A Risk Management for Agent-based Control of Ancillary Service Provision from Distributed Energy Resources in Smart Grids

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Abstract

With increasing shares of renewable power generation, conventional power generation from large-scale and highly predictable fossil power plants decreases. Reliably substituting these plants depends on distributed energy resources (DER) being able to provide ancillary services such as frequency and voltage control that are necessary for a reliable and stable power supply. In this paper, we present first concepts regarding an agent-based approach for a stable and reliable control of ancillary service provision from DER, and we outline research challenges regarding the management of the economical risk an operator faces when trading active power and ancillary services from DER at energy markets.

1. Introduction

In order to reliably substitute conventional power plants, distributed energy resources (DER) have to participate both in active power trading and in the provision of ancillary services that are needed to safely operate the grid. This implies new challenges both for the control of the underlying system and the management of economical risks, as one has to cope with many individually configured, distributed, small generation units (photovoltaic (PV) systems, combined heat and power plants (CHP), wind energy converters etc.) as well as with the fluctuation in their feed-in especially depending on meteorological conditions. Regarding the technical implementation of stable, reliable and scalable control methods, self-organizing agents that represent generators, loads and (electrical) storage systems have been proposed for several years by the Smart Grid community [9], [13], [11].

Within the Smart Nord research project, an agent-based, self-organizing method for clustering DER into so called coalitions is being developed.[2] The agents representing single DER units – thus called unit agents – are not only capable of matching power products at energy markets such as the European Energy Exchange (EEX), but also allow for the provision of ancillary services in order to stabilize the power grid when necessary. For instance, frequency response reserve must be provided as an automatic reaction to a loss in supply or demand in order to stabilize the frequency. This is typically provided by large power plants through a controller yielding a small boost or drop in generation to balance demand and supply, respectively, thus stabilizing the frequency. As these reserves are necessary for a stable power supply, the provision of an ancillary service must be guaranteed and has to fulfil specific reliability constraints.

In this paper we present first concepts regarding an agent-based approach for a stable and reliable control of ancillary service provision from DER. In addition to a discussion of the technical properties of the developed system, we also outline research challenges regarding the management

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of the inherent economical risk an operator faces when trading active power and ancillary services from DER.

2. Related Work

2.1. Virtual Power Plants and Agent-Based Control of Smart Grids

Static virtual power plants (VPP) have initially been designed to overcome market barriers on active power markets [1]. Although several operators of VPPs are currently active participants on energy markets, the underlying concept has several flaws especially regarding its scalability. First, the VPPs are static regarding the pool of aggregated units – changes within the pool creates substantial and costly engineering overhead. Second, the control architecture is centralized, i.e. a single VPP control centre typically supervises and controls each single unit based on centrally optimized schedules – with the obvious shortcomings regarding scalability and complexity in the reflection of local constraints. Third, these VPPs were not designed to take system stability into account. VPPs of this kind only optimize economic integration of distributed energy resources (being a very important issue nonetheless).

As a consequence, a new aggregation type was defined in the project FENIX to overcome some of these shortcomings. Using a technical VPP concept, operational feasibility aspects are integrated into the market mechanism for commercial VPPs [6]. However, the proposed aggregation methods are still prone to flexibility and scalability issues. With the PowerMatcher approach, a more dynamic and agent-based concept was proposed, which was initially dedicated to matching supply and demand locally [7]. DER in the distribution grid trade their schedules locally and try to reduce the necessity of electricity transport from or to other voltage levels. Source [14] propose a similar concept, but focus on real-time requirements. In contrast to the concept presented in this paper, both systems work fully reactive without taking the energy market into account.

2.2. Risk Management

Nowadays, risk management is being applied in the context of conventional power plants. In [4] risk management is described as an economical task to combine the economical view on and the acceptance of risk. Thus, the main tasks of risk management are:

1) defining and implementing risk management,
2) limiting economical risks, and
3) implementing change management and improving planning security.

In the following example, a plant operator’s view on risk management is being used to illustrate these tasks: The operator of a coal power plant applies risk management in order to identify and monitor economical risks. This has to be done at every process level of the business (including management, projects and operative processes). As an economically feasible operation of coal power plants depends on external factors such as long-term prices for fossil fuels (coal), the plant operator has to avoid price risks. For the comprehensive integration of risk management into the business processes it is recommendable to integrate further functions of risk management (like change management or the improvement of planning security) into the operation of the power plant. Those functions might help to detect risks like an imminent breakdown that may lead to (possibly preventable) downtimes of the power plant.

A more detailed discussion on risk management will be given in section 4.

3. Agent-based Control of Ancillary Service Provision in Smart Grids

3.1. Reliability-dependent Agent Coalitions of DER

In Smart Nord, ancillary services are provided by base coalitions and corresponding core coalitions [8]. The purpose of a base coalition is to aggregate and to represent a group of agents at an energy market. This way, agents gain access to the market and may take part in placing bids on the product by collaboratively providing the required amount of power for the entire delivery period of a given ancillary service product. Core coalitions are subsets of base coalitions. Their purpose is to provide the service over a period of time that is typically shorter than the original delivery period of the service. As forecasts are typically more precise with shorter forecasting horizons, the contribution of individual units of a given core coalition might be larger over this shorter period of time than initially anticipated within the base coalition's delivery period. Thus, a more efficient utilization of units within a base coalition can be obtained through more precise short-term forecasts. With an increase of forecasting errors over time, a coalition's reliability decreases respectively (cf. section 3.2). Figure 1 visualizes the decrease of a coalition's reliability over time and the respective restructuring of the coalition, i.e. the contribution of its members for different time intervals. Here, C_{Core} denotes a core coalition within a base coalition C consisting of 13 units U_i with $i \in \{1,2,\dots,13\}$.

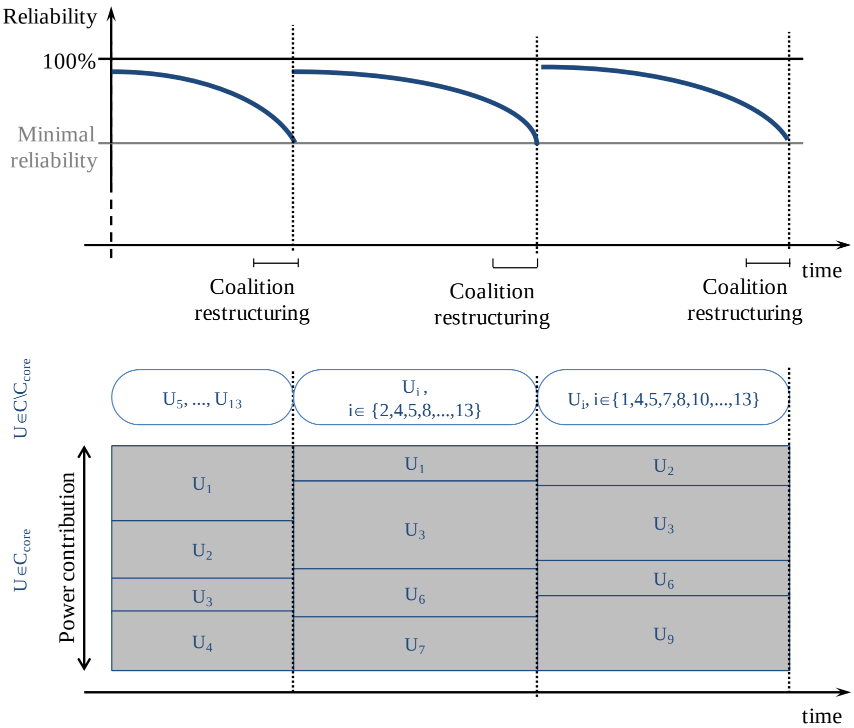

Figure 1: On-line restructuring of core coalitions in regard to decreasing reliability.

In summary, units being in the core coalition are actively responsible for ancillary service provision while the remaining units play a passive role until a minimal reliability threshold is reached and a restructuring yielding a new core coalition becomes necessary. Thus, the provision of ancillary services from agent-controlled DER is guaranteed with at least the minimum acceptable reliability across several core coalitions and ultimately for the whole product delivery period.

3.2. Modelling DER-Reliability for Ancillary Service Provision

Units participating in the provision of ancillary services must guarantee their ability to do so. However, especially renewable energy sources (RES) are subject to fluctuating, hard to predict weather conditions. In order to take the resulting uncertainties into account, a new model for reliability was introduced in [2] that reflects the availability of a unit to provide ancillary services. The reliability of a coalition is thus defined as the probability with which this service is available within a time horizon under normal conditions (i.e. for instance without the existence of vicious agents or extreme weather conditions).

The reliability of an agent coalition depends on the reliability of each of its member units, and the reliability of a single unit is influenced by several factors categorized as *influenceable* and *non-influenceable* factors. Whereas an agent has no control on the non-influenceable factors, it can manipulate the influenceable factors in order to fulfil its objective or fit into a coalition. Those factors are: considered time horizon (directly influencing the quality of a forecast), provided amount of power (smaller quantities may be provided with higher reliability), and acceptable level of reliability.

4. Risk Management for Energy Markets and Ancillary Service Provision

This section deals with the strategic and market-oriented behaviour of agents in ancillary service coalitions. In the context of risk management, “risk” is defined as a financial or an entrepreneurial uncertainty within a business context. The historical definition of risk management comes from an economic context and describes the financial uncertainty that a company is willing to accept, and non-acceptable uncertainties that in consequence have to be eliminated [10]. An undetected and not eliminated potential of risk may influence the business venture of a company in a negative way [5]. Thus, risk management is important to identify potential risks and to rate them in terms of *acceptable* and *non-acceptable*.

The main task of risk management is to avoid risks and to create strategies for handling existing risks. Those risks can be separated into two categories: those who have a critical influence on the current business and those who are acceptable. These categories are described by [10] as *main risks* and *secondary risks*.

Main risks	*Secondary risks*
Risks of the energy market price	Liquidity risk and credit-worthiness of a new co-contractor
fuel price risk	sales fluctuation (especially regarding day-ahead power trading)
risk of investment	risks of new business areas (e.g. ancillary service provision)
risk of prediction error	risks of change management, unbundling and reorganization

The main category already focuses on energy-related risks. The category of the secondary risks is closer to the economical consideration than the first one. For a domain-specific approach, it is necessary to adapt it to an energy-economical context.

In an energy-economical context, risk management has to be discussed regarding two distinct, yet closely related aspects: active power trading markets and ancillary service provision. In the context of active power markets, risk management is differentiated regarding short-term and long-term trading. In both trading activities, risk management is important and sometimes already used in companies. In Europe, energy is traded both short-term and long-term at a central market, the European Energy Exchange (EEX). The main risks listed before, the most important risks are the price risk and the risk of not being able to produce the sold energy to a contract partner. In the past, the risk in long-term energy trading was low because conventional power plants typically generated constant power outputs over a long period of time that could be traded comfortably via future contracts. Nowadays, the share of renewable energies sources (RES) is immensely increasing. The installed capacity of RES has risen up from 11.573 MW in 2000 to 82.356 MW in 2014, which is an increase of 711 percent [12]. The renewable energy law of Germany (EEG) which was created at 2000 and revised in 2008 and 2012 [3] describes the preferential feed-in of RES into the power grid and the guaranteed feed-in compensation. Thus, there is currently no financial incentive for RES to participate in power trading. However, the currently discussed revision of the EEG aims at a more active market participation of RES and DER units. In this case, the owners / operators of RES units face a financial and possible a production risk when selling their power on energy markets. In case a unit (or, more probable, a cluster of units) doesn't generate enough energy, it is possible to buy power 'last-minute' at the intraday energy market in order to maintain a power balance. This may, however, influence the profit of the unit or the cluster in a negative way.

Another aspect of risk management is concerned with ancillary service provision (ASP). Ancillary services such as frequency and voltage control are necessary for a reliable and stable power supply. Regarding for example primary control reserve, a DER unit or a cluster of DER units can sell a constant power reserve to the operating reserve market, realising a variable price that orientates itself on the bid of the unit owner. This power reserve will be activated when the frequency is higher or lower than 50 Hz. The uncertainty of surplus or deficit power production yields the risk of a retribution payment to the operating reserve market.

Both active power trading and ancillary service provision comprise technical and financial risks and therefore require a structured risk management. The research focus for our future work is on financial and production-related risk management for DER, as these units can be active on both active power and ancillary services markets at the same time and are prone to uncertainty and inherent unreliability. A suitable risk management should be able to rate every unit of the cluster in a risk scale describing the level of risk as a function unit reliability. This approach is closely correlated to the reliability modelling as discussed in section 3.2.

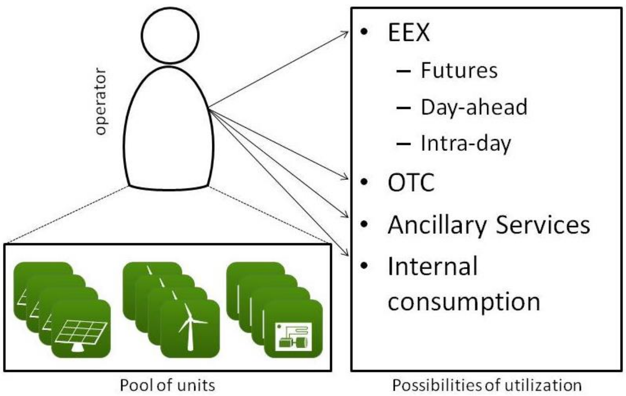

Figure 2: Different power trading points of an unit operator

The investigated setup consists of an owner or operator of RES who has different types of units in his RES pool. The pool consists of a fixed set of units that can be of different types (fig. 2). The operator has different possibilities to market or utilize the energy produced by its units, e.g. at the EEX, OTC, as ancillary service or as internal consumption. However, in the first step the focus lays on the calculation of the risk management of combined heat and power plants, trading on the EEX as a future contract. There are multiple financial and economical risks within the future power trading. If an operator is not able to produce the contracted energy, he has to buy expensive power at the EEX on the Intraday market. This additional expense has to be paid by the operator and can pose a huge financial risk. To avoid those risks, an approach is needed, which is based on forecasts (e.g. like weather-, price- and feeding) and has a connection to the reliability. The reliability model, which is described in chapter 3.2, provides a method to estimate the reliability for an ancillary service product provided by distributed units. This may be used or adapted for the risk management concept since it takes into account uncertainties of energy supply. The risk management approach can create instructions to avoid risks while, e.g. trading power on future contracts in advance. We will report on our progress in related and upcoming publications.

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