Event-driven Reorganization of Distributed Business Processes in Electrical Energy Systems

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Abstract. Business processes, e.g. economic or operational optimization, in large power systems employs heuristics based on solving a relaxation of the original problem due to the number of actors and components involved as well the time-criticality for finding feasible solutions. In order to cope with the large number of conflicting objectives in the problem instance, multi-agent systems (MAS) are often chosen in order to find timely solutions while guaranteeing certain fairness aspects. However, utilizing MAS poses specific challenges achieving observability and other non-functional requirements in the context of safety-critical electrical energy systems. To cope with these systemic risks, we will sketch out methods to increase observability and dynamic reorganization in the sense of regulated autonomy.

Keywords: smart grids, multi-agent systems, safety-critical operation.

1 Summary

The energy transition (Energiewende) introduces rapidly changing requirements into historically grown, heterogeneous industry and application landscapes. Future energy system solutions – so-called smart grids – are increasingly IT-based. The increasingly decentralised and highly automated management of energy sources is changing the existing communication and energy distribution structure as well as introduces various new stakeholders to the system. In that sense it is an autonomous cyber-physical system (ACPS) that is controlled or monitored by highly autonomous computer-based systems, tightly integrated with the Internet and its users. Physical and software components are deeply intertwined, each operating on different spatial and temporal scales, exhibiting multiple and distinct behavioural modalities, and interacting with each other in numerous ways that change with context [1].

Additionally, electrical energy systems exhibit special characteristics that set them apart from other ACPS (e.g. transportation systems). Energy systems are considered a **critical infrastructure** (German acronym: KRITIS[1]) and are indispensable lifelines of modern societies. They have a size that **transcends continents** – from North Africa to

[1] https://www.kritis.bund.de/SubSites/Kritis/DE/Einfuehrung/einfuehrung_node.html

Scandinavia, from Ireland to Asia. Phenomena and their dynamics exhibit **instantaneous propagation speed** – this is a special challenge with regard to the analysis and timely reaction, i.e. containability of instabilities. **Conflicts of objectives** are omnipresent – monetary, technical, political (national/international) interests meet in both systems planning as well as operation. Last but not least, the energy system is undergoing **rapid and fundamental change** following the energy transition [2]. In its course, the system is digitalized and becoming ICT-reliant, which yields unique systemic risks considering that the ICT is dependent on a high power quality itself and at the same time indispensable to ensure that quality. These risks have to be addressed properly in order to guarantee a safe and stable energy supply.

From an ICT-perspective, future power systems are composed of billions of components – producers and consumers of electrical energy, grid and operating equipment, markets as well as (local) coordination platforms. This complexity together with non-linear system dynamics and almost immediate propagation velocities results in business processes to be highly decentralized, multi-objective, dynamic, real-time optimization problems [3,4].

One strategy to cope with this complexity is to follow distributed heuristical optimization approaches on the basis of multi-agent systems (MAS) [3,5,6,7,8]. However, in order to apply distributed AI-techniques such as MAS during operation of safety-critical infrastructures, it is desired to infer the state of the solution quality as well as other aspects (e.g. convergence behaviour, spatial disparities) on-line and incorporate this knowledge into operational (autonomous as well as human-in-the-loop) decision-making.

With multiple business process being executed at the same time and within the same technical (sub-)system, it is foreseeable that at any given time there is a set ordering regarding the criticality or priority over a certain number of processes, e.g. stability-relevant processes are more critical than economic dispatch, or large bulk-market contracts being of higher priority than small-scale decentralized contracts.

The goal of this work is to derive relevant solution parameters of distributed process optimization and integrating them into existing supervisory automation and control concepts. This not only allows for facilitating the observability of the most critical processes but also the controllability of the heuristic solution process by assigning specific ICT-resources (computationally or communication-specific) to individual processes. Thus, event-driven reorganization – even temporary centralization of the optimization process – may be achieved, in the sense of a Smart Grid dynamic regulated autonomy approach [9,10].

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