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WHITE PAPER
ng.Grace

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Artificial Intelligence based CAD for Power System Protection and Control

Abstract

Artificial Intelligence based CAD for Power System Protection and Control

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July 10, 2020

ng.Grace is the revolutionary approach to fully automated design of digital substation. The software is based on knowledge base technologies, ontology, and inference mechanisms as well as some other AI techniques. This approach makes CAD system able to automatically synthesize an overall system architecture of the digital substation Protection Automation and Control System (PACS) or Digital Substation Automation System (DSAS) considering requirements on functionality, reliability and costs.

A human engineer needs just to enter the main scheme of a substation or to import this scheme using SSD or CIM files.

Then ng.Grace starts to work. It does:

- PACS functions selection corresponding to main scheme of the substation
- functions logic creation with use of Logical Nodes and Logical Device templates
- attaching selected functions to instrument transformers and circuit breakers
- IEDs and MUs device selection
- assigning functions to IEDs and MUs
- assigning MUs to primary equipment
- process bus and station bus LAN architecture creation
- costs and reliability assessment

ng.Grace is the unique product on the market with AI based technology inside. It is Software-as-a-Service solution.

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White paper

01 Introduction
ng.Grace

01

The design of electrical substations is too complex. Design steps include choosing a digital substation PACS overall architecture, creating a local area networks, defining a set of protection and automation IEDs and their functions, defining a set of signals, defining a set of MUs, and creating a set of special files in accordance with IEC 61850 (SCD, CID and others).

Modern IT and AI techniques provide tools to automate many of described steps. These techniques can reduce the amount of manual labor, the time it takes to complete design, and the probability of errors caused by the human factor.

The use of artificial intelligence methods makes it possible to automatically create design documentation for the PACS of digital substation.
However, designing is a creative and analytical process. The presented technology is based on specialized software and algorithms that can reproduce creative thinking of a human.

02 Background
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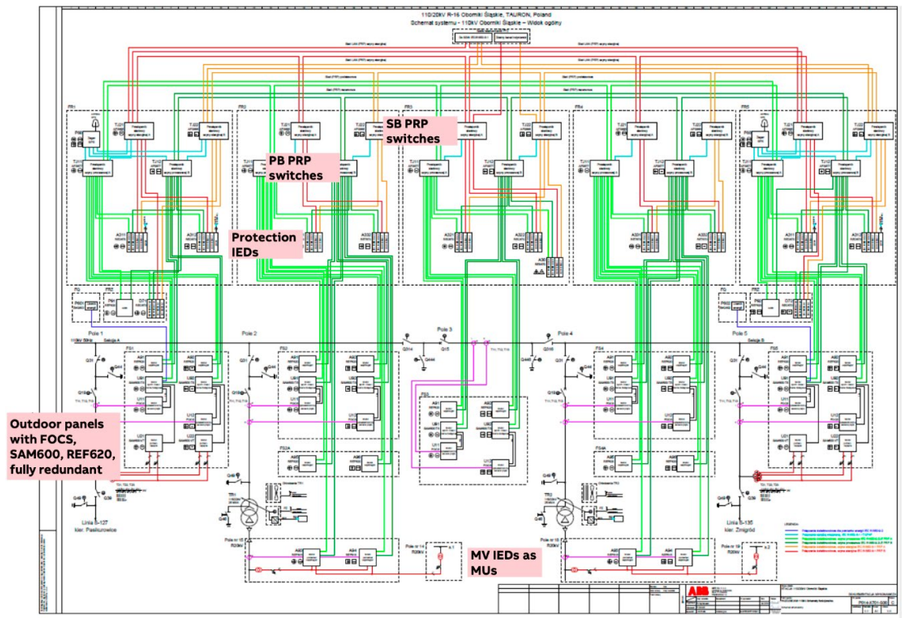
02

The PACS design is based on the regulatory requirements and experience of the designer. Digitalization increases burden on the designer of electrical substations. A lot of new options appear due to flexibility of digital solutions. A designer can`t even observe all basic alternatives and therefore can't create an optimal solution matching different requirements.

Modern substations become Smart Digital Substation due to IEC 61850. The service life of equipment in the electric power industry is long, so there are a lot of old substations now. The reconstruction era has been started all over the world with new digital technologies.

Figure 1:
An example of a digital substation PACS architecture

Power industry needs an opportunity to have a lot of Digital PACS quickly and high quality with proven reliability and minimum costs. Existing CAD solutions can`t provide that.



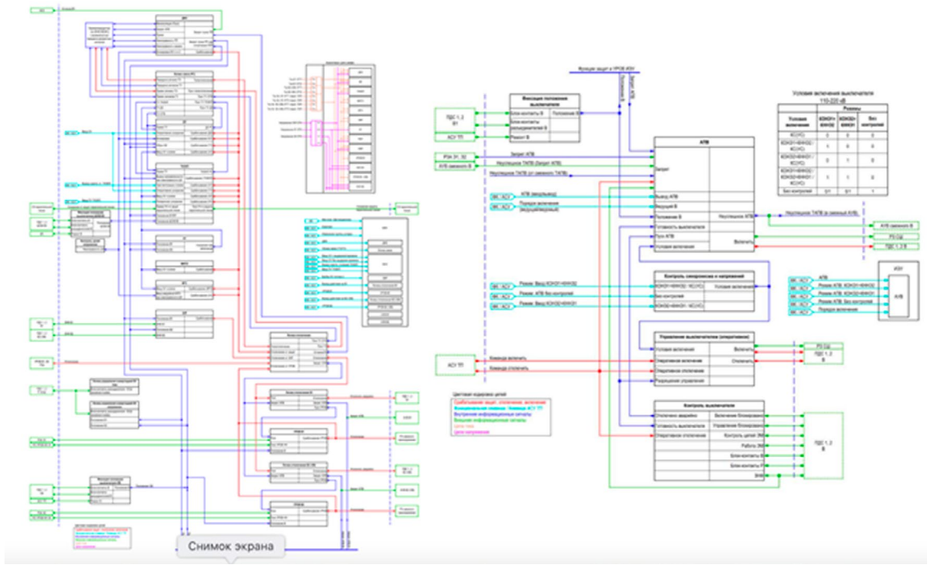


Figure 2:
An example of a digital substation
PACS functional block diagram
(a small part)

Digital substation PACS design problems

Digital substation PACS design problems:

- Long design time - up to 12 months
- Overskilled team required (15-20 people)
- Too many design options due to flexibility of Digital Technologies (an engineer can`t find an optimum)
- Very complex creative task to design PACS architecture and algorithms
- Lack of tools to prove reliability and cost efficiency (CAPEX/OPEX vs Reliability)

There are various software products for the development of configuration and technical specification files in CIM and SCL languages, the settings calculation in an automated mode. These solutions optimize the processes of file creation and settings calculation for relay protection and automation devices; however, they have drawbacks.

There are two types of configurations tools according to IEC 61850: system configurators and IED configurators.

Commonly used system configurators that create SCL configuration files are Helinks STS, ATLAN 61850, SCL Manager, SCADA Studio. These configurators are aimed to create and edit SSD and SCD files, some of them partially configure CID files. However, it should be noted that none of the considered configurators can create SED files described in the IEC 61850 standard.

IED configurator comparison is shown below:

	DIGSI 5	IEC 61850 GE	PCM600
SSD editor	✓	✓	✓
SCD editor	✓	✓	✓
FBD creator	✓	✓	✓
Logic testing in the configurator	✓	✓	✓
Digital twins creator	✓	N/A	N/A

Not all IED configurators can develop functional block diagrams or create digital twins.

There is no product on the market that implements **fully automated design process of digital substation**. Our software, **ng.Grace**, offers a fully automated design cycle.

03 Product description

New technology

03

The new technology based on AI techniques was developed to solve the above-mentioned problems. Developed technology contains formalized regulatory requirements and implements the creative process of PACS architecture design.

A knowledge base system consists of a knowledge base that represents facts about the world and an inference engine that can reason about those facts and use rules and other forms of logic to deduce new facts or highlight inconsistencies.

Ontology contains a representation, formal naming and definition of the categories, properties and relations between the concepts, data and entities that represent one, many or all domains of discourse.

A knowledge base is a formalization of a subject area and its presentation in the form of a semantic network, implemented by logical conclusions and meaningful information processing. It is an information model of the field of knowledge, which has the form of a directed graph, the vertices of which correspond to objects of the domain, and arcs (edges) define the relation between them. The structure of such a graph corresponds to a triplet, which is a form of data representation in ontologies. Ontologies are the framework of the knowledge base and create a basis for describing the basic concepts of the subject area, which is necessary for the full functioning of the system. Ontology represents the formalization of a certain field of knowledge using a conceptual scheme.

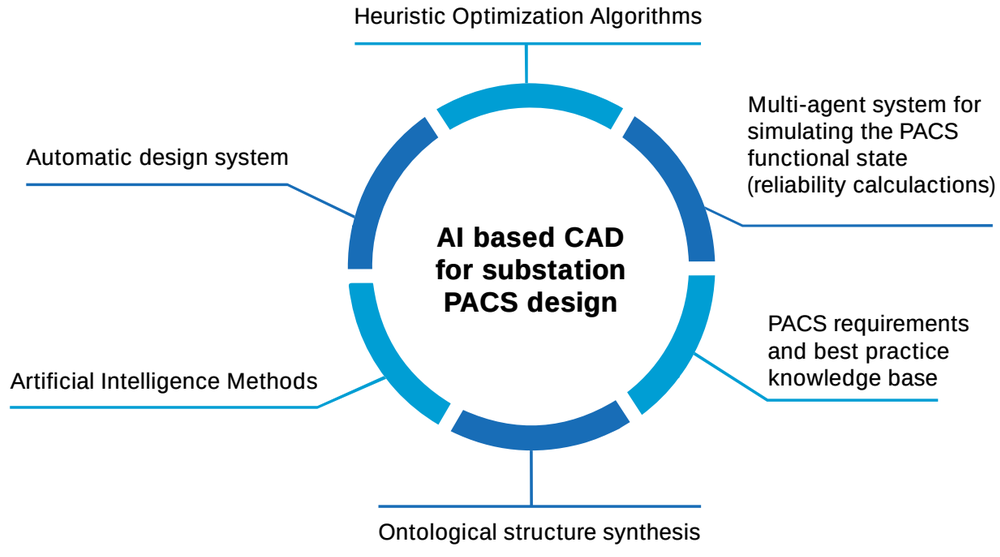
	Conventional designing	CAD design	Proposed technology
PACS function set			
IED set and functional allocations			
Process and station bus schema creation			
PACS function block diagrams			
Configuration and description in SCL			

Ontology model of PACS knowledge base includes:

- Knowledge base classes comply with IEC 61850
- Knowledge base includes requirements and rules of PACS design
- PACS knowledge base automatically scales to the main scheme of every substation
- logical inference mechanism (reasoner) is used to complete the implicit properties in the knowledge base

The software uses two knowledge bases

The first one (Design rules KB) is used for storing and processing PACS requirements including regulatory documentation, best practices, etc. The second one (Substation KB) represents primary and secondary substation equipment, PACS functions, etc.



The result of the design process is represented by the files:

XML-files	ng.Grace
SCD-file	✓
SED-file	✓
CID-file	✓
CLD-file (IEC 61850 flexible logic extension)	✓

PDF-files	ng.Grace
Substation single line diagram	✓
Distribution of IEDs by instrument transformers diagram	✓
Circuit diagram of PACS	N/A*
FBD diagram	✓
Process bus and station bus LAN architecture	✓
Cabinets and IEDs/MUs/LAN switches specification	✓
Cabinet layout	N/A*
Cable to terminal connection diagram	N/A*
Table of LAN cables	✓
Table of signals for SCADA	✓
Table of electrical cables	N/A*

ng.Grace design process consists of the following steps:

1. a user input of a substation specification (*.ssd or manual input)
2. automatic adjustment of the project knowledge base of the substation schema
3. automatic determination of the required PACS functions (LDs) using the reasoner
4. automatic determination of instrument transformers and operated equipment (circuit breakers, disconnectors etc.) for each PACS function
5. automatic linking of LDs and LNs (protection and control algorithms)
6. automatic selection of the IEDs and MUs
7. automatic creation of an optimal process bus and station bus architecture using a genetic algorithm
8. automatic assessment of capital and operating costs
9. automatic reliability assessment based on simulation using multi-agent systems

ng.Grace performs a full cycle from the main substation scheme to the PACS architecture and algorithms.

*** is done by the conventional CAD systems**

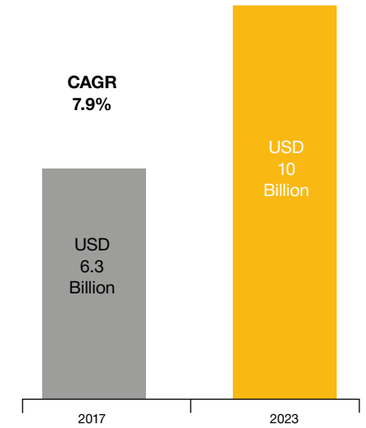
04 Marketing analysis
Forecast 2015 - 2023

04

With the arrival of the Fourth Industrial Revolution, Industry 4.0, and with the growing demand for electricity the global digital substation market has been growing phenomenally in recent years. This trend is associated with an increase in demand for the replacement of the traditional substation infrastructure, growing demand for renewable energy projects, and the rising need for secure electrical networks across several industrial, commercial, utility and residential applications.

Attractive Opportunities in the Digital Substation Market

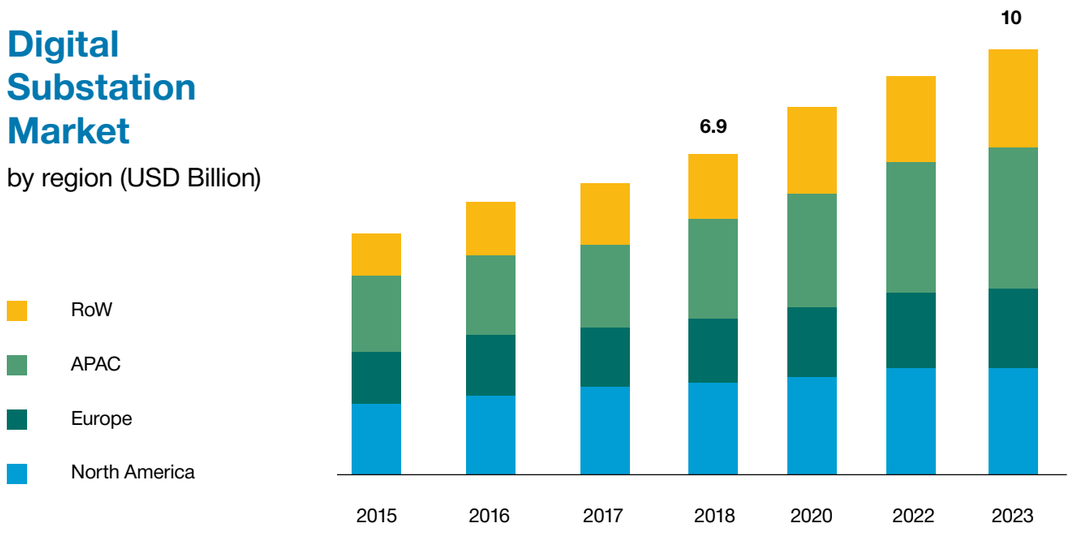
- The overall digital substation market was valued at USD 6.3 billion in 2017 and is expected to grow at a CAGR of 7.9% between 2017 and 2023.
- The market growth is attributed to the increased adoption of digital substations in the utility industry for renewable applications, such as wind and solar projects.
- Product launches and contracts by large corporations, such as ABB (Switzerland) and General Electric (US), provide growth opportunities for the digital substation market.
- Increased installation of digital substations in the Middle East and India are expexted to present unexplored opportunities in the market.



Sourse:
Investor Presentation, Secondary Literature, Expert Interviews and "MarketsandMarkets" Analysis

Digital Substation Market

by region (USD Billion)



Sourse:
Investor Presentation, Secondary Literature, Expert Interviews and "MarketsandMarkets" Analysis

About 3 to 7% of the market is formed by design services. ng.Grace reduces costs of Digital PACS design two times.

05 Project Team
Core Team and Leaders

05

Team

Our team consists of the **MPEI NTI Centre** and **SmartEPS LLC**. We have experience in designing substations 35 kV - 750 kV based on different vendors: ABB, Siemens, and others.

The amount of designed substations is **more than 100**.

Our team has developed and launched three CAD systems for designers of digital substations.

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06 Conclusion
ng.Grace

06

The presented product ng.Grace implements the concepts of generative design and AI based CAD systems. The software corresponds to IEC 61850 standard. Manual labor is limited to substation schema input. The solution provides economical vs reliability goals and optimal PACS architecture.

Optimal design is carried out by modern artificial intelligence techniques and optimization algorithms.

The design rules KB can be adjusted to local regulations and preferred design practices.
The product is suitable for designing PACS not only for new substations but also for modernization existing PACS.

R&D is completed. First software release December 2020.

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