How to Master the Energy Transition ("Energiewende")?

My work as a software engineer for power grid calculations at BTC

Overwiew

- the company
- power grids
- the energy transition
- power grid calculation
- coding and work

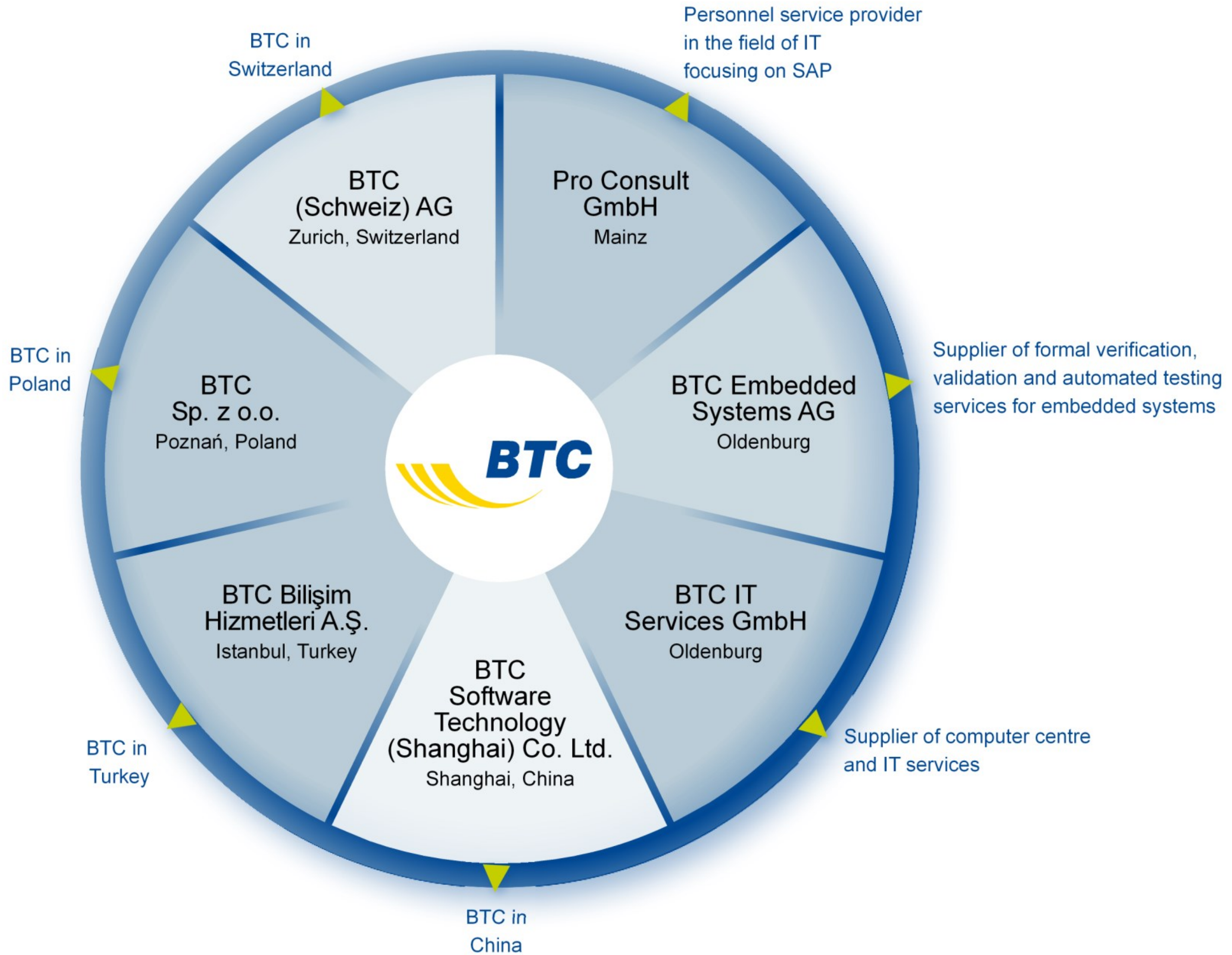
part I

the company

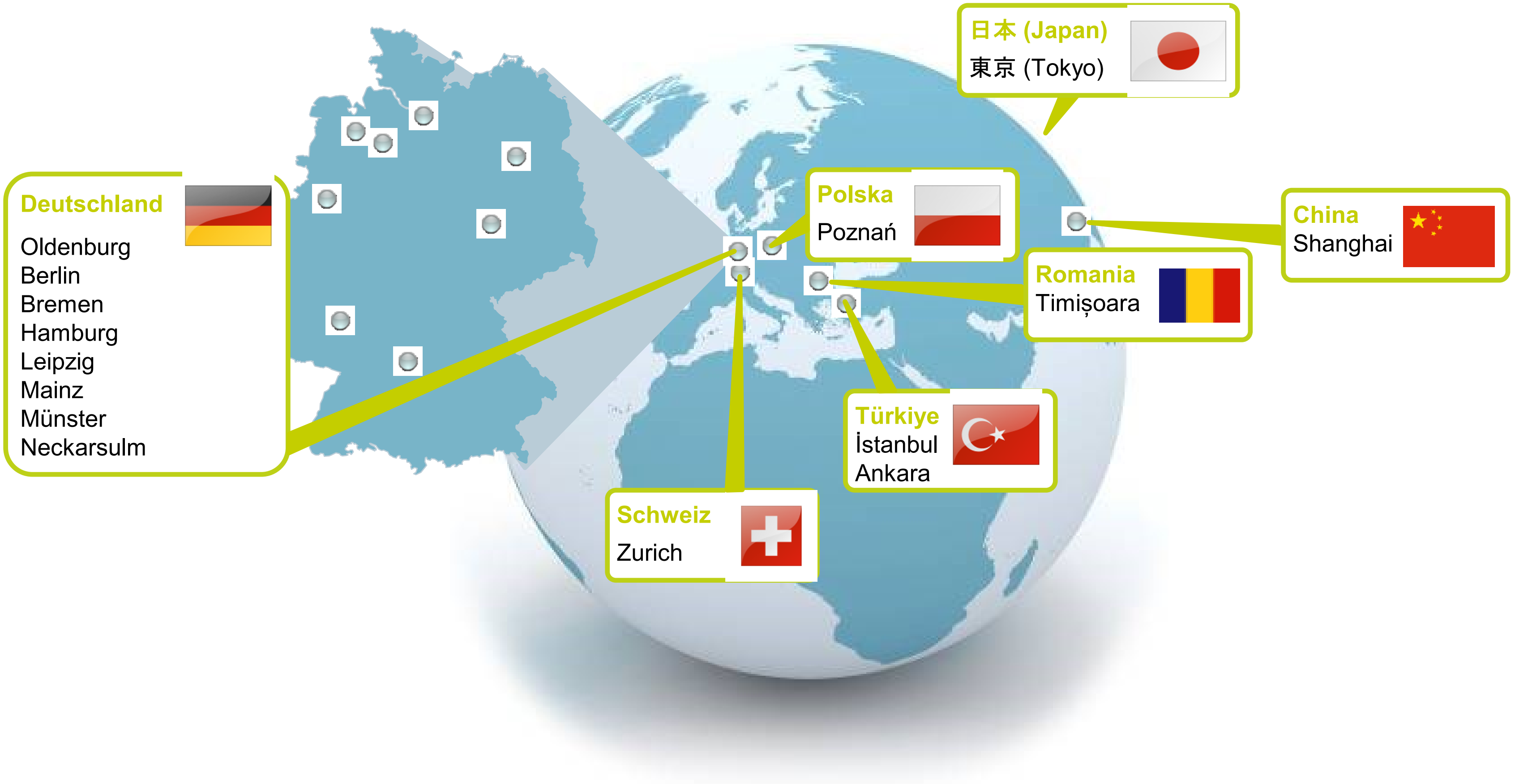
BTC – Facts And Figures

Company	BTC Business Technology Consulting AG
Headquarters	Oldenburg
Established	2000 (merger of UMC, CCC and NETplus)
Business units	Consulting, System Integration, Application & System Management, Software Products
Competence	Utilities, telecommunications, manufacturing, service provider, public sector
Locations	Berlin, Bremen, Hamburg, Leipzig, Mainz, Münster, Neckarsulm, Oldenburg
	Ankara, İstanbul/Turkey, Poznań/Poland, Shanghai/China, Timișoara/Romania, Tokyo/Japan, Zurich/Switzerland
Employees	1. 585 (as of 12/2015)
Sales	€ 171.7 million (as of 12/2015)

BTC – The Group



BTC – We Are Close To Our Customers



BTC – Consulting People

Customer

Consulting	Software Products	System Integration	Application & System Management
			
• Implementation and optimisation of standard software: process consulting service, preliminary studies, architecture	• Standardized applications for challenges in utilities …	• Development and implementation of systems: ERP, SAP, ECM, CRM, BI, GIS, process control technique …	• Outsourcing, out-tasking, lifecycle-management, application management…

BTC – Software Products

Customer's challenges

- Time-to-Market
- Cost efficiency
- To use an experience advantage
- Regulatory requirements
- Meet Standards
- System handling

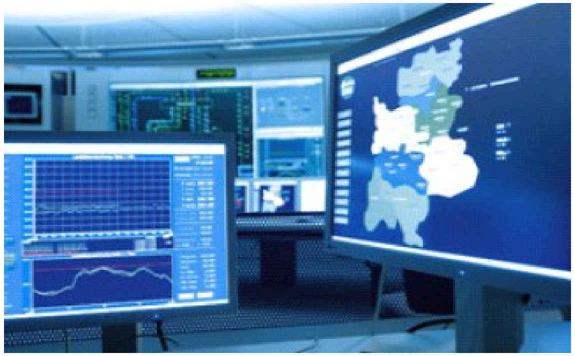
Solutions offered by BTC

Customer's benefits

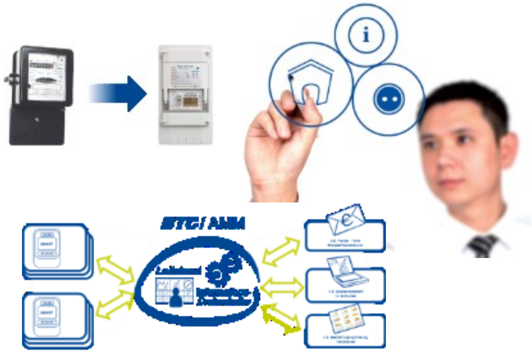
- Concentration on core business
- Faster market access
- Compliance
- Efficiency increasement
- Total Cost of Ownership

BTC – Software Products (Exerpt)

BTC | WIND 2.0
(Offshore Wind Park Management)



BTC | PRINS
(Central Power System Management)



BTC | AMM
(Advanced Metering Management)

BTC | VPP
(Distributed Energy Resources)

BTC | GRID Agent
(Smart Grid Agent)

BTC – Software Products

Challenges

- To use an experience advantage
- Cost efficiency increasement
- Meet legal requirements
- Meet current and future standards
- Time-to-Market optimization
- Systems handling
- Risks minimization

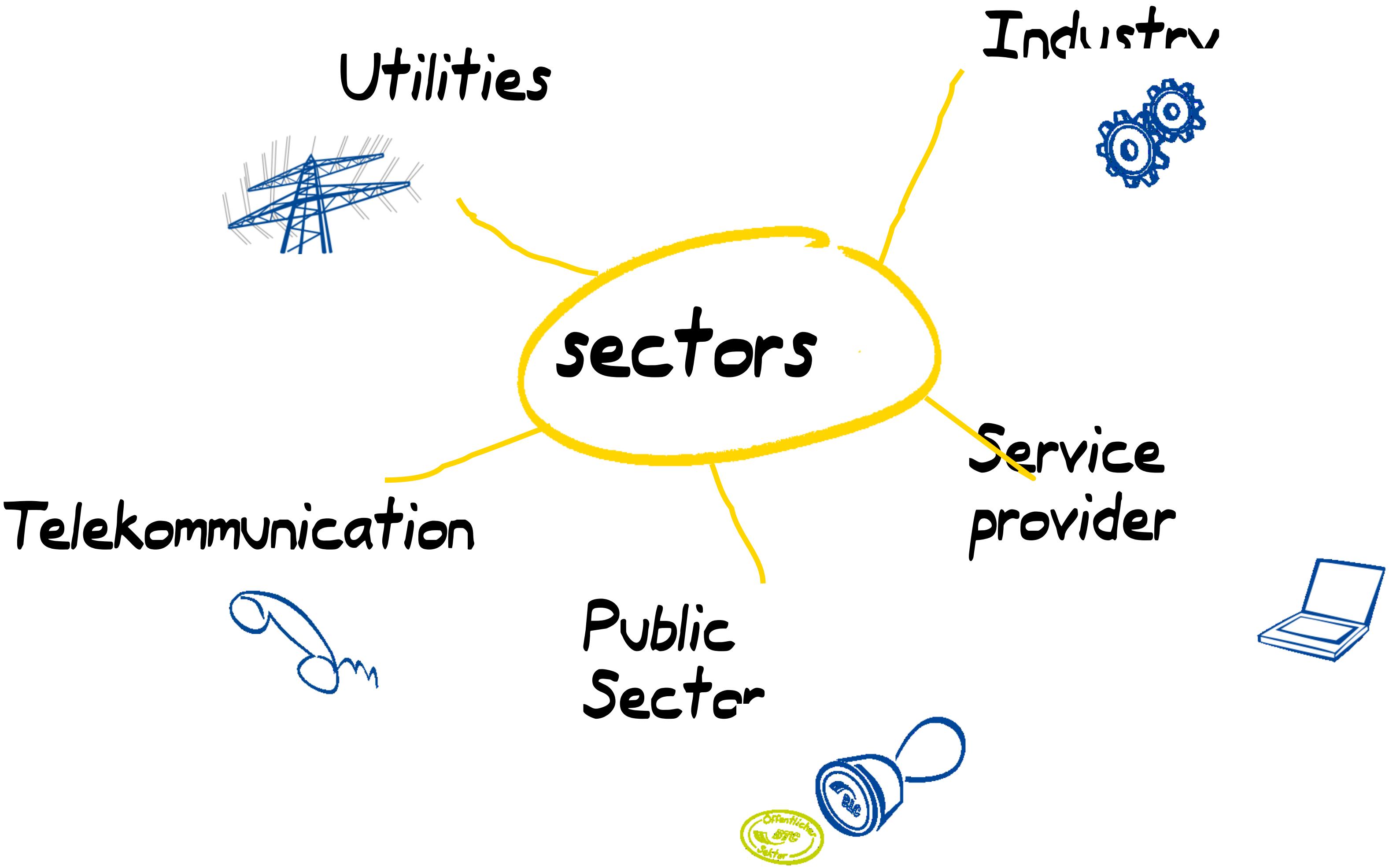
BTC Products

- BTC | AMM
  future oriented Metering
- BTC | Control Center
  System connection
- BTC | Grid Agent
  Active – and reactive power control
- BTC | PRINS
  Network control technique
- BTC | VPP
  Virtual power plant
- BTC | WIND 2.0
  Offshore wind parks management

Customer‘s benefits

- Concentration on core business
- Faster market access
- Compliance
- Efficiency increasement
- Cost optimization
- Scalable business processes
- Manufacturer assured quality
- Industry Know How of BTC AG

BTC – Sectors


sectors
Utilities
Industry
Service provider
Public Sector
Telekommunication

BTC – Utilities

Customer‘s challenges

- Decentralised infeed of electricity and gas
- Declining energy sales
- Cost pressure
- Business unit development
- Competitors
- Regulators, legislation and politicians

Solutions offered by BTC

BTC Energy Process Management (EPM)

Customer‘s benefits

- Customer orientation
- Energy efficiency
- Process efficiency

BTC is TOP CONSULTANT

BTC is a TOP Consultant.

TOP Consultant stands for professionalism and customer satisfaction.

- This is an award for the best consultants to medium-size businesses.
  - Survey in the following categories: Competence, Respectability, Connectivity, Satisfaction
- Result:
  - The award was given to five IT consulting firms.
  - BTC achieved grade A in every category.
  - Our customers regard BTC consultants as especially competent, reliable and loyal.
  - BTC is recommended by its customers.

BTC is an accredited SAP Active Quality Global Management Partner

BTC is a SAP AQM partner.

The Active Quality Management programme (AQM@SME) stands for quality assurance with regard to the implementation of SAP projects in the field of SME.

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- As the first partner in Germany, BTC has been awarded the formal AQM@Channel accreditation in 2010 – a recognised seal of quality of SAP for channel partners.
- Five companies (EMEA) were accredited in 2010.
- The award was given for consistent active quality orientation of the marketing processes and delivery methods based on compliance with high SAP quality standards.
- Precondition/assessment:
  - Annual quality planning
  - Quarterly monitoring of the quality score card
  - Compliance with the accreditation criteria (min. 70%)

BTC – Partnership with SAP

BTC is a SAP Gold Partner

With BTC as your contractual partner, you will receive all services from one source – from SAP software to services and maintenance to outsourcing!

- BTC is a SAP Partner in the following fields:
  - SAP Channel Partner for SAP licences
  - SAP Channel Partner for SAP Business Object licences
  - SAP Service Partner
  - SAP Hosting Partner
- SAP attests BTC special expertise in:
  - SAP NetWeaver Application Server
  - SAP NetWeaver Process Integration
  - SAP Business Process Management
  - SAP NetWeaver IDM
  - SAP for Utilities
  - SAP for Automotive
  - SAP for Public Sector
  - SAP ERP Upgrade

BTC – Partnership with Microsoft And Oracle

BTC is a Gold Partner: Microsoft and Oracle

Microsoft GOLD CERTIFIED Partner

Microsoft and BTC have a long-standing and and varied partnership!

- BTC AG has been holding the highest partner status already since it was established.
- Microsoft and BTC AG are continuously looking for synergy potentials.
- BTC AG develops and implements Microsoft-based applications.
- BTC AG is a standing advisory member of the Trusted Advisor Community.
- Joint technology and IT expertise for the first German offshore wind farm

ORACLE PARTNERNETWORK

Gold Partner status partnership since 2004!

- Development of database-supported solutions
- Use of Java as programming language
- Special solutions such as identity management and Embedded Java
- SAP integration into Oracle environments

BTC – Customers
(Excerpt By Industries)

BTC

EWE | PRISMA EUROPEAN CAPACITY PLATFORM | e.dis | IVG | VATTENFALL | Open Grid Europe The Gas Wheel

berger | remmers schützt Werte am Bau | ATLAS ELEKTRONIK A joint company of ThyssenKrupp and EADS | SALM | BRÜGGEN | NORD

dodenhof | POLYGON VATRO | Ulla Popken | Freiberger The Convenience Food Group | hannover re® | seit 1876 BRUNS Pflanzen

dz Datenzentrale Baden-Württemberg | ITK RHEINLAND IT für Kommunen | HZB Helmholtz Zentrum Berlin | KDRS RZRS | kiru | LBM LANDESBETRIEB MOBILITÄT RHEINLAND-PFALZ

EWE | Thüringer Netkom | amplus™ | BREKOM | primacall the world goes prima | BREKO BUNDESVERBAND BREITBANDKOMMUNIKATION

part II

power grids

Power Grids

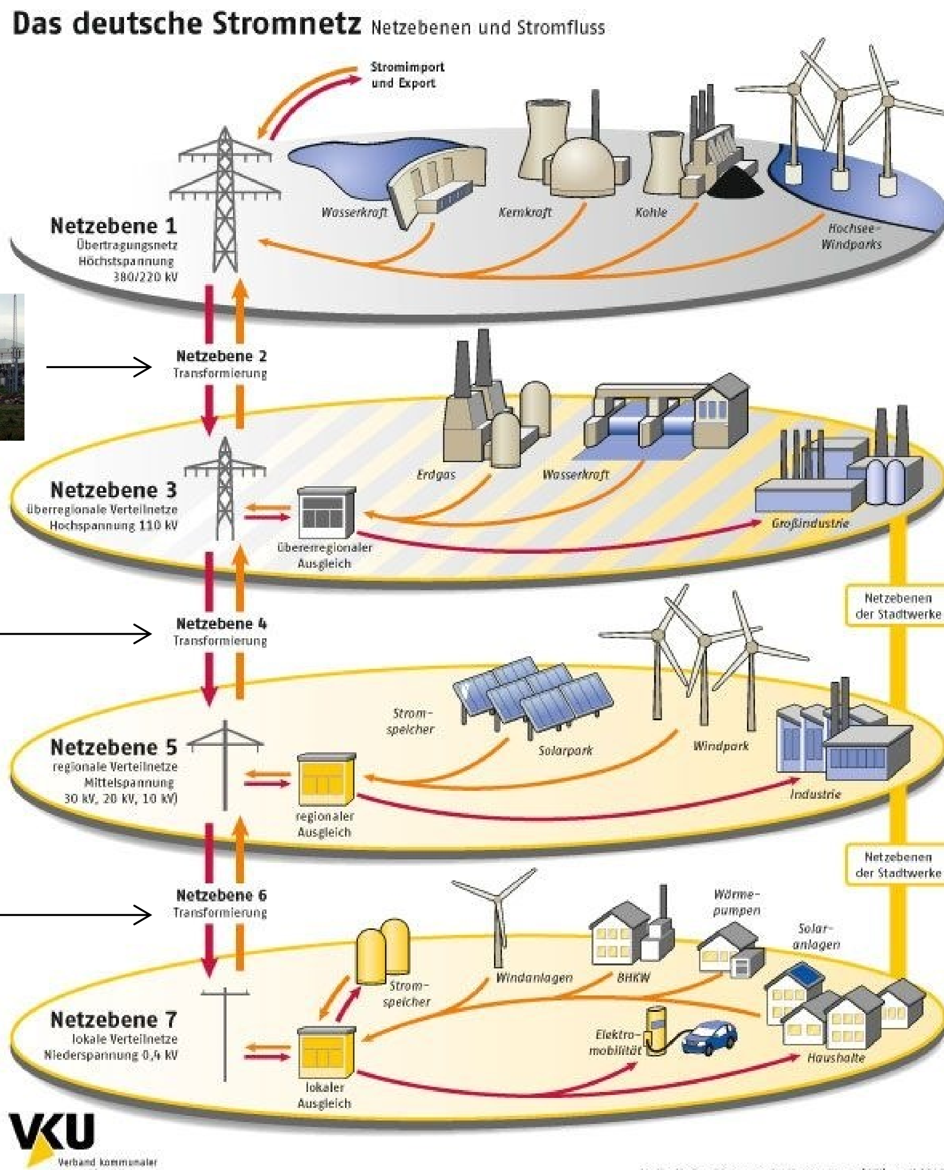
power plant

power grid

consumer

production → transport and distribution → consumption

Power Grid – General Structure



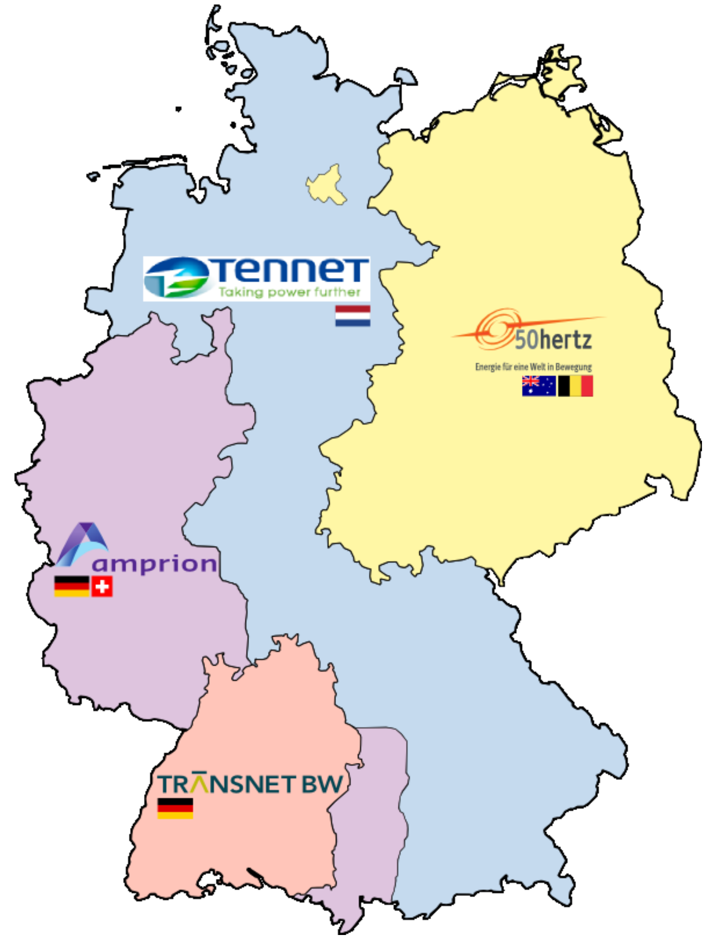
transport system

distribution system

photo source: Ikar.us - Eigenes Werk, CC BY 3.0 de

Power Grids – Transport Systems

- there are four tansport system operators (TSOs) in Germany, see figure
- alternating three-phase current, 50 Hz frequency
- high voltage: 380 kV / 220 kV / 110 kV



source: Francis McLloyd - Eigenes Werk, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=22232969

Power Grids – Distribution Systems

- there are about 940 distribution system operators (DSOs) in Germany:
  - regional DSOs
  - municipal suppliers ("Stadtwerke")
  - private suppliers
- frequency: 50 Hz
- voltage levels: 110 kV, 30 kV, 20 kV, 10 kV

source: Verband der Netzbetreiber e. V.

Power Grids - Operation

- Electical energy cannot be accumulated on the large-scale. Therefore power consumption and power production must be in balance.

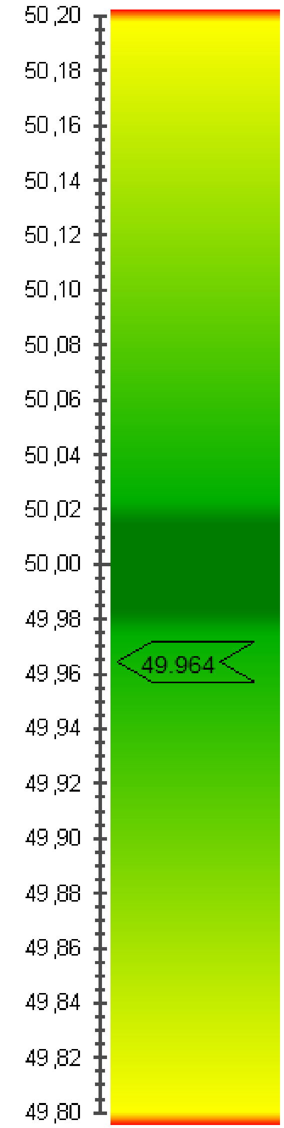
- balance indicator: frequency
  - too much consumption → decreasing frequency
  - too much production → increasing frequency

- goal: keep frequency always at 50 Hz by providing or draining power from controlling power range

- every power plant which can react quickly enough at any time can contribute to controlling power range

- if the controlling power range mechanism fails to restore 50 Hz, some percentage of consumers are discarded → local power outage

- The whole process works completely automatically (SCADA systems).



part III

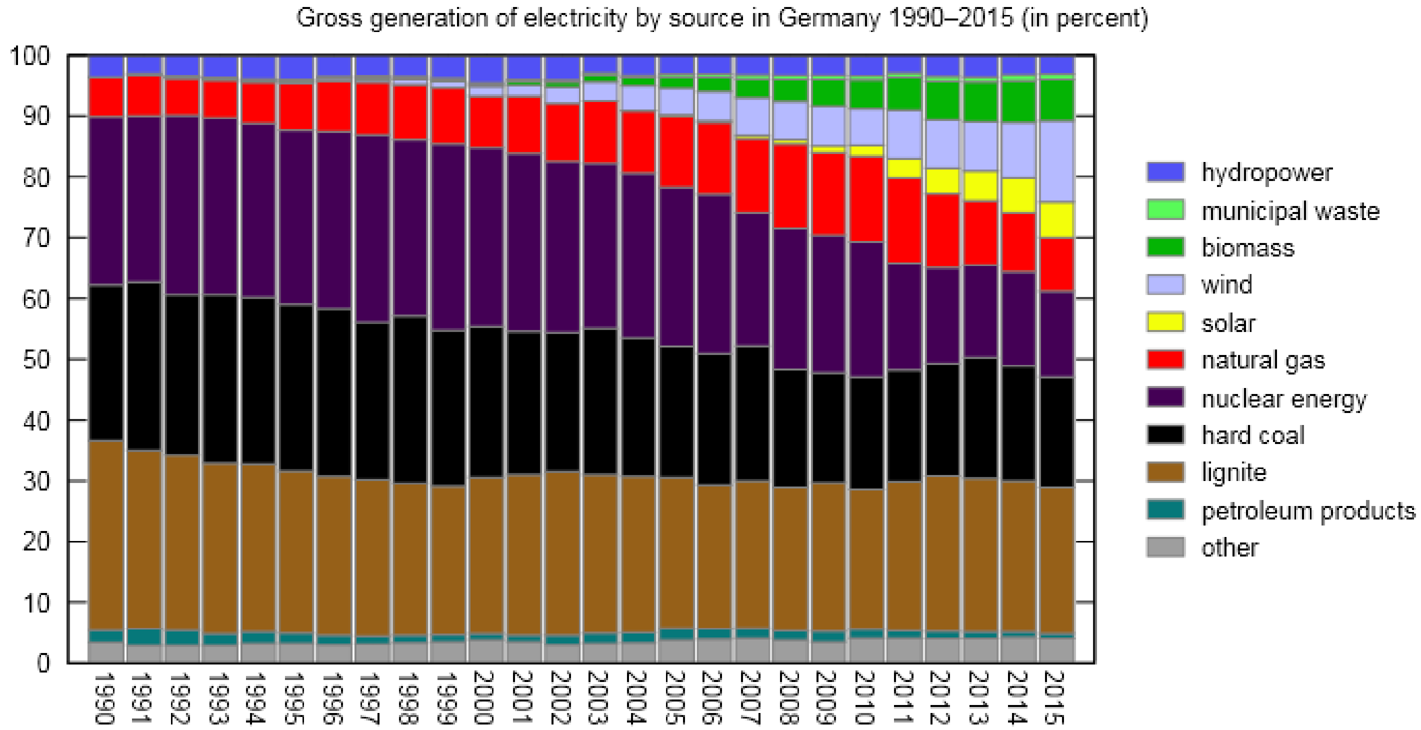
energy transition

Energy Transition – The Prospective Energy System

Energy Transition – Goals of the German Government

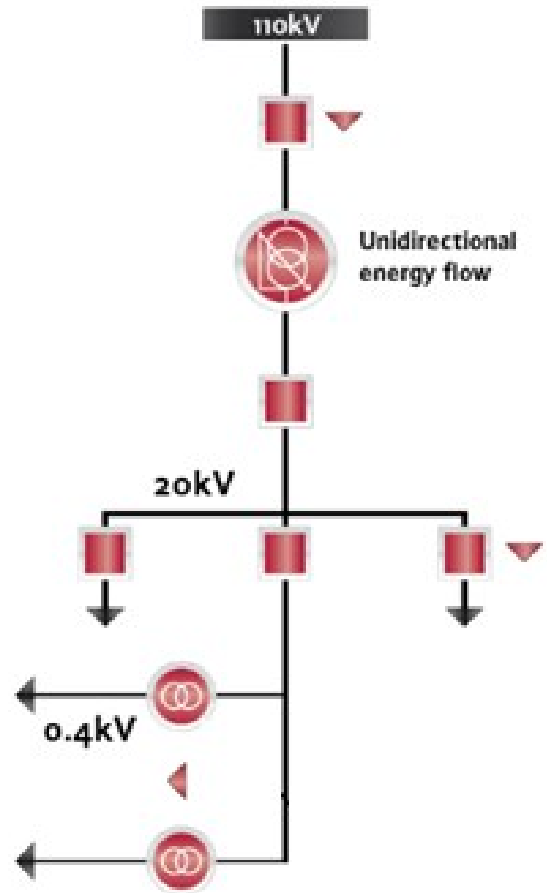
Percentage of renewables according to German Renewable Energy Sources Act (EEG)

- 40-45% by 2025
- 55-60% by 2035
- > 80% by 2050



Energy Transition – The Past

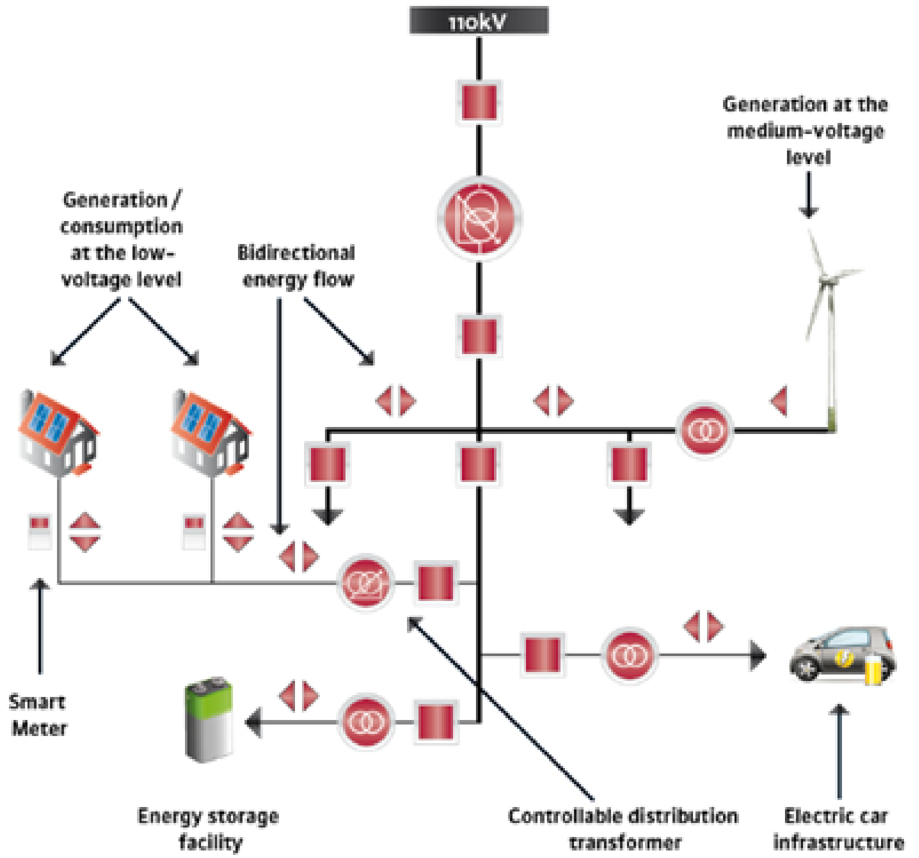
- The energy system was essentially kept in balance by accounting for production and consumption at the level of the transport grid.
- Power was generated in a small amount of large-scale power plants, injected into the high voltage level and transported to the consumer through medium and low voltage. Hence the load flow used to be unidirectional.
- Production and consumption used to be easily projectable.



Bildquelle: BDEW, Verteilnetzstudie

Energy Transition – The (Present and the) Future

- Large-scale power plants are being replaced by many power plants creating energy from **fluctuating renewable energy sources**, which inject into the medium voltage level. Also **"prosumers"** (e.g. a house with a photovoltaic system on the roof), inject power into the low voltage level.
- Energy storage facilities can be employed to balance production peaks.
- Energy flows are bidirectional, accounting and frequency management are more challenging due to the increasing number of power producers.
- Active power grid management is needed at all voltage levels, the complexity of the grid is increased by orders of magnitude!



Quelle: BDEW, Verteilnetzstudie

Energy Transition – Challenges for Power Grid Operators

Reminder: Previously “predictable by humans“ due to simple structure of transport/high voltage grid, now all voltage levels need to taken into account.

- identification and elimination of current and future “bottlenecks“
- keep voltage level in a small range around desired value
- keep frequency in a small range around 50 Hz
- accounting in cooperation with operators of adjacent grids

Needs to be done by computers!

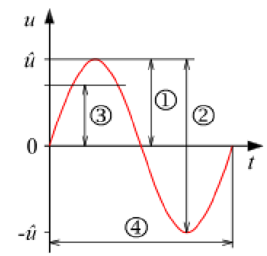
part IV

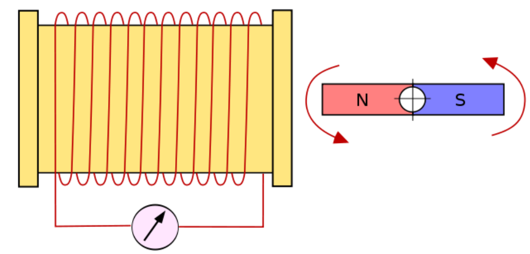
power grid calculation

Power Grid Calculation – A Very Short Introduction to Electical Engineering (I)

BTC

- AC Power:
  - Voltage $V(t) = V_{max} \sin(\omega t)$
  - Current $I(t) = I_{max} \sin(\omega t+\varphi)$,
  - Power $P(t) = V(t)\, I(t)$





Erzeugung von Wechselspannung

- In practice effective values are used:
  $V = V_{max}/\sqrt{2}$, $I = I_{max}/\sqrt{2}$

- However: Inductive (e.g. coil) and capacitive (e.g. capacitor) resistances modify the phase angle between voltage and current.
  $P = V\, I$ only holds for $\varphi = 0$.

- Solution: Use complex numbers!
  - complex power $S = V\, I^*$, $S = P + iQ$,
  - reactive power Q, active Power P, apparent power |S|
  - complex resistance (impedance) $Z = R + iX$

Power Grid Calculation – A Very Short Introduction to Electical Engineering (II)

What is reactive power?

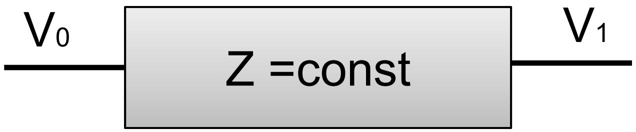
- Q cannot be consumed (no energy is transported), but still stresses power cables!
  (note: actually, it is the electric current that heats the lines)

- If Q is high the same power consumption at the end of the line demands a higher voltage drop compared to zero Q
  → managing Q is crucial for voltage stability

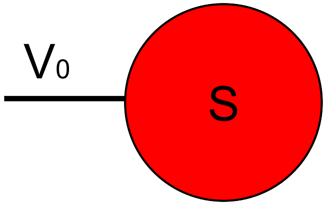
Power Grid Calculation - Grid Model (I)

It is most convenient to model a power system network in terms of unified building blocks using equivalent circuit models, which are often a linear approximation of the real behavior.

Simplifying, every relevant equipment that does not inject or drain power actively (e.g. power transformer, power line), can be modelled as



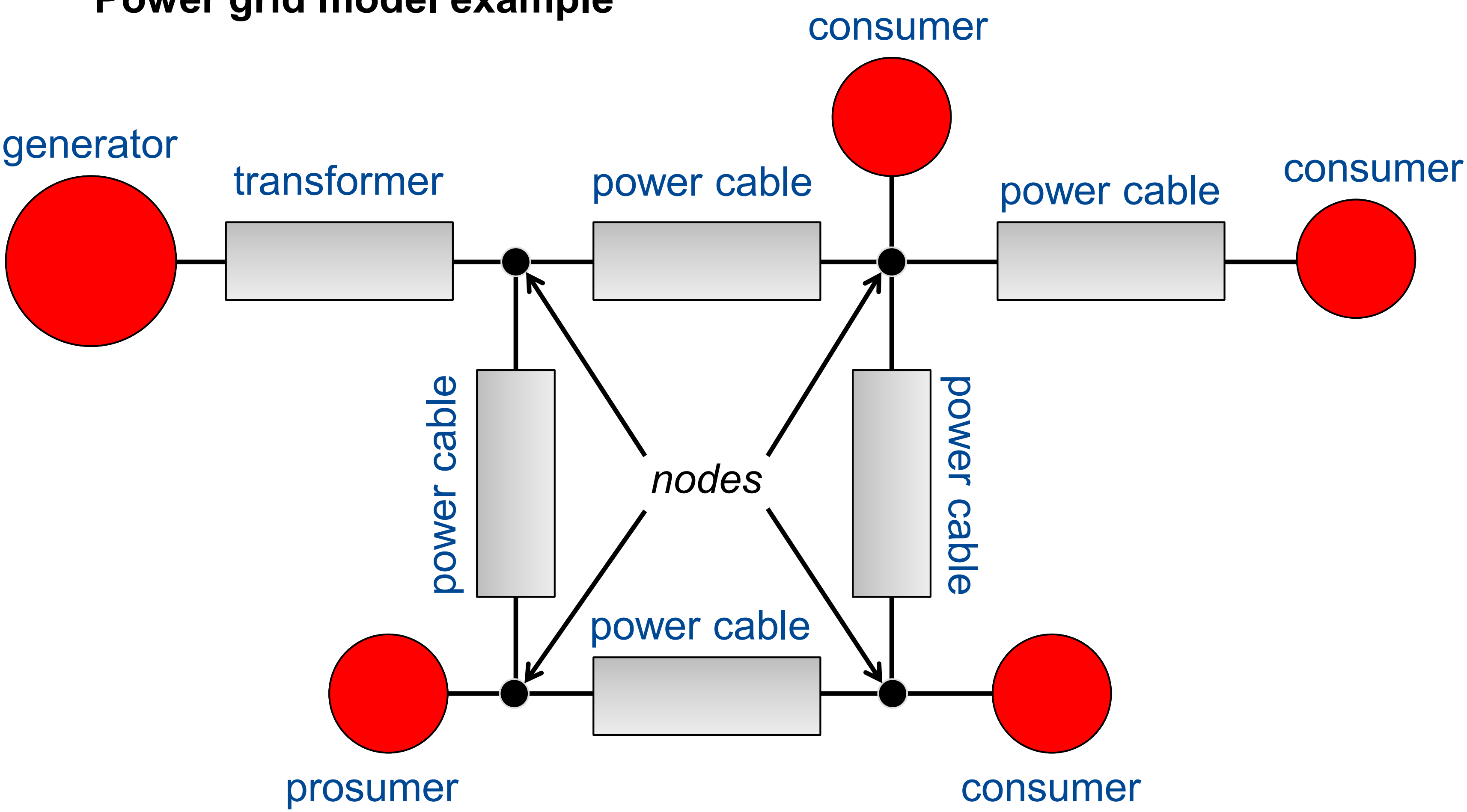
and every active power producer or consumer (e.g. a generator or a consumer) can be modelled as



Note: Z, V and S are complex!

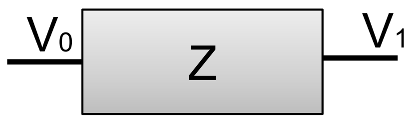
Power Grid Calculation - Grid Model (II)

Power grid model example



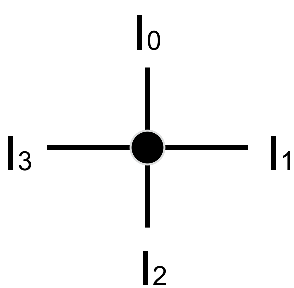
Power Grid Calculation – Equations (I)

a) Ohm‘s law (complex version): $\Delta V = V_1 - V_0 = Z\, I$
holds for every “branch“



grid model → system of equations

b) Kirchhoff rule (conservation of electric charge):
The sum of electric currents at a node is zero.

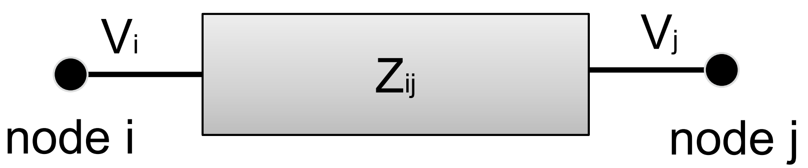


$$I_0 + I_1 + I_2 + I_3 = 0$$

→ constraints
Note that the same holds for apparent power.

Power Grid Calculation – Equations (II)

- Usually voltages and powers are given (measured) at some nodes and branches.



equation for apparent power at node i:
$S_i = V_i \sum_k Y_{ik} V_k$
for all nodes k connected to node i, $Y_{ij} \sim 1/Z_{ij}$

→ Whole system can be written as matrix equation!

Matrix Y is sparse in practice, because every node has only a few connections.

Power Grid Calculation – Applications

- **load flow calculation**: given node voltages, compute the power and the current flowing through each branch (e.g. power cable, transformer). Can be used to identify bottlenecks. Usually always automatically executed before a human operator opens a switch or makes other dynamic changes to power grid.

- **state estimation**: use statistical methods to estimate the most probable state (node voltages) of an overdetermined system (i.e. more measurements available than needed to solve the system). This will also identify faulty measurements.

- **short circuit analysis**: connect node to earth potential and perform load flow calculation. Observe which power lines become overloaded.

- **(n-1) contingency analysis**: remove one equipment from grid and run load flow computation. Usually used for planning power grid design, the power grid must be able to carry the load if any equipment fails.

- **(n-x) ?**

Power Grid Calculation – Future Applications

- **state prognosis:** given prognoses for power production and consumption (based on weather forecast, date/time, special events like football world championship final, ...), predict the most likely state of the power system.

- **bottleneck optimization:** suggest solution to eliminate bottlenecks for power system operator. Possible options:
  - reduce power injection of wind power plants (expensive/unwanted!)
  - ask smart home appliances (e.g. freezer, thermal storage heating) to consume energy
  - adjust voltage at power transformer
  - toggle switches in order to connect other power lines (change topology of the power system)
  - ...

part V

coding and other aspects of my work

Coding - Principles

- Our group uses C++ (the 2011 standard) as main language.
- IDE: MS Visual Studio
- Main set of rules derived from “Clean Code“ by Robert C. Martin
- BTC actively invests in non-functional properties, i.e.
  - Maintainability
  - Reusability
  - Robustness/reliability
  - Efficiency, particularly scalability
- Agile software development along the lines of SCRUM, using e.g.
  - project management tool
  - frequent code reviews and refactoring
  - pair programming
  - test driven development
- Automated tests for various architectures

Coding – What do I actually do?

- Responsible Software Engineer for all components/modules which perform the calculations mentioned before
- Current main focus: Refactoring of a prototype in order to make it ready for “production“ (includes writing elaborate tests, verifying performance, delegating work, coordination with Software Architect, documentation)
- Occasionally: PR
- Occasionally: Support/maintenance for older versions
- Sometimes: Project planning/coordination with other teams
- 1h/week: „sprint“ planning (project management)
- 30min/week: office (e.g. timekeeping, travel expense accounting)
- 1h/week off-topic discussion with other developers / scattering knowledge
- 2d/year (more, if needed): external coaching

Jobs at BTC

We are looking for C++ and Java developers with high motivation for software quality.

Our team is currently looking for a student assistant!

Contact:

simon.dinter@btc-ag.com

Vielen Dank für eure Aufmerksamkeit.

BTC Business Technology Consulting AG
Escherweg 5
26121 Oldenburg
Tel. 0441 / 36 12-0
www.btc-ag.com