resilience of Eurasian Countries

by

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ABSTRACT

Electricity is a central resource for the functioning of today's society. Therefore, electricity grids are categorised as critical infrastructures that need to be protected against threats and catastrophes. A failure of the electricity supply system can quickly cascade into other vital systems (e.g. communication, transport, security) and create severe, irreparable damages.

The study of "Security of Electricity Supply" and the assessment of risks is an important factor in the improvement of infrastructure, system design and policy decisions. While many studies analyse risks in the electricity system with technical or holistic approaches, there is limited research on the resilience behaviour of these systems. However, since resilience emphasises the survival and quick reestablishment of electricity supply after disruptions, it is of outmost importance for critical infrastructures to consider resilience. Many other impacted systems may relay on the speedy recovery and resupply of electricity to start their own regeneration process after a catastrophe. Investments and policies that strengthen the reactive capabilities towards disruptions should not be neglected in favour of short-term efficiency and stability gains.

The difficulty in calculating risk and, especially, resilience lies in their abstract and intangible concepts that makes the assessment and measurement of electricity supply resilience challenging. To create awareness as well as highlight problematic areas, a quantifiable comparison is desirable. The creation of a valid and robust electricity resilience index is a dynamic process involving many stakeholders and researchers, and with the need for a solid framework that enables an interdisciplinary discussion and collaboration. Although previous studies have assessed and compared single countries with a wide selection of indicators, their results are either qualitative and country specific and, thus, without international applicability or do not handle resilience holistically.

This thesis applies an interdisciplinary and holistic resilience concept to the specific conditions of national electricity supply systems. The developed framework enables the search and selection of quantifiable and measurable indicators that are then aggregated into a composite indicator. 14 indicators are selected to describe and assess the functionality of resilience. The selection followed an assessment of currently available indicators and with the requirement of quantitative measurability and international applicability.

To showcase the application of this composite indicator framework, a case study on 26 Eurasian countries is conducted. The sample represents a variety of electricity systems within advanced or developing economies, multiple fuel sources and generation technologies as well as differing diplomatic relations and political stability.

The case study shows a clearly identifiable resilience trend with distinct differences between groups of countries, while highlighting implications in the creation of such a resilience index. Especially the selection of a specific normalisation and aggregation method can create significant differences in the final ranking due to the levels of compensation allowed between indicators. While many researchers use an additive-mean, which allows full substitution between indicators, this research suggests that a stronger penalty on low performing indicators is better suited to highlighting critical areas. This is especially important in risk and resilience assessments, where the weakest system link might be the driver for failure.