

Gerd Balzer  
Christian Schorn

# Asset Management for Infrastructure Systems

Energy and Water

*Second Edition*

 Springer



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Gerd Balzer · Christian Schorn

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Energy and Water

Second Edition

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Gerd Balzer  
Technische Universität Darmstadt  
Darmstadt, Germany

Christian Schorn  
TransnetBW GmbH  
Karlsruhe, Germany

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## Preface to the Second Edition

In the present edition, due to further changes, especially in the electrotechnical infrastructure, essential parts have been added or the structure has been changed, so that an extended new edition seemed reasonable.

The legal framework for infrastructure companies has changed at both national and European level, which is discussed in more detail in the first chapter (Sect. 1.3). Based on the activities at national level on the part of the DKE (German Electrotechnical Commission), an international IEC standard has been developed in the meantime, which was published in 2019, also as VDE 0109, Sect. 2.2. In addition, further asset management activities at international level are presented.

The topic “Optimization of maintenance” has been significantly expanded, which is reflected on the one hand by the addition of the Markov model (Sect. 3.4.1.4) and on the other hand in the complete revision of Sect. 3.5. Special thanks go to Dr.-Ing. A. Rhein for his review.

In addition, a separate chapter has been devoted to the extended topic of “Statistics” and Chap. 7 lists possibilities for detection of the condition of electrical power supply equipment. However, no assessment of the condition of the equipment is made, as this is the responsibility of the asset manager, and therefore this presentation is in accordance with IEC/DKE regulations IEC/TS 63060 or VDE 0109.

It can be seen that the development of the “Asset Management” task area will not be completed in the future as well, especially since the externally imposed boundary conditions are constantly changing.

Exemplary, the predetermined conditions in Germany and European Community (legal and regulatory requirements, standardization, etc.) have been used. It is assumed that there are similar conditions in all countries and thus the described approaches can be transferred to other regions.

Darmstadt, Germany  
Karlsruhe, Germany  
July 2021

Gerd Balzer  
Christian Schorn

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## Preface to the First Edition

The implementation of competition in the area of infrastructure has often led to the consequence that within utilities, new decision-making and organizational structures were developed and installed. Here, the term “Asset Management” has been established in recent years; particularly in the area of technical as well as economical considerations. Globally considered, the essential task is to optimize the financial and operational tasks of an infrastructure system. In this context, the examples presented in this book often refer to the area of the electric power supply, but this should be considered only exemplary, as all considerations can be applied to other infrastructure sectors (gas, water, telecommunications, etc.). The principles and examples, which are presented in the following sections, essentially have two different sources, which in turn refer to the international discussion in companies, organizations, and associations:

- The Department of “Electrical Power Systems” at Darmstadt University of Technology (Technische Universität Darmstadt) dealt intensely the past 20 years with questions and solutions concerning asset management, with the aim of optimizing the maintenance from the viewpoint of the supply reliability. The results of this work are expressed in many publications and dissertations that were published during this period. At this point, we would like to thank the employees for their work.
- The suggestions from the experience of an appropriate organization were received by the EnBW AG, Karlsruhe, who has with their subsidiary Netze BW GmbH one of the largest distribution network operators in Germany. The implemented structure of asset management which was developed and expanded with the help of a national and international exchange of other network operators are used as a basis for discussion of the operational content. Organizational models, established procedures, and the system landscape in information technology are of crucial importance.

Since this whole process is not yet completed while in permanent change and continuing development, particularly against the background of the political and regulatory framework, methodologies and results of this book represent the current state of both, research discussion and the current operating implementation in those companies which possess an appropriately developed organization.

The authors are grateful to the following colleagues who helped in the translation: Y. Tsimberg, R. Wakefield, A. Krontiris, C. Balzer.

Exemplary, the predetermined conditions in Germany (legal and regulatory requirements, standardization, etc.) have been used. It is assumed that there are similar conditions in all countries and thus the described approaches can be transferred to other regions.

Darmstadt, Germany  
Karlsruhe, Germany  
December 2014

Gerd Balzer  
Christian Schorn

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# Contents

<b>1</b>	<b>Introduction</b>	1
1.1	Basis of the Asset Management	2
1.2	Development of the Investment Management	4
1.3	Legal Framework for Infrastructure Companies	6
1.3.1	Energy Industry Act (EnWG)	7
1.3.2	Ordinance on Incentive Regulation (ARegV)	8
1.3.3	Law for the Expansion of Renewable Energies (Renewable Energy Act; EEG)	10
1.3.4	Act on Metering Point Operation and Data Communication in Smart Energy Grids (MSbG)	11
1.3.5	IT Security Catalog (IT-SIKAT)	13
1.3.6	Clean Energy Package CEP of EC	14
1.4	Motivation for Asset Management	16
1.5	Challenges of Transmission and Distribution System Operators (TSO and DSO)	18
1.6	Activities of the Asset Management	19
1.7	Conclusion	22
	References	23
<b>2</b>	<b>Tasks of the Asset Management</b>	25
2.1	Development of Strategies	25
2.1.1	Overview of Maintenance Strategies	27
2.1.2	RCM Strategy	35
2.1.3	Maintenance by Fuzzy Logic	56
2.1.4	FMEA Method	70
2.1.5	Aging Behavior of Equipment	81
2.1.6	Lifetime of Electrical Equipment	96
2.1.7	Strategy for System Development	99
2.1.8	Renewal Strategy	117
2.1.9	Short- and Long-Term Considerations	125
2.1.10	Project Development and Assignment	126

2.2	Developing and Securing Standards . . . . .	127
2.2.1	Intern Regulations . . . . .	128
2.2.2	National and International Standardization Processes . . . . .	129
2.2.3	ISO Standard 55000 ff. . . . .	130
2.2.4	Standard for Maintenance of Electrical Systems DIN VDE 0109 and IEC/TS 63060 . . . . .	132
2.2.5	Evaluation of ISO 55000 and DIN (VDE 0109) Standards . . . . .	136
2.2.6	IEC TC 123 . . . . .	137
2.3	Securing the Resources . . . . .	138
2.3.1	Material and Service . . . . .	138
2.3.2	Operating Staff . . . . .	140
2.3.3	Reserve and Special Situations . . . . .	140
2.4	Conclusion . . . . .	141
	References . . . . .	142
<b>3</b>	<b>Control Functions . . . . .</b>	<b>147</b>
3.1	Economic Control Functions . . . . .	147
3.1.1	Budget Planning and Structure . . . . .	148
3.1.2	Budget Control . . . . .	155
3.1.3	Economic Considerations . . . . .	160
3.2	Technical Control Functions . . . . .	176
3.2.1	Failure Statistics . . . . .	177
3.2.2	Data Files of Damages . . . . .	181
3.2.3	Assessment of the Network Asset Value . . . . .	182
3.2.4	Assessment of Condition Data . . . . .	186
3.2.5	Monitoring/Diagnosis . . . . .	188
3.2.6	Risk Analyses . . . . .	195
3.3	Indicators . . . . .	229
3.3.1	Target Values of the Participating Groups (Stake Holders) . . . . .	230
3.3.2	Selection of Indicators in Case of a Maintenance Measure . . . . .	232
3.3.3	Benchmarking . . . . .	234
3.4	Asset Simulation . . . . .	237
3.4.1	Development of a Long-Term Strategy . . . . .	237
3.4.2	Input Data . . . . .	260
3.4.3	Application of Dynamic Simulation . . . . .	261
3.4.4	Simulation: Condition Assessment . . . . .	262
3.4.5	Simulation: Statistical Failure Rate . . . . .	270
3.4.6	Conclusion Asset Simulation . . . . .	273
3.5	Optimization of Maintenance . . . . .	274
3.5.1	General . . . . .	275
3.5.2	Basics of the Calculation . . . . .	276
3.5.3	Objective Functions of the Optimization . . . . .	281
3.5.4	Optimization Model: Knapsack Problem . . . . .	282

---

3.5.5	Solving a Problem with Different Objective Functions . . . . .	283
3.5.6	Algorithms for the Optimization of Single-Objective Problems . . . . .	286
3.5.7	Algorithms for the Optimization of Multicriteria Problems . . . . .	291
3.5.8	Evaluation and Example in a 220 kV Grid . . . . .	297
3.5.9	Example in a 110 kV Grid . . . . .	300
3.6	Conclusion . . . . .	304
	References . . . . .	305
<b>4</b>	<b>Integration into the Business Organization . . . . .</b>	<b>309</b>
4.1	Functional Allocation in the Area of Asset Management . . . . .	310
4.2	The Role Model of the Management of Infrastructures . . . . .	311
4.3	Corporate Organization . . . . .	316
4.3.1	Decision Criteria . . . . .	317
4.3.2	Service Provider Model . . . . .	319
4.3.3	Network Manager Model . . . . .	319
4.3.4	Asset Manager Model . . . . .	320
4.3.5	Asset Owner Model . . . . .	320
4.4	Influence of the Infrastructure Systems on the Organization . . . . .	321
4.4.1	Economies of Scale of Systems . . . . .	321
4.4.2	Effect of System Homogeneity of Infrastructure . . . . .	324
4.5	Conclusion . . . . .	325
	References . . . . .	325
<b>5</b>	<b>System Landscape in the Area of Asset Management . . . . .</b>	<b>327</b>
5.1	Asset Management Data . . . . .	327
5.2	Enterprise Resource Planning (ERP Systems) . . . . .	330
5.2.1	Asset Documentation (AD) . . . . .	332
5.2.2	Finance Module . . . . .	335
5.2.3	Operation and Maintenance Module . . . . .	337
5.2.4	Project Module . . . . .	339
5.2.5	Procurement and Material Module . . . . .	340
5.2.6	Staff Module . . . . .	342
5.3	Geographic Information Systems (GIS) . . . . .	343
5.4	Asset Strategy Planning Systems (ASP) . . . . .	347
5.5	Project Prioritization Systems (PPS) . . . . .	353
5.6	Mobile Workforce . . . . .	355
5.7	Network Planning Systems and Network Control Systems . . . . .	357
5.8	Conclusion . . . . .	361
	References . . . . .	362

<b>6</b>	<b>Statistic</b> .....	363
6.1	Probability .....	363
6.1.1	Simple Probability .....	363
6.1.2	Conditional Probability .....	364
6.1.3	Venn Diagrams .....	364
6.1.4	Rules of Probability Calculation .....	364
6.2	Characteristic of Probability Distributions .....	371
6.2.1	Expected Value—Mean Value .....	371
6.2.2	Median Value .....	372
6.2.3	Variance (Statistical Spread) and Standard Deviation .....	372
6.2.4	Spread .....	373
6.2.5	Scaling .....	373
6.2.6	Density Function .....	374
6.2.7	Distribution Function .....	374
6.2.8	Hazard (Failure) Rate of Equipment .....	376
6.2.9	Correlation .....	378
6.2.10	Confidence Interval, Random Sample .....	378
6.3	Equicontinuous Distribution .....	380
6.3.1	Gaussian Distribution (Normal Distribution) .....	380
6.3.2	Exponential Distribution .....	384
6.3.3	Weibull Distribution .....	387
6.3.4	Further Distribution Functions .....	391
6.4	Discrete Random Variable .....	392
6.4.1	Poisson Distribution .....	392
6.4.2	Binominal Distribution .....	393
6.5	Best Fit Calculation .....	395
6.5.1	Measurement Errors .....	395
6.5.2	Regression Function .....	396
6.6	Chi-Squared Test ( $\chi^2$ -test) .....	400
6.7	Theory of Evidence (Theory of Belief Functions) .....	405
6.8	Conclusion .....	410
	References .....	410
<b>7</b>	<b>Condition Assessment</b> .....	413
7.1	Equipment of Air-Insulated Substation (High Voltage) .....	413
7.1.1	General .....	414
7.1.2	Power Transformer .....	414
7.1.3	Circuit-Breaker .....	415
7.1.4	Disconnecter/Earthing Switch .....	416
7.1.5	Current and Voltage Transformer .....	416
7.1.6	Surge Arrester .....	417
7.1.7	Protection .....	417
7.1.8	Control .....	418

7.1.9	Scaffold (Air Insulated) . . . . .	418
7.1.10	Foundation (Air-Insulated, Power Transformer) . . . . .	418
7.1.11	Air-Insulated Gantry . . . . .	419
7.1.12	Busbar . . . . .	419
7.1.13	Infrastructure . . . . .	420
7.1.14	Remote Control System/Telephone System . . . . .	420
7.1.15	Auxiliary Power Transformer . . . . .	420
7.1.16	Auxiliary MV Switchgear . . . . .	421
7.1.17	Auxiliary LV Switchgear . . . . .	421
7.1.18	Auxiliary DC Voltage Supply . . . . .	421
7.1.19	Auxiliary Emergency Power Unit . . . . .	422
7.2	Gas-Insulated Substation (High Voltage) . . . . .	422
7.2.1	General . . . . .	422
7.2.2	Power Transformer . . . . .	423
7.2.3	GIS Circuit-Breaker . . . . .	424
7.2.4	GIS Disconnecter/Earthing Switch . . . . .	425
7.2.5	AIS Current and Voltage Transformer . . . . .	425
7.2.6	GIS Current Transformer . . . . .	426
7.2.7	GIS Voltage Transformer (Inductive, Encapsulated) . . . . .	426
7.2.8	GIS Surge Arrester (Encapsulated) . . . . .	427
7.2.9	AIS surge Arrester . . . . .	427
7.2.10	GIS Bushings (SF6/Air or SF6/Oil) . . . . .	427
7.2.11	GIS Housing . . . . .	428
7.2.12	Protection . . . . .	428
7.2.13	Control . . . . .	428
7.2.14	Scaffold (Air Insulated) . . . . .	429
7.2.15	Foundation (Air-Insulated, Power Transformer) . . . . .	429
7.2.16	Infrastructure . . . . .	429
7.2.17	Building . . . . .	429
7.2.18	Remote Control System/Telephone System . . . . .	430
7.2.19	Auxiliary Power Transformer . . . . .	430
7.2.20	Auxiliary MV Switchgear . . . . .	430
7.2.21	Auxiliary LV Switchgear . . . . .	431
7.2.22	Auxiliary DC Voltage Supply . . . . .	431
7.2.23	Auxiliary Emergency Power Unit . . . . .	432
7.3	Overhead Line (High Voltage) . . . . .	432
7.3.1	Tower . . . . .	432
7.3.2	Foundation (Tower) . . . . .	433
7.3.3	Line Conductor . . . . .	433
7.3.4	Ground Wire . . . . .	434
7.3.5	Insulators, Clamps, Joints . . . . .	434

---

7.4	Substation (Medium Voltage) . . . . .	435
7.4.1	General . . . . .	435
7.4.2	Switchgear Panel/Construction . . . . .	436
7.4.3	Circuit-Breaker . . . . .	436
7.4.4	Switch-Disconnecter . . . . .	437
7.4.5	Disconnecter/Earthing Switch . . . . .	437
7.4.6	Voltage Transformer . . . . .	437
7.4.7	Current Transformer . . . . .	438
7.4.8	Protection, Control, Monitoring . . . . .	438
7.4.9	Auxiliary Voltage Supply . . . . .	438
7.4.10	Remote Control System/Telephone System . . . . .	439
7.4.11	Power Transformer (Medium/Low Voltage) . . . . .	439
7.4.12	Arc Suppression Coil/Petersen Coil (Medium Voltage) . . . . .	439
7.4.13	Ripple Control Technology (Secondary Part) . . . . .	440
7.4.14	Building . . . . .	440
7.5	Switching Substation (Medium Voltage) . . . . .	440
7.5.1	Total Detection . . . . .	440
7.5.2	Switchgear Panel/Panel Construction . . . . .	441
7.5.3	Voltage Transformer . . . . .	441
7.5.4	Current Transformer . . . . .	442
7.5.5	Disconnecter/Earthing Switch . . . . .	442
7.5.6	Switch-Disconnecter . . . . .	442
7.5.7	Power Transformer (Medium/Low Voltage) . . . . .	443
7.5.8	Building . . . . .	443
7.5.9	Tower . . . . .	443
7.5.10	Low-Voltage Installation . . . . .	444
7.6	Cable (Medium Voltage) . . . . .	444
7.7	Motor (High Voltage, Above 250 kW) . . . . .	444
7.8	Conclusion . . . . .	445
	References . . . . .	445
	<b>Glossary</b> . . . . .	447
	<b>Index</b> . . . . .	451



The advanced infrastructure of a country is one of the main drivers behind its economic development and the most important factor for successful global development in the world. While new structures are built primarily in countries that are developing strongly in terms of infrastructure, in contrast, the task in the other countries has so far been to renew existing infrastructures at the end of their service life. In the meantime, this challenge is exacerbated in the power sector by the changing characteristics of the transmission grid. The original grid designed to transmit energy from large power plants to the load end user has now changed into a power grid, which incorporates, along with energy consumers, centralized and decentralized power producers. In addition, with climate change and environmental protection plans, a fundamental change in generation with a huge reduction of conventional generation can be seen. This also causes a change of the transport infrastructure in the energy sector, which must connect the new generation centers, e.g., offshore wind farms, with the existing load centers.

In recent years the term “asset management” became accepted in the area of utilities business and the basic task is to optimize the management of grid infrastructure assets by using clear defined procedures [3] and to define the development of infrastructure along emerging or new challenges. The development of these infrastructure assets along newly emerging tasks has to be defined within the framework of forward-looking planning processes.

According to [13], there is a distinction between the terms “asset managing” and “managing assets”. The term “managing assets” covers the majority of activities that deal directly with operating assets, e.g., life cycle activities, availability, database, staffing, budget, costs, indicators (key performance indicators, KPIs), etc. In addition, the term “asset managing” mainly covers the strategies to optimize the benefits of fixed assets for all stakeholders of the business organization. These include, for example, the following

activities: increasing of long-term enterprise value, business risk, regulation, customer relations, etc.

In this book, the term “asset management” covers both activities described above.

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## 1.1 Basis of the Asset Management

A good infrastructure is one of the basic requirements for the growth of country’s economic strength as it facilitates investments from various industries and increases prosperity of the population thus resulting in higher living standard. In general, the term infrastructure can be applied to different areas, such as

- Energy supply system (electricity, gas),
- Water, sewage,
- Roads,
- Rail network (trains, trams),
- Telecommunications.

The main characteristic of the above areas is that the construction of the necessary network is highly capital intensive in long term, so that wrong decisions at the beginning of the investment phase will have negative effect over decades and will need considerable efforts to correct. Investment management as it is described by a holistic approach has the goal to ensure the optimal development and maintenance of infrastructure by utilizing comprehensive planning criteria.

The largely uninterrupted capability of infrastructure to maintain its functionality and fulfillment of the customers’ expectations are essential in the areas of energy and water supply so that situations leading to “traffic jams” or “busy signals” should be minimized. This book exclusively focuses on the description of asset management methodology for infrastructure in the areas of energy (electricity, gas) and water supply. According to [5] the investment in networks in Germany for expansion or new construction had the following amount in the year 2010:

- Electricity: 3.8 billion €
- Gas: 1.1 billion €
- Water: 1.3 billion €

According to figures from the German Federal Network Agency, the total investment in the electricity sector in 2018 already amounted to €6.4 billion. In addition to these values, there are studies that show an investment requirement in the range of €30–€40 billion in the years from 2010 to 2030, specifically in the German electricity distribution system [17]. In the German network development plan, a total project volume of around €60 billion is discussed in 2019 for the transmission grid area up to 2030 [14]. These figures point up the importance of correct decision-making regarding the optimal timing for these long-term investments in order to conserve and save available resources to the

extent possible. Additionally, it has to be taken into consideration that many utilities are not monopolies like in the past; all decisions today have to be made under competitive conditions. This means the presence of maximum revenue caps for the investments and maintenance expenditures in the grid infrastructure as prescribed by regulators, enforced by legislators, and evaluated using efficiency benchmarks. The basis for this approach is the Energy Industry Act [18], with the essential statements for asset management in §§1 and 11.

- §1: Purpose of the Act is the most secure, cost-effective, consumer friendly, efficient, and environmentally sustainable supply of electricity and gas to public transmitted via network lines.
- §11: Operators of energy supply systems are required to operate a safe, reliable, and efficient power grid in a non-discriminatory manner, to maintain and to expand as needed, where it is economically feasible.

From guideline of the Energy Act it can be deduced that the duty of a utility is to construct and operate grids in a way that provides a safe and reliable supply in an economically feasible manner. This makes it clear that the two basic additional criteria:

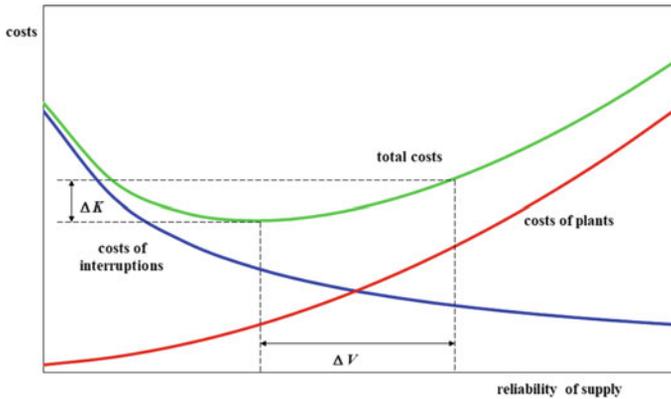
- Technical condition and
- economic condition

have to be evaluated against each other, whereby the technical conditions can be represented by the quality of supply. In the new energy world, not only the consumption (load) side but also the production (generation) side have to be considered and taken into account at all voltage levels. The considerations have to include two aspects:

- On one hand, the required grid development driven by changing conditions, such as load growth, additional construction of decentralized generation, and development of electric mobility needs to be considered. This aspect is addressed by grid development and planning assumptions.
- The second aspect represents the needs associated with replacement of assets due to their end of life. These have increased influence on the reliability of supply according to the failure probabilities.

The following analysis focuses on the second aspect, as the issues related to the grid development will be addressed in appropriate detail in a later chapter. A solution of this issue is now performed by a widespread established “asset management” in the field of the supply companies, and not only different processes are defined but also the organizational structures are changed accordingly at the same time. The “unbundling” also influences this process, which means that the various functions of the formerly vertically integrated energy supply companies, from production through trade and sales to transportation and distribution, have to be transferred into legally independent corporate structures.

The two represented boundary conditions (technical and economic) are each influenced by the maintenance and the investment in new equipment. However, results from this



**Fig. 1.1** Evaluation of the optimum of costs and reliability of supply

calculation have a reciprocal influence on the cost of the overall system. The fundamental relationship between the cost and reliability of supply is exemplarily presented in Fig. 1.1.

The relationship between the cost and quality of maintenance can be derived as follows:

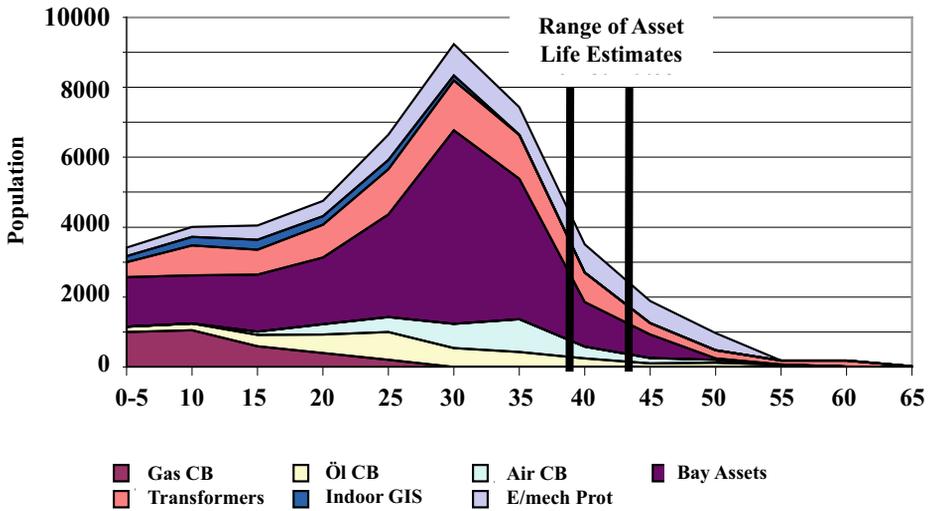
- Costs of supply interruptions decrease with increasing reliability of supply, as the number of interruptions is reduced and hence the costs of repairing faults will decrease (repair costs, cost of not delivered energy, etc.).
- Costs of the asset quality increase with rising reliability of supply, as a larger expenditure on maintenance and new investments is required in order to achieve a better reliability.

According to Fig. 1.1, it can be calculated analytically, which financial effort is required if a certain reliability of supply should be achieved. This however requires knowledge of the exact dependency, which would only be achieved in practice if the exact time of a fault is predictable so that quality assurance measures are possible in time. The role of asset management consists of deriving the optimum reliability of supply, which of course must meet the legal requirements.

## 1.2 Development of the Investment Management

A brochure of Cigre Group 37-27 was published in 2000 shows the result of a survey of the members of this working group regarding the age distribution of installed high voltage assets [15]. The result of the age distribution is shown in Fig. 1.2.

The age distribution according to Fig. 1.2 illustrates the impact of different technologies in the asset category of circuit-breaker (CB). In recent years a significant technology change took place from air blast circuit-breaker (Air CB) via the minimum oil (oil-CB) to



**Fig. 1.2** Number of assets and age distribution (status 1998) [15]

SF<sub>6</sub>-type circuit breakers (Gas CB). Moreover, at the end of the 60 s, the first encapsulated switchgear (GIS) has been installed, which today represents the state of the art if—due to the space and environmental limits—air insulated technology cannot be used. The high growth in particular in Central Europe after the Second World War meant that the power grids were significantly expanded in the 50s and 60s. This trend was reinforced in the so-called “Years of Economic Miracle” in Germany. Growing load requires further expansion, so that on the one hand many existing devices had to be replaced before the end of their technical life by new devices with higher technical capability and new technology, and on the other, additional new networks were built. This situation can also be seen as shown above in the age distribution back calculated from 2000 showing high investments in the 60s and 70s and the subsequent flattening of the curve in later years. Meeting of customer needs required rapid expansion of infrastructure during that period. Consequently, there was no need for an optimized investment management process.

In contrast to this, a moderate load growth is assumed in the decades to come. It should therefore make sense to use the installed components until the end of their technical service life. On the other hand, new challenges arise. The system of generation centers, load centers, and the connection of these two via existing electricity transmission grids, which has been developed over decades, is currently facing immense change due to political decisions. Examples of this include Germany’s decision to phase-out nuclear energy and also the decision to phase-out coal-fired power generation, as well as the provisions of the European Energy Policy “Clean Energy for all Europeans—CEP”. It is to be expected from this that a complete change of geographic focal points of generation is needed and also new technologies in the electricity grid infrastructure, in order to

guarantee the secure supply of electrical energy in the future. In addition, the structure of energy supply has been changed for several years, especially in the electricity and gas sectors, due to the emerging of the number of small generation units. As a consequence of the energy transition, the number of electricity applications is also increasing in the heating and transport sectors in order to create a CO<sub>2</sub>-free future. This also increases the complexity of the overall system and consequently the demands on the infrastructure.

Assuming an average age of equipment of 40 years according to Fig. 1.2, it is clear that in the coming years the existing infrastructure is facing a growing number of replacement investments on the one hand, but also new investments due to the new requirements. New technologies are developed and deployed to control the reliability and security of the energy supply. The so-called “smart grid” has become very important in the development of infrastructure systems and is all the time presented as a solution for all future energy supply problems. With the presumption of transmission grids are already relatively “smart”, due to their good observability by the control centers of the transmission system operator, the development of distribution networks “smart grid” means the increased use of information and communication technology, but also the utilization of completely new components; for example, controllable power transformers feeding low voltage systems or controllable charging devices for electric vehicles. This aims to operate and to control safely the low voltage systems due to many challenges, such as the volatile supply of renewable generation units (especially wind and solar), a presumably increasing volume of distributed storage systems, the volatile energy prices, and variable market-driven loads.

The resulting “investment avalanche” already makes very high demands on the personnel resources of utilities, the delivery capability of component manufacturers, the availability of service providers, and also on the financial resources capability of investors, since these are capital-intensive and long-term investments.

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### 1.3 Legal Framework for Infrastructure Companies

Due to the fundamental importance of infrastructures for society, especially in the utility sector, there are a large number of legal regulations that create the regulatory framework for the infrastructure business, which is ultimately organized by the private sector. These laws are regularly amended in order to adapt them to current developments, and in some cases, new laws are added. This is also a significant task of the asset manager to know these laws for his various tasks and to align his actions accordingly. It is not possible to cover all the laws in a single book, as almost everything is affected, from environmental issues to data protection. Nevertheless, the most important laws and regulations will be listed below as examples for Germany and their significance for asset management will be shown. In addition, the energy policy framework of the European Commission will be discussed, as this has a fundamental and binding significance for the national regulations within the European Union.

### 1.3.1 Energy Industry Act (EnWG)

In 2005, the German Energy Industry Act [18] was fundamentally republished. It forms the legal basis for all companies operating in the energy supply sector. This naturally also affects the operators of infrastructures in this segment, and the following key sections are of relevance to asset management:

- §1: Purpose of the Act
  - (1) Purpose of the Act is the most *secure, cost-effective, consumer friendly, efficient, and environmentally sustainable supply of electricity and gas* to public transmitted via network lines.
  - (2) The regulation of the electricity and gas distribution network will be aimed at ensuring effective and fair competition in the supply of electricity and gas while maintaining *long-term performance and reliable operation of energy supply networks*.
- §11: Operation of power supply networks
  - (1) Operators of energy supply systems are required to operate a safe, reliable, and efficient power grid in a non-discriminatory manner, to maintain and to expand as needed, where it is economically feasible.
  - (1a) *The operation of a secure energy supply network shall also include, in particular, adequate protection against threats to telecommunications and electronic data processing systems necessary for secure network operation. To this end, the regulatory authority shall draw up a catalog of security requirements in consultation with the Federal Office for Information Security and publish it.*
- §49: Requirements for energy installations
  - (1) Energy installations shall be constructed and operated in a manner *that ensures system technical security*. In subject to conformance with other laws, the generally accepted rules of technology have to be respected.
  - (2) Compliance with the generally recognized rules of technology is presumed if, in the case of systems for the generation, transmission, and supply of
    1. Electricity: The technical rules of the “Verband der Elektrotechnik Elektronik Informationstechnik e. V.” (Association for Electrical, Electronic & Information Technologies), and
    2. Gas: The technical rules of the “Deutsche Vereinigung des Gas- und Wasserfaches e. V.” (German Association for Gas and Water).have been complied with....

These passages define the criteria according to which an asset manager must develop and operate his system. As already mentioned, the consideration of economic constraints is also explicitly listed here with the statement “as far as it is economically reasonable”.

Furthermore, an important basis for the work of a responsible manager is the legal anchoring of the consideration of norms and standards in the so-called “presumption paragraph 49”. This stipulates that the operator is legally on the safe side if the standards of the respective energy sector are demonstrably complied with or if the correct interpretation of these rules and regulations by experts was used as a basis in the decisions. If the standards do not say anything about a particular issue, it is correspondingly helpful to use more extensive experience, such as expert groups from international organizations like CIGRE, CIRED, or scientific studies, to create arguments as a basis for the decisions to be made. If necessary, this can be used to confirm compliance with the “general rules of technology” to a supervisory authority or, in the worst case, to the judiciary.

### 1.3.2 Ordinance on Incentive Regulation (ARegV)

Historically, due to the monopoly, a utility’s revenues were determined based on a calculation of all expenses (capital and operating), including a reasonable amount for capital employed. With the adoption of the Ordinance on incentive regulation ARegV [16] in 2007 (last amended in 2019), this system was completely replaced. The transition to incentive regulation means that revenue caps are set that defines the amount of revenues, which are available to the company. Incentive regulation was introduced because, in the eyes of politicians, there was a fundamental lack of pressure on companies to be efficient in the periods before regulation, since the reimbursement of all network expenses meant that there was no incentive to ensure supply at optimum cost.

The incentive regulation was thus used to introduce competition into a monopoly market, which is generally a natural monopoly market due to technical conditions because it makes no economic sense for new competitors to first build and then operate a parallel infrastructure.

After becoming effective on Jan. 1, 2009 [8], the first regulatory period lasted five years and the second regulatory period started on Jan. 1, 2014. The essential component of the regulation is a revenue cap, which defines the total allowable revenue of a system operator. This revenue cap is determined by Eq. (1.1), where the influence of a quality element  $Q_t$  is implemented in further regulatory periods:

$$EO_t = KA_{\text{dnb},t} + (KA_{\text{vnb},0} + (1 - V_t) \cdot KA_{\text{b},0}) \cdot \left( \frac{VPI_t}{VPI_0} - PF_t \right) \cdot EF_t + Q_t \quad (1.1)$$

The various parameters in Eq. (1.1) are defined as follows:

$EO_t$	revenue caps of system charges
$KA_{\text{dnb},t}$	permanent non-influenceable costs
$KA_{\text{vnb},0}$	temporary non-influenceable costs
$V_t$	factor for the reduction of inefficiencies
$KA_{\text{b},0}$	controllable costs

$VPI_t$	overall consumer price index of the year $t$ of the regulation period
$VPI_0$	overall consumer price index (Federal Statistical Office) of the base year
$PF_t$	productivity factor
$EF_t$	expansion factor
$Q_t$	surcharges and discounts to the revenue cap (quality element)

A detailed description of some values is essential to assess, which costs in Eq. (1.1) are of interest to the asset manager:

- Permanent non-influenceable costs, e.g.,
  - legal purchase commitments and payment obligations,
  - concession fees,
  - operating taxes,
  - expenditure of the approved investment budget; this includes capital investment, which are necessary for the stability, the integration into the overall system or grid or a tailored expansion of the power grid,
  - required use of overlaid voltage levels,
  - reimbursement of decentralized power generation,
  - education and training, etc.
- Temporary non-influenceable costs: These costs are calculated as part from the total costs, if the system operator can claim special challenges with respect to its task.
- Influenceable costs: These are costs that cannot be assigned to the two parts of costs defined above; for example, this includes the repair and maintenance costs of the grid assets.

The expenditures for the maintenance of supply system assets represent a major cost variable, which can be influenced by the asset manager. In theory, it is possible to reduce the maintenance costs by increasing the maintenance cycles, however, this may lead to a deterioration of the reliability of supply. A quality element ([16], §19) is included in the incentive regulation to ensure a sufficient system reliability. The introduction of the  $Q$  element is intended to ensure network reliability, safety, and quality of supply, as the system operator has ability to request more revenue to address the compliance with reliability of supply and the power quality requirements. The evaluation of network reliability can be performed by the following criteria ([16], §20):

- Duration of supply interruptions,
- Frequency of supply interruptions,
- Amount of not delivered energy, and
- Amount of not supplied load.

If these criteria are exceeded or not met, based on the average for the total supply, the revenue cap can be increased or reduced by the regulator ( $Q_t$ ).

Despite the multitude of regulatory requirements, it should be noted that generally, the system operator has the ultimate responsibility for the system operation in a private market structure.

### **1.3.3 Law for the Expansion of Renewable Energies (Renewable Energy Act; EEG)**

For the first time in 2000, the law regulated the handling of renewable energies and the “Renewable Energies Act” EEG [10] was passed. This law also gave its name to the so-called EEG surcharge, which end consumers have to pay with every used kilowatt-hour in order to enable the generation of electrical energy from wind and sun. Since then, there have been many developments and thus numerous new versions (last 2017) and amendments (last 2019) to follow the requirements of the advancing energy transition. The EEG pursues the goal of a sustainable supply of energy in particular through defined target quotas for the share of renewable energies. Concisely, the target quota for Germany is 80% in 2050. Because of the needed connection of these plants to the infrastructure and their assigned special role in the energy system, there are key paragraphs and passages that are important for system operators and thus asset managers.

- §8 Connection:
  - (1) System operators must immediately connect systems for the generation of electricity from renewable energies and mine gas to their grid at the point that is suitable with regard to the voltage level and which is the shortest linear distance to the location of the system. This shall apply unless this or another grid has a technically and economically more favorable connection point. When examining the economically more favorable connection point, the costs directly arising from the grid connection must be taken into account.
  - (4) The obligation of grid connection also exists if the consumption of electricity is only made possible by the optimization, reinforcement, or expansion of the grid in accordance with §12.
- §11 Purchase, transmission, and distribution:
  - (1) Subject to Section 14, system operators shall immediately purchase, transmit, and distribute physically on a priority basis all electricity from renewable energy sources or mine gas that is sold in a form of sale in accordance with Section 21b Paragraph 1...
- §12 Expansion of the grid capacity:
  - (1) System operators shall, at the request of those willing to feed-in electricity, immediately optimize, reinforce and expand their grids in accordance with the

state of the art in order to ensure the purchase, transmission, and distribution of electricity from renewable energy sources or mine gas.

- (2) The obligation shall extend to all technical facilities required for the operation of the system as well as to the connection installations owned by the system operator or transferred to its ownership.
- (3) The system operator does not have to optimize, strengthen, or expand his grid if this is economically unreasonable. Section 11 Paragraph 2 of the Energy Industry Act applies accordingly.

These provisions restrict the freedom of action of the planning and network development departments in asset management in particular for the long-term strategic development of a grid to the extent that they have to react immediately to unforeseen connection requests from asset investors. Particularly in the boom years after 2010, this made for large expansion volumes in the distribution grid that could be strategically incorporated neither into a development plan nor into permit reliable forward-looking financial planning in asset management. In addition, there is the so-called feed-in priority of renewables, which still requires great efforts in balancing and stabilizing the system. A feed-in management defined in §14 has a certain optimization potential, which, however, the asset manager must tap into through the development of appropriate measurement sensors and automation technology. In principle, however, the obligation remains to ensure sufficient connection grid capacities and to expand the grid up to the level of cross-border transport. According to §17, the financing of such an expansion is also the responsibility of the system operators.

### **1.3.4 Act on Metering Point Operation and Data Communication in Smart Energy Grids (MSbG)**

This law, also in a short form known as the Metering Point Operation Act [11], aims to introduce intelligent metering systems (including meters) in Germany, also as a basis for system operation optimization, while guaranteeing maximum data security. Originally planned as an ordinance, the issue was published as a law on Aug. 29, 2016, after many years of discussion. Italy and Sweden were the role models for the basic introduction of smart meters, where this technology is now being used nationwide in the 2nd or 3rd generation. The assumed importance to the grid, and thus to the asset manager, can be inferred from the original cost–benefit analysis for the deployment in Germany, which assigned the technology such a large impact on grid expansion and operational processes that savings in these areas should cover a large share of the implementation costs.

In addition to the definition of the metering point operation organization and specifications for the customer relationships including the contractual relationships, the law includes important specifications and terms of reference for the asset manager.

- §1 Scope:  
This law makes regulations
  1. for equipping metering points of the grid-bound energy supply with modern metering devices and smart metering systems, ...
  4. on minimum technical requirements for the deployment of smart metering systems, ...
  3. for energy-related data communication and general data communication with smart meter gateways, ...
- §2 Definitions:
  7. Smart metering system: a modern metering device integrated into a communication network via a smart meter gateway to record electrical energy, reflecting real energy consumption and time of use. ...
  16. System condition data: voltage and current values and phase angles, as well as values that can be calculated or derived from them, which can be used to determine the grid condition.
- §50 Admissibility and scope of the survey:
  4. To grant the ability to execute a task of the system operator which is carried out in the exercise of official authority delegated to the system operator.

The technical requirements of the law and the provisions for handling data aim to ensure that, ultimately, only data from the smart metering system will be used for system operation management and then for automation in the smart grids of the regulated system operators. This is indicated by the term “official authority” in §50. If this concept would be rolled out accordingly, system operators at all levels would have the information they need to operate the system as efficiently as possible, allowing asset managers to use historical condition data and a forecast into the future to optimally design their network development strategy with all the potential for flexibility. Unfortunately, the conditions laid down in the law for a mandatory rollout of this technology in the grid have not been met; there are some problems with the so-called market declaration confirming the availability of certified smart meter gateways from three different manufacturers. The law and its implementation is a negative example of a technically unsettled regulatory framework with the long clarification times possible with public authorities. This leads to a great deal of uncertainty in investment decisions and thus largely to a standstill in the technological further development of the system operators and the meter manufacturers. However, the positive influence of these information possibilities in the grid can be illustrated by many international examples and is still an important field of development for digitalization and automation in asset management.

### 1.3.5 IT Security Catalog (IT-SIKAT)

The IT security catalog for energy systems in accordance with Section 11 (1b) EnWG [6] is bindingly defined by the Federal Network Agency, legally based on the Energy Industry Act, and is thus mandatory for all system operators to implement. This is associated with the obligation to provide evidence of a corresponding audit with associated certification by a certain deadline. The catalog is to be applied to all IT systems that are operationally necessary for the operation of critical energy supply systems according to a definition, the so-called KRITIS regulation, of the Federal Office for Information Security (BSI). This is to ensure adequate protection of these assets against information technology attacks. Some examples of attacks on energy companies around the world, first on nuclear facilities in Iran and later the disruption of energy supply in Ukraine, were showing the vulnerability and criticality of this technology. The catalog defines the following three protection goals:

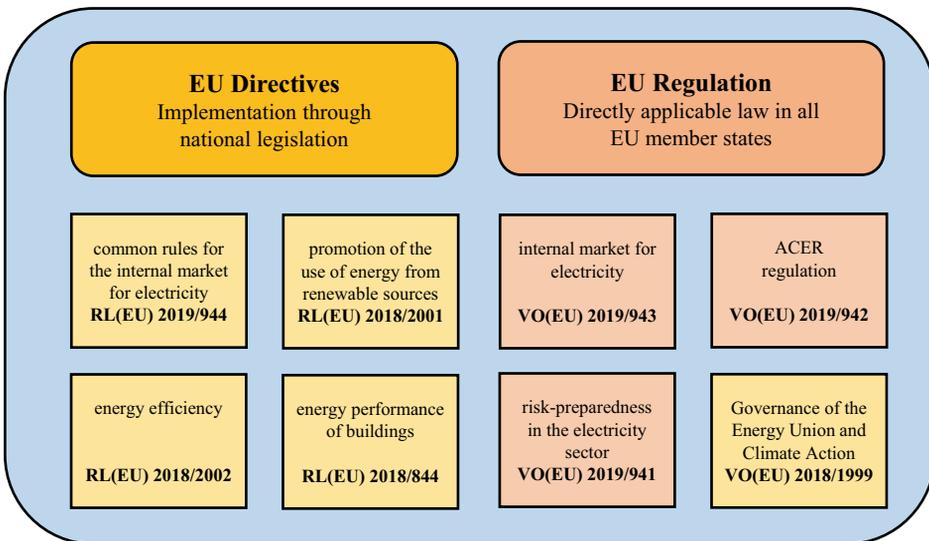
- **Availability**—includes accessibility and secured usability of the systems to be protected.
- **Integrity**—means the correctness and completeness of the data to be used, as well as the correct functioning of the systems.
- **Confidentiality**—aims at the data content that must not be accessible to unauthorized persons.

In order to achieve these protection goals, the security catalog prescribes the establishment of an Information Security Management System (ISMS), which monitors all measures as a central instrument. This management system can be located at various points within a company, but affects the asset manager directly at several points in his function as the person responsible for standards and specifications, but also in the commissioning of the asset service. Since IT systems include both telecommunications equipment, including telecontrol links, and secondary equipment such as protection and system control technology, the associated specifications must define minimum-security measures that meet the protection goals. In particular, the use of passwords, the ability to change them, and access to these systems via network connections require close consideration of security. Another major focus is the accessibility of the systems in the facilities and thus the access protection (fencing systems, locking systems, camera surveillance intrusion detection systems, etc.) to these facilities themselves. Here, the asset manager must define a balanced system of active and passive access protection and arrange for its implementation in construction and operation with asset service. In this area, depending on the design, a cost-intensive part of asset management has newly emerged, which should be taken into account especially in the design phase of substations in order to avoid expensive retrofits as far as possible. However, the system must in any case meet the requirements within the scope of an audit in order to obtain the mandatory certification.

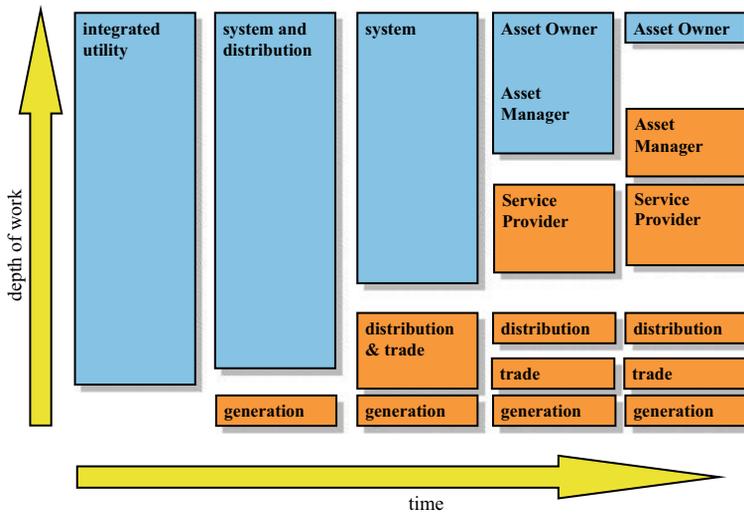
### 1.3.6 Clean Energy Package CEP of EC

With the passing of the 1st Internal Market Directive of the European Commission for the implementation of an energy market in Europe in 1995, the regulation of this sector began across all member states. This regulatory framework evolved over time into a construct of various directives and regulations, with the distinctive feature that they have the character of law. The member states are obliged to transpose the regulations from the directives into national law within a defined period; the contents of the regulations apply immediately after publication. The aim is to create uniform conditions for the energy market throughout Europe. While the first directive still defined the separation of the various business areas of system operation, generation, sales, and trading (see also Fig. 1.4), a complex set of regulations has emerged in the meantime, which found its provisional final version in the passing of an amended package in June 2019 for the internal electricity market. In 2020, a similar amendment has been made for the internal gas market, and it is foreseeable that these two sectors will converge significantly in the medium term. The revised package bears the official title “Clean Energy for all Europeans”, but is abbreviated to “Clean Energy Package CEP”. It consists of eight building blocks, which are shown in Fig. 1.3. The legal texts are available on the website of the European Commission [9].

The directives represent the policy development in electricity Europe intended by the Commission, such as the definition of the unbundling of the individual business functions in the electricity business from the first internal electricity market directive. Fundamental developments in the fields of renewable energies, building efficiency, and energy



**Fig. 1.3** Building blocks of the EC’s Clean Energy Package (CEP)



**Fig. 1.4** Temporal evolution of utilities

efficiency are described in a similar way. As a first approximation, these regulations are of minor importance for asset management and still need to be transposed into national law, which usually involves interpretations of the energy strategy of the respective member state. For this reason, the directive will not be discussed in detail here. However, the relevance of the individual regulations of the pact, which has a total volume of several hundred pages, for the asset manager, will be briefly discussed here.

- Rules for the internal market for electricity

The Internal Electricity Market Directive is, so to speak, at the heart of the CEP and describes several new strategic orientations of the Commission. One focus of the specifications concerns trading functions, definitions of bidding zones, and the handling of grid congestions in the European market. These passages, as well as the deposited revenue mechanisms, are rather irrelevant for the asset manager. An important determination is the definition of new “Regional Coordination Centers RCC” to be created to perform capacity and, if necessary, stability calculations across control areas. These calculations shall be coordinated in daily arrangements with the transmission system operators operating in the region and shall be considered the basis for system operation. This is particularly important for the planning task of the asset manager, as it is explicitly stated that different planning premises of the individual system operators must not lead to distortions of competition. In other words, all those responsible for the transmission system are obliged to apply at least basic, uniform, and coordinated planning assumptions. Another focus is the definition and establishment of a variety of principles in Article 3 according to which system operators must conduct their operations. This is to be supported by a system of grid codes described in

Article 58. These codes are to be drawn up by the European association Entso-E, in cooperation with the other “stakeholders” in energy supply, and the system operators must compulsorily align their operations with them. This provides a narrow framework of European standards for strategy development in asset management.

- ACER Regulation

The function of the European Agency of Regulators is described here. The main task in the cooperation with the system operators is the monitoring of the network planning and network expansion activities for cross-border energy transport with the association of transmission system operators Entso-E and the system management including trade settlement, together with the regional coordination centers defined in the Internal Market Regulation. Due to the increasing interdependence of distribution system operators in the energy transition, with development of smart grids, massive decentralized generation, etc., cooperation with the newly to be created European Association of Distribution System Operators (EU-DSO) is also defined. The relevance of this regulation for the system operators lies primarily in the secure provision of appropriate planning strategies with sufficient justification acceptable to ACER. Thus, the asset management functions network planning and development strategy are particularly in focus.

- Risk regulation

Due to the importance of electricity supply to society, the Risk Provisioning Regulation describes the roles and procedures of the various responsible parties in the event of a crisis. This also includes early identification of the risk of such a situation arising by providing forecast calculations, which focus in particular on the availability of sufficient generation capacity to cover the load at all times. The regulation clearly assigns the responsibility for the execution of such calculations to the transmission system operators in their respective control areas, or to the European association of transmission system operators Entso-E for the Europe-wide consideration. The importance for the asset manager is rather low, as he has hardly any possibilities to influence this topic strategically. Here, a mechanism for the creation of sufficient generation units—nationally but also Europe-wide—is required.

- Energy Union Governance Regulation

This regulation describes the function of the European Commission in the performance of the governance function and has no direct relevance for system operators or asset managers.

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## 1.4 Motivation for Asset Management

The long-term guarantee of a reliable grid infrastructure—a requirement of the Energy Industry Act [18]—is an important objective of asset management. In addition, the entire approach of the asset management process is mandatory even though it excludes

considerations for different influences and targets of various stakeholders. Consequently, the main task of asset management considers in the long-term revenue optimization with simultaneous high supply reliability while being subjected to an acceptable risks. Based on the various definitions and fields of activity of the asset management process, participants can select between various types of models regarding the operational realization. Moreover, an integrated and linked information flow and a decision-making process are essential components necessary to enable such a consistent asset strategy for the whole grid.

Markets for conducted energy (gas, electricity) have been opened in Germany by the Energy Industry Act [12] in 1998. Until that time, the utilities had a monopoly in their supply areas, which was in line with the competition laws. Further legal provisions were made by the Energy Act Amendment 2003 [8] regarding free access of third parties to the system in order to facilitate competition.

The transition from the negotiated to regulated system access came into force with the Energy Act on July 13, 2005 [18]. The key aspect of this was that revenues had no longer been negotiated between the groups involved in the market but are specified by legal requirements (regulatory). These stipulations were made in the Incentive Regulation Act [16], which has already been discussed.

The regulations require unbundling of the system operators in a competitive electricity market so that market participants have to operate in separate legal entities with exceptions for smaller utilities. Figure 1.4 shows the time evolution as a result of the transition from an integrated utility to a confederation of various parts, where different entities can operate separately depending on their expertise and area of business.

Starting with a vertically integrated company, which covers all areas of generation, transmission, and distribution, today the different functions are operated by well-defined entities, which could be categorized as follows:

- Grids transmission,
- Grids distribution,
- Metering and billing,
- Sales,
- Trade, and
- Generation.

The infrastructure part of the electricity and gas transmission business was subject to stricter ownership conditions for unbundling. Electricity transmission system operators and gas transmission system operators must be fully independent of other companies in the energy sector—including and in particular distribution system operators. The separation of ownership was politically desirable. In Germany, however, the special case of the “Independent Transmission System Operator ITO” has been created, in which ownership can remain in a group, but no influence may be exerted from there on the operational business.