Power System Analysis and Planning

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9 Power System Analysis and Planning

9.1 Introduction

Every society today is highly dependent on electricity – as becomes painfully evident when large disturbances with supply interruptions to customers, or even blackouts, occur. In our increasingly “digital societies”, almost all aspects of business and private life are based on the availability of electricity. The reliability of power supply systems cannot be taken for granted – especially not availability requirements of 99.9 % or higher, a value not often met by other technical systems of comparable complexity. The challenge to provide electricity – any amount required, at any time, at any customer’s premises, and with the appropriate quality – is achieved by a large and complex system of power plants and extensive transmission and distribution networks.

Building and operating the power supply system are comprehensive tasks of their own, with special facets for the different system segments:

- **Generation**
  Whether conventional, centralized power plants, or decentralized renewable generators – the generation equipment has to be reliably and stably connected to the system, and an appropriate export capacity has to be provided by the system.

- **Transmission**
  The key task of transmission networks is to connect generation and loads over large distances, and to ensure stability and integrity of the overall system.

- **Distribution**
  The traditional role of distribution networks is to transfer power from the infeeding points “down” to the end customers – however, in today’s situation distributed generators need to be interconnected as well. In any case, the performance of the distribution networks is decisive for supply reliability and several other power quality parameters.

- **Industry**
  Reliable power supply with defined power quality is a basic prerequisite for commercial and industrial processes. In addition, larger sites often run captive generation with related requirements on stability and also operational flexibility.

In addition, the ever faster changing world of today holds special challenges. Every power supply system worldwide is facing its individual mix of challenges including aspects like:

- Increasing infed from distributed and/or renewable generation, often with highly fluctuating power output, and in extreme cases leading to a complete change of the power generation system and resulting power flow patterns.
- Changes in market regimes, continuing liberalization and entry of new market players such as renewable generation or active prosumers.
- Introduction of new, “smart” technologies such as smart metering, demand response, virtual power plants, or advanced, localized automation and control concepts – but also power electronics (HVDC or FACTS), electromobility, or energy storage.
- Ever increasing economic pressure.
- Ageing equipment and systems.
- Emergence of new business models driven by either changes in market regimes and/or technological advances.

These requirements and challenges call for constant analysis, adaption, optimization, and strategic development of power systems. And the pace of change is increasing, as well as the scope of changes: In certain situations, the appropriate changes will even be radical modifications of business models and system hierarchies, starting from, e.g., microgrids up to wide-spread systems consisting of separate power islands connected by a trimmed transmission backbone, or even operating completely independent.

Siemens PTI has built significant competence and expertise on power systems over decades, and over literally thousands of successfully completed studies and projects. Engaging actively in the technical community and Siemens-internal developments, the scope is constantly expanding into the latest technological trends and concepts. The worldwide distribution of projects, combined with local teams of experts in more than 15 countries, ensures familiarity with both local and, of course, also international standards and requirements. This forms a sound basis to address – independently and objectively – any issue in the strategic and technical development of power systems.
9.2 Power System Consulting

9.2.1 General

A power supply system is more than just a combination of switchgear, transformers, overhead lines, cables, and secondary equipment for protection, control and communication. It is the integration of all these components into an overall solution meeting all relevant expectations and requirements: support of the overall business targets and strategy, sound financial performance and adequate technical performance – both in the view of the utilities and also of the end customers.

While there are highly complex and important tasks to be addressed in the detailed planning and design work on the equipment level, it is the task of power system planning to support the definition of overall business targets and business models, to design system models, organizational structures and business processes, and to derive functional specifications for the separate subsystems, plants and components – all in order to ensure the safe, secure and efficient operation of the system as a whole. Key requirements to be addressed include:

- **Strategy**
  Ensuring that system development and operation support the overall business strategy of the utility.

- **Economical performance**
  Meeting defined budgets and other economic performance criteria in individual projects and for the system in total.

- **Safety**
  Protecting people and equipment against harm and damage caused by electricity, especially by electrical failures.

- **Security**
  Safeguarding the stability of the system, especially after disturbances like load shifts or electrical failures.

- **Technical adequacy and power quality**
  Connecting and supplying all end customers according to the defined technical requirements, including power quality requirements on, e.g., reliability and voltage level – both in normal operation and also in disturbed operation.

- **Ecological performance**
  Preventing pollution and minimizing the impact of electrical equipment (e.g., lines) on the environment.

Besides the large set of different – and often, contradicting – requirements, planning activities in power systems have to address very different time horizons: from operational planning focusing on the immediate future within a few minutes or hours, via project planning addressing months to years, up to long-term planning developing guidelines and visions for several decades into the future. In order to ensure that the development of the power system follows one clear strategy and roadmap, it is important to have a commonly agreed long-term system concept available at first – so that all activities and measures in short- and medium-term frames can be oriented and aligned accordingly.

Power supply systems are under constant development to keep pace with operational needs and adjustments in day-to-day business, and to meet the ever changing demands and requirements of customers and regulation. This is why planning activities are relevant and beneficial over the complete lifetime of equipment, plants and systems – and not just in the explicit concept and planning phases at the beginning of their lifecycle. Examples for relevant planning tasks along the complete lifecycle are given in fig 9.2-2.

In the first instance, any power system consulting project is fully individual since it has to consider the specific challenges and requirements, current status, overall framework, and history of the system, utility and customers. Still, there are certain focus topics that are frequently addressed in projects, and typical domains that contribute to projects. The next chapters give a short overview over such focus topics and consulting domains.

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Fig. 9.2-1: Strategic system planning process

Fig. 9.2-2: Planning tasks related to a typical project lifecycle
9.2.2 Focus Topics in Today’s Power Systems

Smart Grid Compass®
Around the world, the power industry is facing major changes. On the one hand, the core system paradigm is shifting from “generation follows load” to “load follows generation”, due to the installation of massive amounts of fluctuating renewable generation. On the other hand, regulation and market conditions are getting less stable, which forces utilities to adjust their capabilities and become more flexible. In order to help utilities cope with these challenges, Siemens has developed the Smart Grid Compass® framework. Leveraging this framework, Siemens supports utilities to develop comprehensive strategies and derive solid implementation roadmaps, according to their business needs.

- Orientation phase
  Development of a first high-level roadmap consisting of candidate initiatives derived out of the prioritization of business objectives, an assessment of the current business capability level, and the definition of the aspired business capability level.

- Destination phase
  Further detailing of the created roadmap, and evaluating of the contained elements in order to develop different implementation scenarios. Each scenario will be backed by a qualitative business case, and will include a rough timeline as well as a first budget estimation.

- Routing phase
  Extending the level of detail of the chosen scenario in order to transform it into an implementation program. Quantitative justification of the program with a business case based on impact chains, parameters, KPIs, work packages, roles and hourly rates. Alignment of the program with already existing investment programs and other relevant plans.

- Navigation phase
  Ensuring that the program stays on course, and implementation on track incl., e.g., setup of the necessary organizational structure, training of resources, running a dedicated program management office, executing value management, implementing regular “refresh” workshops, and supporting individual implementation projects.

System security
The growing complexity of power systems, and power system operation at ever closer safety margins increases the risk of blackouts. To correctly assess a power system’s stability, the operator needs to know the stability margin and have assistance during the decision making process when it comes to finding the most efficient solution in case of stability issues.

- Dynamic Security Assessment (DSA)
  Power system stability plays an increasingly important role in system operation and planning today. The stability limits of these systems are often reached far earlier than their thermal or rated limits. Plus, the growing complexity of power systems increases the risk of blackouts. This means that network operation cannot rely on data acquisition and static n-1 analyses only. Using DSA methodologies and tools is the most reliable way to avoid blackouts and at the same time safely operate the power system closer to its limits. Such tasks are enabled by the product SIGUARD® DSA (see section 9.3) which is also used in related offline studies.

- Protection Security Assessment (PSA)
  Protection systems are crucial for system security because they limit the impact that faults have on power systems. Continuously evolving power systems and quickly changing operating conditions make it a complex task to calculate, verify and validate protection settings. Rigorous protection security assessment that takes into account all relevant network, operating and fault conditions is required to review the adequacy of protection settings. Such protection security assessments should be carried out at regular intervals, and only automated solutions can manage them efficiently.

- Phasor Measurement Unit (PMU) placement studies
  Optimum PMU placement studies help to decide for the number and location of PMU devices in power systems. The locations are depending on the topology of the power system and on the physical phenomena the system is prone to, such as power swings, angle separations, and voltage stability problems. Optimum PMU placement avoids one-time costs for devices and installation, as well as continuous costs for communication, data storage, and maintenance and support.

Grid code compliance
As electric power system loads continue to increase and older power plants are being retired, a significant number of new power generation units, including conventional fossil-fired and renewable energy units, will be connecting to the transmission network. These new power plants create new challenges for the exiting transmission network. Interconnection criteria or grid codes help ensure that the interconnection of a proposed generation project will not negatively impact the reliability performance of the power system.

- Screening study
  High-level review of the transmission capacity in the immediate neighborhood of one or more proposed plant sites to determine if the plant’s output can be exported to the network with no or limited restrictions.

- Feasibility study
  Steady-state power flow and short-circuit analyses of the transmission network with the proposed plant interconnected. This will provide the power plant developer or owner with preliminary information on whether major investments will be required to reinforce the transmission network for interconnecting the project.

- System impact study
  Thorough steady-state and short-circuit analyses that consider a range of relevant system operating scenarios, as well as dynamic simulations that evaluate the transient and dynamic performance of the network to ensure compliance with the transmission network criteria or grid code.

- Facility study
  Definition of equipment requirements for interconnecting the project and, if necessary, for upgrading the network to maintain reliability. This step typically involves the interconnecting transmission network owners, who will provide input on their equipment preferences and practices.
Integration of distributed and renewable energy sources
Due to environmental and also customer-specific, economic or supply security requirements, there are increasing shares of power generation from distributed energy resources (DER) or renewable energy sources (RES), of controllable loads, and possibly of co-generation or storage units. Beneficial integration of dispersed and renewable generation into a distribution grid, and also of large-scale renewable generation into transmission systems, poses a considerable challenge to existing network planning as well as operation methods and software tools.

• Integration of dispersed generation
  Successful integration of dispersed and renewable generation into distribution networks relies heavily on effective planning and operation strategies. Integration studies address all relevant issues in system architecture and configuration, especially the identification of the optimal connection point, power quality, protection concepts, and decoupling concepts.

• Wind farm design
  Successful wind power plant design and system integration should consider both the design requirements for the internal network of wind power plants (WPPs), and a reliable performance and control of the plant amid full compliance with the grid code. A generation interconnection study ensures an optimum integration of the WPPs into the grid with regards to reliability as well as cost-effectiveness.

• Grid code compliance investigation
  A thorough analysis enables the project developer and/or network operator to identify the right connection strategy before the actual installation of DER and/or RES generation. Such an analysis considers several aspects including optimum connection point to the grid, dimensioning of the switchgear considering technical and economical aspects, losses, power quality, and reliability of supply.

• System interconnection studies
  System interconnection studies support the interconnection of DER/RES plants while maintaining the overall system’s technical performance. The results identify impacts on power grids and solutions, in order to address relevant issues and provide technical advice to either the project developer or the system operator.

• Wind turbine modeling
  Comprehensive modeling of wind turbines with specialized simulation software forms the basis for detailed wind farm investigations, which are an essential part of any design or interconnection study. The validation of model performance to measurements is required for certification in some markets, and is a valuable sales asset for the turbine manufacturers.

Smart Grid concepts and new technologies
The increasing share of renewable energy sources and the growing number of available technologies have brought about different trends and requirements in the Smart Grid market. Power system operators are challenged with minimizing the impact of new generation on performance, and with maintaining or even improving security of supply and power quality. At the same time, investments for network extensions are under increasing economic pressure.

• Design of Smart Grid network concepts
  An optimum overall concept for innovative system architecture and configuration is developed, considering the latest innovative technologies such as primary components, communication technologies, and Smart Grid applications and functionality. Performance analyses ensure adequate network performance, sustainability, and efficient network operation.

• Microgrid and off-grid solutions
  Island or off-grid power supply system operators, or developers of special customer projects, often struggle with high costs for electricity and low supply reliability. Intelligent solutions for system design, system protection, automation, and the integration of renewable energy sources form the basis for a technically and economically feasible, and even more ecological microgrid power system concept.

• Electromobility
  The increasing trend to substitute cars with combustion engines by electric vehicles (EVs) will have a large impact on the existing power systems, especially on LV and MV distribution. With an analysis of the current power system and of future scenarios, the enhancement of system performance, and the integration of Smart Grid technologies can be prepared for the integration of electromobility at reasonable extension costs.

• AC/DC hybrid systems
  The increasing installation of, e.g., offshore wind farms far away from the shores, and the increasing wide-area power transfers in large interconnected systems requires transporting large amounts of power over long distances. In many projects, DC solutions are preferred over AC solutions due to technical and/or economical reasons. Due to reliability issues, in the future the existing point-to-point HVDC connections can be interconnected, in order to form a DC network integrating, e.g., several wind farms and connecting several AC networks into one system. A thorough understanding of the individual components is required to design complex DC network concepts and hybrid AC/DC systems to ensure appropriate and stable behavior.

Feasibility studies for projects in the oil & gas industry
Several key processes in the oil & gas industry are highly energy-intensive, and all-electric concepts often provide additional benefits in operational flexibility, efficiency and overall performance. Special requirements and conditions in the oil & gas industry call for explicit and detailed feasibility studies to validate the technical and economical appropriateness of solution concepts.

• Feasibility studies
  Advanced concepts for the power supply system in oil & gas installations, e.g., new “all-electric” concepts for LNG compression plants, offshore vessels or refinery processes, pose high challenges especially on the dynamic performance of power generation equipment and the network. Special dynamic models and simulations, considering both the power system and also key aspects of the production processes explicitly, can analyze and verify the performance of solution concepts.
9.2 Power System Consulting

- **Subsea systems**
  New concepts and new technologies for offshore subsea production units are being developed to exploit such locations using subsea systems fed from deep water platforms or fed from onshore grids far away from the oil or gas fields. Suitable subsea power distribution and transportation is a key aspect to fulfill the challenging demands of moving power supply equipment onto the sea bed in deep water.

**Disturbance investigation**
From the system perspective, equipment faults and failures do occur frequently. Many fault and failure events do not even impact system operation – however, some events do cause undesired and sometimes incomprehensible impacts. Especially for multiple faults, the actual root causes, or even the observed events in system operation, are not easily to trace. In these cases knowledge of different specialists has to be coordinated, e.g., on protection, insulation coordination, system dynamics, network operation, and equipment of different vendors. It is also necessary to consider post-failure conditions, events and operational procedures, and to cross-check official statements.

- **Site investigation and measurements**
  Data verification may include site visits, interviews, analysis of reference events, and measurements on-site or in a laboratory. The analysis is backed and supported by state-of-the-art, calibrated measuring devices.

- **Modeling and simulation**
  Based on the theoretical analyses, a draft hypothesis on the disturbance event is developed. By modeling the steady-state, dynamic and transient behavior of equipment and of systems in appropriate detail, it is possible to verify the root cause and to validate proposed mitigation measures.

9.2.3 Consulting Domains

**Steady-state system studies**
Steady-state system studies define the structure and configuration of power supply networks. This builds the basis for solid system performance – and is an ever more demanding task given today's challenges, such as system integration of renewable generation, security requirements, and overall tighter operational margins. The following types of steady-state system studies can be performed:

- **Network analysis**
  Technical calculations of power networks in their present structure and configuration

- **Network structure development**
  Development and performance validation of alternative structures and configurations for power networks, from short-term operational planning to long-term master planning

- **Neutral earthing studies**
  Development and performance validation of appropriate neutral earthing concepts and configurations in power systems

- **Earthing system measurement and design**
  Measurement of specific soil resistivity, as well as development and performance validation of earthing system concepts and configurations

**Dynamic system studies**
Various activities and events in power supply systems trigger dynamic phenomena in the interconnected network equipment and generators. Modeling, analyzing and optimizing the dynamic performance is a key requirement to ensure stability and security in the system – both in normal, and especially in disturbed operation – and for the design and optimization of equipment. The following types of dynamic system studies can be performed:

- **Dynamic system analysis**
  Modeling and analysis of dynamic performance of equipment, such as generators, motors and systems – also comprising mechanical equipment (e.g., shafts of rotating equipment) and steam supply systems

- **Power electronics modeling and analysis**
  Detailed modeling and performance analysis of AC/DC power converters, high-voltage direct current (HVDC), or flexible AC transmission systems (FACTS) equipment

- **Controller and machine measurement, modeling and analysis**
  Detailed modeling and performance analysis of controllers, as well as measurement of controller response and performance on electrical machines

**Transient system studies**
Overvoltages from lightning strikes, electrical failures or switching actions, as well as other transient phenomena, may significantly impact system performance and equipment condition. Respective modeling, analysis and insulation coordination studies build the foundation for the resilience of equipment and systems. The following types of transient system studies can be performed:

- **Transient studies**
  Modeling and analysis of overvoltages and other transient phenomena, as well as detailed modeling and analysis of switching actions and their impact on system performance
• Insulation coordination studies
  Evaluation of voltage stresses, and determination of appropriate insulation levels and of protective devices for equipment and systems

Protection and control system studies
Protection and control aspects are essential for the operational performance of power supply systems, and are thus also integral parts of planning studies. A sound analysis of requirements, of the current system, and of relevant operating scenarios, the development of appropriate schemes, and the detailed coordination of individual relays and equipment ensure that operational performance targets are achieved. The following types of protection and control system studies can be performed:
• Protection system design and coordination
  Development of suitable schemes for power system protection and coordination of appropriate settings for protection relays
• Instrument transformer analysis
  Dimensioning of instrument transformers in substations and switchgear, especially current transformers in gas-insulated switchgear (GIS)
• System control and automation concepts
  Concepts, configurations, and equipment for communication, automation and control in power supply systems

Power quality system studies
Power quality issues, mainly harmonics, but also flicker or voltage fluctuations, are of increasing concern in today’s power systems, driven, e.g., by the increasing use of power electronics. These issues may significantly impair system performance and customer processes – up to equipment damages and process shutdowns. Appropriate studies on the analysis, modeling and mitigation of such issues built the foundation to ensure operational performance. The following types of power quality system studies can be performed:
• Power quality measurements, analysis, and filter design
  Measurement, evaluation and analysis of power quality phenomena, especially harmonics, fault diagnostics, development and performance validation of appropriate filters
• Interference and electromagnetic field analysis
  Analysis of interferences from power supply systems to other networks and systems, as well as modeling and calculation of electromagnetic fields

Business transformation and solution engineering
The classical utility business environment has been undergoing massive structural change for the last years due to an increase in renewable generation, changes in regulatory frameworks, new market players, and advances in technology. However, these changes under the overall headline of Smart Grid not only create new challenges for utilities and their executive management teams, they also provide opportunities and rationales to transform utilities into customer-focused service companies that offer innovative and customized products and services. The primary challenge lies in navigating the transformation through a comprehensive strategy that integrates technical capabilities with business opportunities in a structured way, in order to create sustainable business value.

• Business transformation consulting
  – "Utility of the future" strategies – Development and implementation of strategies for the improvement of a utility’s business capabilities including detailed planning of measures and financial justification.
  – Integrated Smart Grid strategies – Development and implementation of strategies that combine business capability enhancements with the definition of innovative business models.
• Solution engineering
  – Owner’s engineer – Delivery of engineering services in the context of implementation projects/programs in order to help utilities reduce overall resource and skill requirements or bridge short-term gaps in resource and skill availability.
  – IT / OT convergence – Design and realization of concepts focusing on closing or reducing the gap between the IT and OT worlds within utilities.
• Strategic asset management
  Development and setup of strategic grid management concepts considering both technical and financial aspects.
• Energy market studies
  Modeling and analysis of the entire power market and regulatory regimes and aspects, especially production cost modeling
• Due diligence
  Investigating and evaluating utilities considered as targets for future acquisition with respect to technical and economic current situation and performance, as well as future plans

More information on Siemens Power Technologies International visit:
www.siemens.com/power-technologies
9.3 Software Solutions

Various calculations of technical and economic characteristics of the actual system or of planning variants are part of the network planning process. The availability of suitable tools is highly important. Besides the obvious requirement that calculation results should be as accurate and reliable as possible, particularly with regard to the quality of both calculation tools and input data, several other aspects are also relevant for the successful and efficient use of network planning tools:

- **Network model**
  The quality of calculation is dependent, above all, on the quality of the input data. The structure and complexity of the data model must support the various calculations, including those for very large network models. In large systems, the question of how the network and the data are structured and presented to the user is of crucial importance for the effective use of the software tools.

- **User interface**
  Calculation algorithms implemented in the software tools have reached a very high level of complexity and are controlled by a multitude of different parameters. The handling and management of large network models is a complex task on its own. Therefore, an intuitive but comprehensive user interface is a key requirement for modern software tools.

- **Management of calculation results**
  After the actual calculations have been performed, the results need to be analyzed and presented. In many cases, this means more than printing tables or network diagrams with certain result values attached to the respective components. The compilation of comprehensive graphical representations, tables and reports – both according to predefined and user-defined structures – provides significant support in the execution of network planning projects and should be supported by the software tools.

9.3.1 PSS® Product Suite

Siemens has used its great experience and know-how in network planning to develop powerful system simulation and analysis tools to assist engineers in their highly responsible work. The software tools of the Power System Simulator (PSS®) Product Suite are leading products with respect to technical performance and user-friendliness. Comprehensive interfaces enable the interaction of all PSS® Product Suite tools, and also support the integration with other IT systems.

The PSS® Product Suite includes:

- **PSS®E**, power flow, dynamics, short circuit, and optimal power flow for transmission network planning
- **PSS®SINCAL**, power system planning for generation, transmission, distribution and industrial grids
- **PSS®NETOMAC**, dynamic system analysis
- **PSS®PDMS**, protection device management system
- **PSS®MUST**, transmission transfer capability, sensitivity, and impact analysis

**PSS®E**

PSS®E high-performance transmission planning software has supported the power community with meticulous and comprehensive modeling capabilities for more than 40 years. The probabilistic contingency analyses and advanced dynamics modeling capabilities included in PSS®E provide transmission planning and operations engineers a broad range of methodologies for use in the design and operation of reliable networks.

PSS®E is the Siemens offering for power system transmission analysis that continues to be the technology of choice in an ever-growing market that exceeds 115 countries.

PSS®E is an integrated, interactive program for simulating, analyzing and optimizing power system performance. It provides the user with the most advanced and proven methods in many technical areas. PSS®E base power flow package can be enhanced to include one or all of the following modules:

- **Advanced Power Flow**
- **Dynamic Simulation**
- **Short-Circuit Calculations**
- **Optimal Power Flow (OPF)**
- **Geomagnetic Induced Currents (GIC)**
- **Advanced Results Visualization (RAV)**
- **Graphical Model Builder (GMB)**
- **Eigenvalue and Modal Analysis (NEVA)**

Fig. 9.3-1: Visualizing PSS®E results using one-line diagram contouring
**PSS®SINCAL Platform**

PSS®SINCAL Platform is a comprehensive, high-end network analysis software solution for all network planning needs. It is the Siemens offering for power system transmission, distribution and industry planning. PSS®SINCAL provides a full unbalanced network model for high-, medium- and low-voltage grids, and supports in the design, modeling and analysis of electrical networks as well as pipe networks, such as water, gas, and district heating/cooling systems.

Through its modular and fully integrated design, PSS®SINCAL enables a high level of customization according to individual needs, making it the optimum solution for all planning tasks in the areas of generation, transmission, distribution and industrial grids.

PSS®SINCAL also provides the capability of solving a full range of tasks with its high-quality algorithms optimized for both accuracy and performance. User-defined applications can easily be developed with its object-oriented data model. Sophisticated case and data management facilitate the handling of complex projects including multi-user projects. PSS®SINCAL can be easily integrated into systems such as Geographical Information Systems (GIS), SCADA and Meter Data Management Systems (MDMS).


**PSS®NETOMAC**

PSS®NETOMAC was designed to facilitate access to and manage any kind of information on the dynamic performance of a power system. PSS®NETOMAC offers a wide range of options for simulating all kinds of electromagnetic and electromechanical phenomena in electrical power supply systems. It links up the most important methods for the analysis of dynamics of electrical networks in the time and frequency domains. System operators can choose between a variety of program configurations – from “Basic” to “Professional”. Numerous program modules allow for this program to be adjusted to the individual requirements of each user.
**PSS®PDMS**

Numerous settings are needed to parameterize different functions of a modern protection device (time-overcurrent protection, overload protection, impedance protection, intermittent earth-fault protection, monitoring measurements, etc.). At any point in time, starting from the setting calculation, parameterization and testing, the settings as well as the accompanying documents must be traceable, and the workflow state clearly indicated. Considering the involvement of different staff members during the workflow, as well as the changing network configurations with corresponding parameter sets and handling of different firmware, the management of protection data is a complex process.

PSS®PDMS (Protection Device Management System) is a universal program to centrally manage protection devices and their settings. All data is stored in a central relational database, and is available for data exchange with other programs such as relay parameterization software. Settings can be exchanged between the power system analysis software PSS®SINCAL and PSS®PDMS.

**PSS®MUST**

PSS®MUST is a powerful tool for quickly and easily calculating transfer capabilities, finding the impacts of transfers on transmission networks, and performing advanced sensitivity analysis.

PSS®MUST complements PSS®E data handling and analysis functions with the most advanced and efficient linear power flow and user interface available. PSS®MUST’s speed, ease-of-use, and versatile Microsoft® Excel interface simplifies and reduces data setup time, and improves the display and versatility of the results.

**CTDim**

The optimization of instrument transformers with respect to their technical requirements and their economic impact builds an important milestone within every power system project. CTDim is a software tool for current transformer (CT) and voltage transformer (VT) dimensioning.

Main features include the following:

- Straightforward check whether CTs and VTs fulfill requirements of connected devices.
- Supports distance protection, generator protection, transformer protection, line differential protection, busbar protection, as well as overcurrent protection.
- Powerful documentation: Short and long reports are prepared automatically.
- Includes both protection as well as metering CT cores. Covers dimensioning for VT protection and metering windings. Supports international standards IEC and ANSI.
- Transient simulation of CT behavior for all above-mentioned protection CT classes and protection devices. Comtrade export function allows hardware testing.
- Large relay and metering instrument database: Siemens numerical relays are fully supported, as well as a large number of non-Siemens devices.
CTDim makes instrument transformer dimensioning more efficient. It saves engineering and production costs by optimizing the current transformer data.

**PSS®ODMS**

PSS®ODMS is a multi-purpose software product for electrical power transmission system planners and operators. The software is currently used by power companies around the globe to manage grid/network models, train system operators, augment existing SCADA/EMS network analysis functions, and facilitate compliance with interoperability regulations based on the IEC CIM 61970 standard.

PSS®ODMS allows transmission planning and operations engineers to create, maintain, analyze and exchange network-related data quickly and easily. It tears down interoperability barriers by providing a fully CIM-compliant (IEC 61970) network modeling platform, including the ability to convert between various proprietary data formats. PSS®ODMS customers around the globe are enjoying the benefits of:

- Greater efficiency in their model exchange workflows/business processes
- Higher degree of accuracy in power system studies and simulation
- Increased power system reliability/security
- Reduced regulatory violations/fines.

**PSS®MOD**

PSS®MOD is a software product that makes it easier and more efficient for existing PSS®E users to manage a large number of change cases across multiple concurrent users. The product brings efficiency, order and accuracy to the process of creating, maintaining and exchanging PSS®E-based network models in complex, multi-user settings.

PSS®MOD revolutionizes traditional approaches to managing network models used in transmission planning studies by providing a web-based application with an extensive set of features supported by a centralized data repository. PSS®MOD is currently used by large and small planning departments to coordinate production and publication of large, aggregated base cases as well as support for interconnection and reliability cases. PSS®MOD coordinates time-bound network model data inputs from multiple users, and is able to assemble a complete study case for any point in time. PSS®MOD provides consistency and transparency for network models.
9.3.2 SIGUARD® Solutions

SIGUARD® solutions offer a combination of software, training and consulting to prepare the customer for the new challenges and the upcoming security requirements in power system operations. Applying SIGUARD® solutions provides the following benefits:

• Blackout prevention
• Increase of power system utilization
• Improvement of situational awareness.

SIGUARD® solutions support the decision making process of the power system operator. The basic idea is to increase the observability and the controllability of the system, and to perform an automatic, intelligent security assessment.

The SIGUARD family includes:
• SIGUARD® DSA, dynamic security assessment
• SIGUARD® PSA, protection security assessment
• SIGUARD® PDP, wide-area monitoring

SIGUARD® DSA
SIGUARD® DSA, the dynamic security assessment tool, analyzes possible contingencies and assesses the system stability. It provides the operator with an overview of the current and near-future state of system stability.

The highly sophisticated algorithms of the PSS® Product Suite perform dynamic contingency simulations. The computation power required for this is scalable from a single laptop all the way to computation clusters. The dynamic stability problems transient stability, voltage stability, and oscillatory stability are taken into account. The high-speed simulation engine makes it possible to analyze the entire range of stability issues ahead of real time – with a single tool that uses a single system model. Cascading outages caused by system dynamics can be observed and analyzed with the embedded protection simulation in order to prevent blackouts of the power system.

The solution includes customization and integration of SIGUARD® DSA into any IT environment. The adaptation and long-term maintenance of the power system model as well as consulting services are offered.

SIGUARD® PSA
SIGUARD® PSA, the protection security assessment tool, analyzes the selectivity, sensitivity and speed of the entire protection system. It enables a rigorous protection system performance audit.

SIGUARD® PSA offers a comprehensive protection security solution that comprises:
• Network and protection data management (including data collection and update)
• Network and protection simulation
• Protection security assessment, such as the detection of non-selectivity, and of hidden as well as critical faults
• Online result visualization and documentation
• Protection setting improvement

SIGUARD® PSA enables protection engineers and operators to perform fast protection security assessments for reliable protection setting determination, secure system operation, and of cascading trippings prevention.

SIGUARD® PDP
SIGUARD® PDP, the phasor data processor tool, uses PMUs (Phasor Measurement Units) – a cutting-edge phasor measurement technology – to observe the actual state of the power system. It monitors system variables and informs about critical system states.

For more information on this product, please see chapter 6.4.7.

Intelligent PMU placement is crucial for cost saving, and for optimum observability of dynamic system behavior. Optimum PMU placement studies are offered as consulting services from Siemens PTI.