# Legal Aspects of Demand Side Management in Germany

## Rechtliche Aspekte des Demand Side Management in Deutschland

Oliver Raabe*, Jan Ullmer, Karlsruher Institut für Technologie (KIT)

* Correspondence author: raabe@kit.edu

**Summary** Information and communication technologies (ICT) will play a key role in electricity distribution grids, especially with regard to grid monitoring and system services conducted through measures of demand side management (DSM). This paper outlines legal aspects to be taken into consideration when designing an ICT infrastructure to establish a market for demand side management and aims at pointing out the need for further legal research and for adaption of the existing legal and regulatory framework. ►►► **Zusammenfassung** Informations- und Kommunikationstechnologien (IKT) werden zukünftig in Elektrizitätsverteilnetzen eine zentrale Rolle spielen, insbesondere mit Blick auf die Netzüberwachung und die Netzstabilisierung durch Lastmanagement (Demand Side Management, DSM). Der vorliegende Beitrag umreißt rechtliche Aspekte, die bei der Gestaltung der IKT-Infrastruktur eines Marktes für Lastmanagement einbezogen werden müssen und zeigt auf, wo aus rechtlicher Sicht noch Forschungs- oder Anpassungsbedarf besteht.

**Keywords** Demand Side Management, DSM, energy market, smart meter, privacy, standardization ►►► **Schlagwörter** Lastmangement, DSM, Energiemarkt, intelligente Stromzähler, Datenschutz, Standardisierung

## 1 Introduction

### 1.1 Responsibilities of Power Grid Operators

The German power grid infrastructure is operated on different network levels by different companies. Four transmission system operators (TSOs) are responsible for the nationwide long-distance transmission of extra high and high voltage electricity, whereas local distribution of medium and low voltage electricity is carried out by several hundred local distribution system operators (DSOs) [1; 2].

According to §§ 12 and 13 of the German Energy Industry Act ("Energiewirtschaftsgesetz", hereinafter abbreviated as "EnWG") transmission system operators are obliged to maintain a secure and reliable network and to ensure that sufficient transmission capacity is provided at any given time. If the security or reliability of the power grid is endangered or disturbed, they are obliged and entitled to undertake certain actions as defined in § 13 EnWG. Possible reactions include grid-related measures and market-related measures; the latter comprising especially interruptible supply contracts and activation of balancing energy reserves.

Since 2005, § 14 EnWG declares §§ 12 and 13 of the EnWG to be also applicable to any distribution system operator bearing responsibility for security and reliability of his grid section. Moreover, said statute explicitly obliges distribution system operators to take measures of demand side management into consideration during the course of their grid planning.

### 1.2 Need for Demand Side Management

Today's German and European grid infrastructure was basically designed for a top-to-bottom delivery of rather predictable amounts of electricity, generated by relatively few centralized power plants and distributed to passive consumers. Several factors can have an influence on power grid stability. Physical laws, for instance, require that feed-in and consumption of electrical energy are exactly balanced at any given time. Failure to maintain this balance results in deviations from the regular network frequency of 50 Hz, raising the risk of system instabilities and even blackouts. Another considerable problem is caused by bottlenecks within the power grid infrastructure. Existing power lines and transformer substations are technically limited with regard to their transmission and transformation capacities and were originally designed to handle a unidirectional flow of energy from top to bottom.

Integrating more and more decentralized sources of renewable energies into this historically grown infrastructure while at the same time handling the expected steady increase in the number of electric vehicles poses a hitherto unprecedented challenge especially for local distribution systems. Most sources of renewable energies depend on current meteorological conditions and provide a fluctuating and rather unpredictable feed-in that may at peak times even cause a reversed flow of electricity from bottom to top of the infrastructure [3]. Electric vehicles on the one hand pose a threat for grid stability because they are unpredictable with regard to their location and cause peak loads when charging, but may on the other hand serve as controllable loads in order to smoothen the energy demand curve or even to store surplus energy.

### 1.3 Establishment of an Infrastructure and a Market for Demand Side Management

Taking into account all of the aforementioned factors, it becomes quite obvious that a paradigm shift is imminent and inevitable. Previously passive consumers must become "prosumers" who actively contribute towards stable grid operation and to the balancing between electricity consumption and generation capacities. The necessary paradigm shift can, however, only be handled by means of information and communication technologies (ICT) which will have to be integrated not only into the existing grid infrastructure but into households and businesses of end consumers as well [4].

First of all, intelligent local grid management and power quality optimization require a grid-wide collection of relevant data like voltage, amperage, frequency and phase angle in order to enable detection and prediction of power quality disturbances and bottlenecks within the grid infrastructure. Modern communication-enabled metering systems ("smart meters")[1] are not only capable of measuring these values but can even transmit them in real time, thus providing all underlying data necessary for conducting intelligent grid management, including information about end consumers and their controllable loads.

Adjustment of energy consumption patterns can be realized through different means. Demand response programs grant incentives like flexible tariffs that consumers can benefit from by adapting their use of electricity in order to reduce their energy bill. Far more precision and predictability can be achieved by demand side management programs that enable direct control of loads provided by consumers[2]. Since ancillary services carried out in order to stabilize the power grid or to optimize power quality are critical with regard to a reliable energy supply, demand side management meets the requirements of distribution system operators much better than demand response. Based on gathered metering data, controllable loads could be selectively addressed in a way allowing distribution system operators to maintain grid stability and power quality without costly expansions of their grid capacities.

High transaction frequencies and the exponential increase in the number of energy market participants that will result from widespread use of demand side management can only be handled by an ICT-based infrastructure. Similar to the existing solution covering the procurement of balancing energy via tenders on a web-based plattform, offering and acquisition of DSM services as well as formation of prices could be handled via highly automated transactions carried out on electronic market places [5; 6].

A significant problem yet to be resolved arises due to the fact that power suppliers and grid operators are often having conflicting interests with regard to controlling of loads provided by end consumers. The former are mainly interested in adapting the energy demand of their customers according to generation capacities and energy prices and in order to keep feed-in and consumption balanced, whereas the main interest of distribution grid operators is to influence consumption patterns in order to prevent local transmission congestions and other grid-related problems.

Our further considerations focus exclusively on local demand side management by pooling of small controllable loads, carried out for purposes of either grid stabilization or power quality optimization.

### 1.4 Legal Influences to Be Considered

The primary aim of this paper is to outline legal aspects concerning a future market for DSM services and the underlying ICT infrastructure necessary to handle these services. Furthermore, it will be pointed out where the legislator and regulatory bodies will have to adapt or extend the existing regulatory framework.

In addition to the already applicable statutes of energy law, corresponding ordinances by the Federal Govern-

[1] According to § 21d EnWG, the term "metering system" refers to a metering device that is connected to a communication network and is capable of visualizing the actual energy consumption and the actual time of energy use.

[2] The terms "demand response" and "demand side management" are used inconsistently by different authors. Disambiguition used in this paper according to [7].

ment and decisions issued by the Federal Network Agency, several other fields of law will have an influence on the creation and regulation of a future DSM market. Gathered metering data in most cases contains personal information and is therefore subject to data protection law, calibration law must be taken into account because billing data is concerned and competition law might be necessary to prevent monopolies and to guarantee the development of an open and non-discriminatory market. As of today, only few provisions cover partial aspects of demand side management, but its widespread adoption is not yet laid down in detail by legislation.

## 2 Aspects of Energy Law

Not only does § 14 EnWG refer to § 13 EnWG, but system services conducted in pursuance of stable distribution grid operation are highly comparable to measures already established on the transmission system level. Consequently, the same general legal principles already applicable to transmission system operators must be applied (in analogy) to distribution system operators which use local DSM to run their grid.

### 2.1 Ensuring an Open and Non-Discriminatory Market for Demand Side Management

The European Union Directive on energy efficiency encourages member states to create markets for DSM, explicitely demanding to include controllable loads provided by small end consumers and to integrate load aggregation services in a non-discriminatory way [8].

As laid down in § 22 EnWG, transmission system operators are already obliged to procure balancing energy through transparent, market oriented and non-discriminatory procedures, namely via tenders published on a jointly operated web-based platform or similar procedures the Federal Network Agency may specify. As of December 2012, the newly introduced provision of § 13 (4a) EnWG states that TSOs shall, as far as technically feasible and economically reasonable, establish a similar tender platform to acquire contractually agreed switchable loads.

Given that conduction of local DSM as a means of providing system services for the distribution grid is comparable to the aforementioned measures on the transmission system level and since the general principle of unbundling between network and production must also be applied to DSM, similar trading platforms will have to be established to create an open and transparent market. Besides fostering competition, a market-based approach will also encourage the development of innovative, effective and cost efficient solutions with a sufficient level of consumer acceptance.

The solution in use for procurement of balancing energy has to handle a number of transactions still managable in a transparent way without too much technical assistance. DSM in order to compensate local grid problems will require much higher transaction frequencies and the possibility to react at short notice through highly automated solutions. The main challenges when developing and implementing the necessary IT infrastructure will be not only to ensure grid friendly management of a variety of possible measures and offers but to guarantee at the same time that transparent and non-discriminatory mechanisms are used to choose between different bidders and their offers.

Further research will be necessary in order to identify and specify detailed technical requirements to be fulfilled by a legally compliant IT-based DSM trading platform.

### 2.2 Necessity of a Load Aggregation Instance

A second key factor for an efficient and succesful large scale implementation of DSM in power supply infrastructures is load aggregation by specialized service providers.

Since a single household customer or owner of an electric vehicle can only provide a relatively small load shifting potential, an intermediary acting as an aggregator for larger groups of prosumers will be necessary in order to establish functioning and reliable demand side management programs. Besides granting greater flexibility to every single consumer who takes part in a DSM program and thereby increasing consumer acceptance, pooling of controllable loads could also help to compensate for any failures or unforeseen events [9]. If, for example, a control signal could not be transmitted properly or one or several devices fail for other reasons, e. g. because someone providing the battery of his electric vehicle moved or unplugged it, the aggregator could simply shift to other participants in his pool to reach the required capacities anyway.

Bidders participating in the balancing energy market are already required by law to undergo a prequalification procedure in order to prove their technical capabilities and their ability to provide balancing energy on a sufficient level of reliability [10]. Since ancillary services are vital to ensure stable grid operation and to prevent power quality problems or power outages, similar prequalification procedures will have to be introduced in local demand side management. Only load aggregators with access to a sufficient number of controllable loads will be able to provide dependable system services and to prove their reliability before being granted access to DSM markets.

The need to integrate load aggregation instances acting as intermediaries will also influence the design of future DSM enabled ICT infrastructures.

### 2.3 Positioning of the Load Aggregator within the Existing Energy Market

The present-day energy market in Germany is characterized through the mandatory separation between different market roles as defined in the Energy Industry Act. The future role of demand side manager or aggregator could either be assigned to an existing market role or a new role could be created which acts independently of already existing energy market participants.

Below, several possible solutions will be set out and evaluated, especially with regard to competition issues. The decision whom to put into responsibility as an aggregator for local demand side management will have a major influence on the design of the necessary ICT infrastructure and the electronic marketplace to handle DSM transactions.

#### 2.3.1 Distribution System Operators as Aggregators

The first possible option would be to assign the function of load aggregator to the existing distribution grid operators.

One of the measures already established on the transmission system level are contracts allowing the system operator to control customer equipment in order to adapt energy consumption patterns. § 14a EnWG, one of few already existing provisions concerning local DSM, introduces a similar possibility for the distribution system level. The statute obliges distribution system operators to offer reduced grid charges to those users of their grid willing to provide interruptible loads, consisting of either stationary units or electric vehicles. According to the explanatory memorandum for said statute, only loads that can be partially or fully interrupted in order to reduce energy demand are meant to be within its scope of application whereas other DSM measures, e. g. activation of additional loads to use surplus energy, shall remain subject to competition [11].

Regarding measurement and collection of necessary data, transmission of control signals and other details no binding regulations are in force yet, but § 21i (1) No. 9 EnWG entitles the Federal Government to issue an ordinance adressing these questions. This ordinance may also allocate certain DSM measures exlusively to distribution system operators or to third parties, especially to energy suppliers.

At first glance and especially from a technical point of view, it would make sense to allocate other DSM measures to the distribution system operator as well, since he is in charge for maintaining grid stability and has access to necessary data about grid conditions. But doing so would result in a severe hindrance to competition in a market for DSM, since every local section of the distribution grid is operated by a sole entity, a fact that would leave consumers without any choice regarding their demand side management program.

#### 2.3.2 Energy Suppliers as Aggregators

Another possible solution would be to assign the role of demand side aggregator to energy suppliers. This would be an advantage especially with regard to electric vehicles and their load adaption potential. In accordance with general principles of a liberalised energy market characterized by unbundling and equal access to infrastructural assets it will most probably be required by law that charging stations are operated in a way allowing consumers to contract with the energy supplier of their choice regardless of whom the charging station belongs to. Therefore, the energy supplier would be the only entity with constant access to the load shifting potential of electric vehicles used by its customers, whereas distribution system operator and meter operator may change frequently, depending on the area the vehicle is currently located in and the charging station it is connected to.

Despite this advantage, several strong arguments speak against local demand side management conducted by energy suppliers. As already mentioned above, energy suppliers and distribution system operators may often pursue conflicting interest with regard to DSM. In case of peaks in electrical energy generation, energy producers and traders are interested in selling surplus energy rather than having to curtail production. But such peaks in production – in future sceanarios most probably combined with the activation of additional loads through demand response or demand side management – stress power grids to their limits and call for load curtailing in order to maintain a stable grid operation.

Entitling energy suppliers to act as demand side managers could also lead to competition hindrances. Most companies involved in the energy market are already unbundled because they were forced by law to separate grid operation from energy delivery in order to prevent unfair advantages and to ensure competition. But smaller companies with less than 100 000 customers are partially exempt from the strict unbundling policy imposed by energy law.

Such so-called vertically integrated companies acting as distribution system operator could, when in need of DSM-based system services, grant unfair advantages to their own associated energy supply branch if energy suppliers would be the ones entitled to act as demand side aggregators [12]. Hence, the role of demand side manager should not be assigned to energy suppliers, at least as long as partially vertically integrated companies are in existence.

#### 2.3.3 Assignment to Transmission System Operators

With respect to their experience in the field of grid stabilization the four German transport system operators might be qualified and already quite well-prepared for executing the task of demand side management. At present, it is their responsibility to uphold a stable frequency of 50 Hz within the German and European power grid through procurement and activation of positive and negative balancing energy. The TSOs procure balancing energy through tenders on a special internet platform[3] and will soon have to acquire contractually agreed switchable loads in the same way.

[3] This internet platform, accessible at http://www.regelleistung.net, also contains further information on balancing energy.

Despite some strong arguments in favor of assigning the role of demand side manager to the TSOs, it could not be overlooked that they are inexperienced in dealing with large groups of end consumers and lack the necessary large scale infrastructural prerequisites. And since there are only four TSOs, each of whom operates only in its respective network area, the creation of an open and competitive market for demand side management would be impossible if the TSOs would be put into responsibility.

### 2.3.4 Assignment to Meter Operators

At present, electricity meters installed on customers premises are by default operated by the DSO who runs the local power grid, unless the customer chooses to hire a specialised meter operating company. Since DSO and meter operator are usually identical, assigning of DSM aggregation to meter operators would pose the same problems with regard to competition that were already discussed above.

### 2.3.5 Interim Findings

In summary, it can be stated that the question whether to assign the role of load aggregator to an existing market role or to newly establish an independent role depends on preliminary decisions to be made by the legislator and the Federal Government with due consideration given to the findings stated above.

## 3 Regulatory Measures Concerning Market Communication

Another crucial measure to ensure and foster competition within an upcoming DSM market is binding standardization of communication structures, processes and data formats that will be used to handle measurement data, control signals and transactions between market participants.

Creation of an open and non-discriminatory market is only possible, if customers are free to choose whichever DSM program they want to participate in. The use of proprietary technical standards by each company that offers DSM would result in severe competition hindrances. Customers willing to change their DSM program would be confronted with additional costs for exchange or adaption of their controllable devices and may therefore refrain from their decision. Companies wanting to partake in the market for demand side management would face high initial investments in order to build up and maintain an infrastructure able to cope with various business processes and data formats.

A similar situation was encountered in the energy market beforehand with regard to market entry of new energy suppliers. Different distribution system operators used different business processes and a variety of communication interfaces and data formats, which led to substantial obstacles concerning the market entry of new energy suppliers. After energy market actors failed to voluntarily adopt common standards, the Federal Network Agency decided in 2006 to issue binding regulations concerning data formats and business processes between companies partaking in the energy market. The "WiM" [13] deals with aspects of meter operation and exchange of metering data. The "GPKE" [14] covers further details about the exchange of metering data between different energy market participants as well as a variety of other processes like change of energy supplier, and so on.

As stated in the explanations accompanying these decisions [15], the issuance of binding standards was justified in order to facilitate market entry of new participants and in order to ensure competition. Since a similar situation will be given with regard to DSM, binding regulations are inevitable in order to ensure equal access to markets, especially for smaller competitors.

First steps towards standardization are already taken. § 21i (1) No. 9 EnWG entitles the Federal Government to issue an ordinance about communication standards for the type of interruptible devices mentioned in § 14a EnWG. Said ordinance may also rule that control signals shall solely be transmitted via the smart meter gateway. The BSI (Federal Office for Information Security) was authorized to issue a technical guideline concerning security and interoperability of metering systems [16], including the transmission of signals to controllable local systems.

The gathering of measurement values throughout power grid infrastructure assets like transformer substations needs no regulation or standardization, since these values are not market related and concern the respective DSO only.

## 4 Perspective of Data Protection Law

Data gathered by metering systems is, in most cases, to be considered personal data in terms of data protection legislation, since highly sensitive information about the members of a household can be gained by analyzing metering data [17]. The load curve recorded and transmitted by the metering system allows not only to estimate the number of household members but even worse, to analyze their daily routines and habits, like leaving and returning times, preparation of meals, sleeping times, television consumption and so on [18; 19]. Data obtained by use of metering systems is therefore subject to some specific provisions of energy law dealing with privacy concerns. § 21g EnWG contains an exhaustive list of legal uses for metering data and states that both remote reading of meter data and remote control of consumer equipment must not be conducted without prior informed consent of the customer. As stated in § 21g (I) No. 5 EnWG, demand side management is one of the legally recognized purposes metering data can be used for.

As a precondition before conducting any actions of DSM, data to determine power quality or the general condition of a certain grid area must be gathered. § 21g (I) No. 7 EnWG permits the use of metering data to determine the state of the power grid, but limits this use to "justified and documented cases". Accurate analysis and forecast of grid conditions may in some cases require long-term gathering and storage of metering data by distribution system operators, but current regulations only allow for temporary use of such data in case of an imminent or ongoing network disturbance. Therefore, the outstanding ordinance still to be issued by the Federal Government that will cover details about data protection should facilitate and enhance the possibility to use metering data for purposes of power grid analysis. Data protection concerns could be dispelled by limiting the permission for long-term use to pseudonymous or anonymous data.

## 5 Calibration Law and the Need for Reliable Evidence

Finally, requirements set by calibration law and law of evidence must be taken into consideration.

The smart meter is subject to the European Measuring Instruments Directive, national calibration law and technical requirements set by the PTB (German National Metrological Institute). The technical design of a future demand side management market must enable the participating entities and consumers to bring reliable evidence not only for energy consumption, but also for any DSM transactions performed in case the necessity to do so should arise.

Responsibility for major failures could not be borne by single participants of a DSM program and must thus be borne by the entity acting as aggregator. Nonetheless, a participant who fails to contribute in the way contractually agreed upon between him and the aggregator could at least be liable for parts of the damage suffered by the company acting as aggregator. It must therefore be ensured by technical means that data suitable as evidence is not only produced but also stored in a way that secures it against any tampering.

Requirements set by energy law, civil law, civil procedural law and the signature act will have to be taken into account. For every contractual relationship within the DSM market, e. g. that between consumer and aggregator or between DSO and aggregator, technical measures must be established to make sure that accomplished transactions and violations of contractual stipulations can be proven by the parties concerned.

## 6 Summary

In summary, it can be stated that the regulatory framework necessary to create and regulate a functioning competitive market for local demand side management and the necessary ICT infrastructure is barely in existence by now. Several aspects, especially binding standardization of communication ways and protocols as well as the definition of market roles call for further research from a legal point of view and for further detailed regulations.

## References


[1] A. Schwab: Elektroenergiesysteme. 3. Auflage, Berlin/Heidelberg 2012, pp. 16–24. For further information on power grid structure and grid operation see chapters 2, 10 and 11 there.

[2] For details on energy market roles and smart grid communication see: F. Pallas: Data Protection and smart grid communication – The European perspective. In: Innovative Smart Grid Technologies (ISGT), 2012 IEEE PES, pp. 1–8.

[3] H.-J. Appelrath, H. Kagermann, C. Mayer (Ed.): Future Energy Grid. Migration to the Internet of Energy. Acatech study, Munich 2012, p. 21.

[4] H.-J. Appelrath, H. Kagermann, C. Mayer (Ed.): Future Energy Grid – Migration to the Internet of Energy. Acatech study, Munich 2012, p. 41.

[5] Such a market based solution is favored by the European Union (Directive 2012/27/EU of the European Parliament and of the Council on energy efficiency, 25th October 2012, L315/7, L315/23) and by the German e-energy research programs (see "Smart Energy made in Germany – Interim results of the E-Energy pilot projects towards the Internet of Energy", pp. 28ff., accessible at http://www.e-energy.de).

[6] Bundesnetzagentur (Federal Network Agency): "Smart Grid" und "Smart Market" – Eckpunktepapier der Bundesnetzagentur zu den Aspekten des sich verändernden Energieversorgungssystems, Bonn, 2011, p. 15. (accessible at http://www.bundesnetzagentur.de).

[7] B. Droste-Frank et al.: Balancing Renewable Electricity. Berlin/Heidelberg 2012, p. 235.

[8] Directive 2012/27/EU of the European Parliament and of the Council on energy efficiency, 25th October 2012, pp. L315/7, L315/12, L315/23, L315/46.

[9] D. Callaway, I. Hiskens. Achieving Controllability of Electric Loads. In: Proceedings of the IEEE, Vol. 99, No. 1, January 2011.

[10] § 6 (5) StromNZV (Ordinance of the Federal Government about the access to Electricity Supply Grids, accessible at http://www.gesetze-im-internet.de/stromnzv).

[11] Deutscher Bundestag, Bundestagsdrucksache 17/6072, pp. 73–74.

[12] Bundesnetzagentur (Federal Network Agency): "Smart Grid" und "Smart Market" – Eckpunktepapier der Bundesnetzagentur zu den Aspekten des sich verändernden Energieversorgungssystems, Bonn, 2011, pp. 37–38. (accessible at http://www.bundesnetzagentur.de).

[13] Bundesnetzagentur (Federal Network Agency): Decision BK6-09-34 (accessible at http://www.bundesnetzagentur.de).

[14] Bundesnetzagentur (Federal Network Agency): Decision BK6-06-009 (accessible at http://www.bundesnetzagentur.de).

[15] Bundesnetzagentur (Federal Network Agency): Decision BK6-06-009, pp. 16ff.

[16] Bundesamt für Sicherheit in der Informationstechnik (Federal Office for Information Security): BSI TR-03109 (accessible at http://www.bsi.de).

[17] H. Wiesemann: IT-rechtliche Rahmenbedingungen für "intelligente" Stromzähler und Netze – Smart Meter und Smart Grids. In: Multimedia und Recht, 2012, p. 356.

[18] S. Schriegel, J. Jasperneite: Sicherheits- und Datenschutzanforderungen an Smart Grid-Technologien. In: Elektrotechnik und Informationstechnik, 2012, no. 4, p. 268.

[19] K. Müller: Gewinnung von Verhaltensprofilen an intelligenten Stromzählern. In: Datenschutz und Datensicherheit, 2010, no. 6, p. 361.


Received: January 26, 2013

**Dr. iur. Oliver Raabe,** born in 1964; education in communication electronics; law studies at the University of Kiel; PhD in technical environmental law; since 2000 research associate at the Institute for IT law and commercial law of the Karlsruhe Institute of Technology (KIT); since 2003 head of the research group for legal analysis of complex IT systems, specialising in data protection law, energy industry law and telecommunications law.

Address: Karlsruher Institut für Technologie (KIT), Zentrum für Angewandte Rechtswissenschaften (ZAR), Vincenz-Prießnitz-Str. 3, 76131 Karlsruhe, e-mail: raabe@kit.edu

**Jan Ullmer (ass. iur),** born in 1981; law studies at the University of Tübingen; legal clerkship at the higher court of Heilbronn; since 2012 research assistant at the Institute for IT law and commercial law of the Karlsruhe Institute of Technology (KIT); specialising in energy industry law and data protection law.

Address: Karlsruher Institut für Technologie (KIT), Zentrum für Angewandte Rechtswissenschaften (ZAR), Vincenz-Prießnitz-Str. 3, 76131 Karlsruhe, e-mail: jan.ullmer@kit.edu