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ELECTRICAL ENGINEERING INSTITUTE NIKOLA TESLA

ELECTRICAL ENGINEERING INSTITUTE
NIKOLA TESLA

THE MOST IMPORTANT RECENT PROJECTS OF THE INSTITUTE NIKOLA TESLA

2022

THE MOST IMPORTANT RECENT PROJECTS OF THE INSTITUTE NIKOLA TESLA

Electrical Engineering Institute Nikola Tesla
Koste Glavinića 8a, 11000 Belgrade, Serbia

STUDY OF LONG-TERM OVERVIEW OF EMS AD TRANSMISSION NETWORK ON THE TIME HORIZON UNTIL 2035

The goal of the project Expected project results

The transmission network of EMS is relatively old and it is necessary to consider, in addition to the needs for the development of the transmission network, also the need for reconstruction of existing transmission network facilities or if it is necessary to decommission them, to look for new solutions.

The result of this project is a Study that will:

1. Enable EMS to optimally consider the needs for construction, adaptation, extension and reconstruction of transmission network facilities;
2. Provide variant solutions in a form in accordance with the Law on Planning and Construction and acceptable for the preparation of the Feasibility Study;
3. Give solutions to the problem of radially powered transformer stations;
4. Show "ID card" of all existing facilities.

Methodology of the Study

The preparation of the Study can generally be divided into six groups of activities:

1. Collection and systematization of data and substrates;
2. Analysis of the current state of the network and identification of critical points in the network and the possibility of solving burning problems;
3. Forecast of energy consumption and peak power and their distribution by points in the system;
4. Consideration of the target solutions in the network and variants which will be discussed in detail;
5. Detailed elaboration of variant solutions and formation of proposals of optimal variants by work packages;
6. Development of a database with ID cards of network elements suitable for further application in the planning and development of individual projects.

Analysis, forecast and planning of the network

Analysis of the existing situation:

- Forming a transmission system model for maximum winter and summer load and minimum load;
- Identification of usual power plant engagements for different regimes;
- Analysis of normal network operation in defined modes and formation of proposed measures for possible improvement;
- Analysis of "n-1 " criteria of security and analysis of "n-2" criteria according to the defined list of outages.

Demand forecast:

- Forming projections of total electricity and power consumption at the level of Serbia based on the previous period using different statistical models;
- Systematization and grouping of settlements according to supply substations 110/X kV and 35/X kV;
- Analysis of spatial plans and assessment of their impact on economic development growth rates by groups of settlements and supply TS 110/X kV and 35/X kV;
- Forecast of total electricity consumption in different categories of consumption and consumption by groups of settlements and supply TS 110/X kV and 35/X kV.

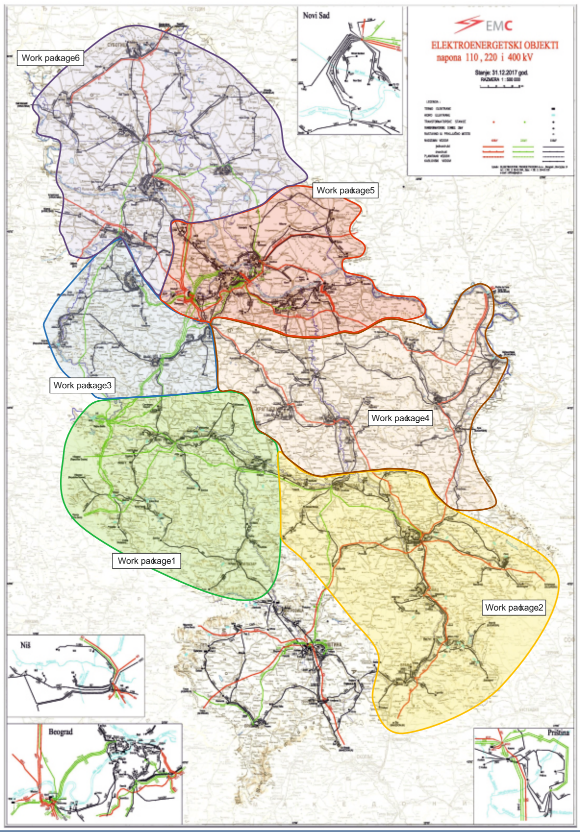
Formation of target solutions and elaboration of network development year by year:

- Analysis of the required capacities of the 400 kV network for the needs of transmission of the forecasted power and substitution of the 220 kV network planned for shutdown, taking into account the planned power transits;
- Formation of variant solutions of new 400 kV lines that include proposals for potential routes;
- Identification of necessary additional capacities in the transformation of 400/110 kV or 400/220 kV, optimal locations for possible new TS and their optimal connection to 400 kV voltage and reconfiguration at a lower voltage level;
- Analysis of the availability of 110 kV lines in the perspective period, the need for a new 110/X kV substation and the development of variant 110 kV network solutions.

Serbian transmission network

The transmission network is divided into 6 work packages:

1. Work package 1 - consumption area of southwestern Serbia;
2. Work package 2 - consumption area of southeastern Serbia;
3. Work package 3 - consumption area of western Serbia;
4. Work package 4 - consumption area of central and eastern Serbia;
5. Work package 5 - consumption area of Belgrade, part of Srem, Danube region behind Belgrade and southern Banat;
6. Work package 6 - consumption area of Srem, northern Banat and Bačka.



References

1. Methodology and criteria for transmission network planning, Electrical Engineering Institute Nikola Tesla, Belgrade, 2000.IECC-2012
2. Study of perspective development of the transmission network of Serbia until 2020 (2025), Electrical Engineering Institute Nikola Tesla, Belgrade, 2007
3. Rules of the Transmission System Operator, Belgrade, December 2017
4. Realization of the electricity balance of electricity distribution companies in Serbia, Public company Electric Power Industry of Serbia, Belgrade
5. Report on electricity flows on the transmission system of the Republic of Serbia
6. Program for the realization of the Energy Development Strategy of the Republic of Serbia until 2025 with projections until 2030 for the period from 2017 to 2023, Belgrade, 2017

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LUSAIL CITY (DOHA – QATAR) POWER SYSTEM STUDY

Purpose of the Study
Main Issues that initiated the Study

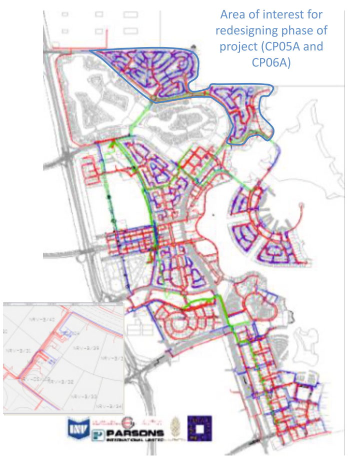
With its numerous hotels, sports arenas and leisure centres, Lusail City, a new part of Doha, will be one of the most important and significant cities hosting the main stadium, teams, fans and audiences during the 2022 World Cup.

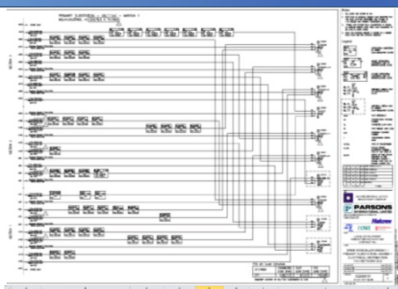
1. Problems with developers' requests for Building Permits due to not adequately allocated power per plots;
2. Expectations of load increase due to reasons from 1.
3. Concerns about cables' and transformers' capacity due to expected load increase.

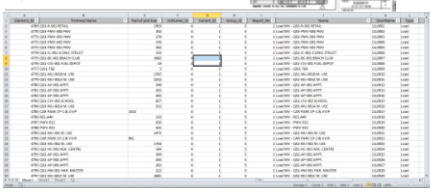
Purpose of the Study
Project Tasks

1. To improve Design criteria keeping in mind latest international and regional standards and available local and regional electricity consumption data;
2. To provide new power allocation based on revised Design Criteria;
3. To create network model in appropriate software (PSS Sincal is selected due to its capability and also it is Kahramaa (Qatar General Electricity & Water Corporation) software tool for distribution network analysis and planning) and new loads which provides: analysis of network operation under modified circumstances, its redesign and future what-if analysis for any future changed circumstances;
4. To redesign network corresponding to CP05A and CP06A plots where the biggest power allocation is expected due to Design Criteria revision.

Current Network Design and Model Preparation







NETWORK DESIGN BASE:

1. Kahramaa approved loading capacity of cables and transformers - restrictive, with regarding cable capacity;
2. "n-1" principle regarding outages of primary substation transformers and 11 kV cables;
3. Related to maximum demand load calculated according to Existing Design Criteria, which is approved by Kahramaa.

MODEL PREPARATION:

1. Based on network design drawings, Kahramaa approved IFC drawings, and As Built drawings;
2. All available network elements data are incorporated in the model starting from 415 V cables up to 220/66 kV substations;
3. If available, network from mega-developers' areas also included into model:
4. Model prepared in PSS Sincal in order to provide easy "what-if" analysis regarding future changes in spatial load and network design;
5. Competent staff are trained to use model.

Identified Constraints

- GFA (Gross Floor area) is the most relevant parameter for load assessment.
- Load density is based on land use types, typologies and subcategories - and for building permit approval it should be calculated according to Kahramaa's regulations, because designers are responsible to Kahramaa for the design of electrical installation which provide safe electricity usage.
- In order to provide sustainable development, for some categories of energy consumption it is necessary to define energy consumption limits which provide rational energy usage - based on standards.
- Definition of diversity factors should be based on actual Kahramaa's measurements starting from smart meters and including SCADA systems.

List of Used International, Regional and Domestic Standards, Regulations and Recommenadions

1. BS-EN 15603 - Energy Performance of Buildings - Annex C
2. IECC-2012
3. ASHRAE 90.1
4. Dubai Electricity and Water Authority Rules
5. British Council for Offices (BCO-2009) Guide
6. BSRIA Rules of Thumb
7. Qatar Construction Specifications 2010
8. Global Sustainability Assessments System by GORD
9. Regulation's for the Installation of Electrical Wiring, Electrical Equipment and Air Condition Equipment (Kahramaa)
10. Electricity Planning Regulation for Supply 2012 (Kahramaa)

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TURBINE GOVERNING SYSTEMS

Control & Automation Department

PRODUCTS

Electrical Engineering Institute Nikola Tesla a. d. Belgrade has many years of experience in the production, delivery and commissioning of turbine governing systems for hydraulic turbines. Our products are of modern construction with a control unit based on a digital platform. For small units the control unit is based on a microcontroller, while for larger units it is based on a PLC platform. On other hand, on small and micro units, it can be more cost effective to implement software solution for turbine governing algorithm in the PLC of the unit control system.

The control unit is modular in both hardware and software terms, allowing easy upgrades, extensions of functionality and adaption of the governor system to each project individually.

The products are intended for the governing of all types of turbines: Francis, Pelton, Kaplan and Banki.

Together with our partners, the Institute implements turnkey projects. Technical input data from the turbine manufacturer are sufficient for us to design and to produce both, hydraulic and electrical part of the turbine governing system.

We provide the Customer with complete support during the installation process, pre-acceptance tests, commissioning, acceptance tests and trial operation of the turbine governing system. We organize training courses for the Customer's staff and provide service support and support in spare parts within and outside the warranty period.

MAIN FUNCTIONS

Turbine governor does the control of:

Guide vane opening (Francis & Kaplan);
Runner blade opening (Kaplan);
Spear and Deflector position (Pelton);
Unit speed;
Generator active power;
Water head;
Turbine discharge/flow.

Participates in:

Unit start-up;
Acceleration & idling of the unit;
Synchronization of the unit;
Unit operation with isolated load;
Unit operation in the grid;
Unit unloading and stopping.

Executes unit protection functions.

Communicates with unit control system.
Communicates with power plant SCADA.

REFERENCES

1. HPP Raška, 2 x Pg=4000kVA (Francis) - 2014.
2. SHPP Crkvine, Pg=750kVA + Pg=450kVA (Francis) - 2015.
3. SHPP Rečica, Nova Varoš, Srbija, Pg=1075kVA + Pg=795kVA (Francis) - 2015.
4. SHPP Lisine, Pg=925kVA (Pelton) + Pg=740kVA + Pg=380kVA (Francis) - 2016.
5. SHPP Dubočica, Pg=875kVA (Pelton) - 2017.
6. SHPP Igrišt, Pg=600kVA (Pelton) - 2017.
7. SHPP Stenjevac, Pg=765kVA + Pg=395kVA (Francis) - 2018.
8. SHPP Brusnik, Pg=1580kVA (Kaplan) - 2020.
9. SHPP Krepoljin, Pg=855kVA + Pg=425kVA + Pg=425kVA (Francis) - 2020.

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SERVICES

Electrical Engineering Institute Nikola Tesla a. d. has decades of experience in all types of turbine governing system testing. Tests and determination of properties and parameters of turbine control systems, based on tests results, are performed in accordance with international technical standards IEC60308 and IEC61362. Within the Laboratory for testing and calibration of the Institute, we also have a Specialized laboratory for testing of the turbine governing systems, which is accredited by the national Accreditation Body of Serbia (ATS). Tests are performed on new or revitalized turbine governing systems and on existing turbine governing systems that are in operation.

ATC
01-134
АКРЕДИТОВАНА
ЛАБОРАТОРИЈА
ЗА ИСПИТИВАЊЕ
SRPS ISO/IEC 17025:2006

TESTS ON NEW OR REVITALIZED TURBINE GOVERNING SYSTEMS

Our engineers are competent at taking part in the preparation and execution of Factory acceptance tests (FAT) of turbine governing system equipment. We have experience in preparing of programs, schedules and testing procedures for the Buyer, which all are subject to a contract with the Supplier. Our engineers contribute, with their participation and advices during execution of FAT, to a more successful and high-quality Buyer perception of the features and functionality of the system that is the subject of test.

During the preparation and execution of Site Acceptance Test (SAT), our engineers participate in the activities in a very similar way as during the factory acceptance tests. With their previous experience in the field of acceptance tests, our engineers contribute to a better managing of the conditions for performing certain tests, which is useful for the Buyer and for the Supplier. Our engineers are most often useful to the Supplier in the technical and organizational sense, while our engineers are always useful to the Buyer both in the technical and in the advisory sense.

Guarantee tests are performed in order to determine the characteristics and parameters of the turbine governing system and compare them with those specified in the Special technical conditions, which are integral part of the Contract on production, delivery and commissioning between the Buyer and the Supplier. Our engineers can prepare the program, schedule and test procedures. After mutual coordination with the Purchaser, with the participation of the representatives of the Buyer and the Supplier, our engineers test the turbine governing system, after which they form a report with the test results. Our Specialized laboratory has the complete test equipment required to perform complex tests as guarantee tests are.

TESTS ON EXISTING TURBINE GOVERNING SYSTEMS

On the turbine control systems that are in operation, we perform tests resulting with:

- Determination of the current state of the system;
- Determination of the causes of improper operation of the system and system repair;
- Determination of the quality of the unit participation in Load-frequency control (LFC).

Determining the existing condition of the turbine control system in operation is achieved by performing a set of tests which is agreed with the Client. The scope of the tests may be equal or similar to the scope of the tests performed during the acceptance or guarantee tests. Also, we perform this type of tests for the purpose of assessing the remaining system resources and planning system replacement and / or revitalization of the unit .

We have significant experience in the periodic inspection and testing of turbine governing systems in operation, with the aim of determination of the causes of improper operation or system downtime. Also, after determination of one or more reasons of improper system operation, with the consent of the Purchaser, we proceed to the replacement of the malfunctioned part and / or readjustment of the governing system.

By introduction a large number of alternative power sources and by liberalization of the market, the importance of providing LFC services for production units has gained in importance. Our engineers have significant experience on more than 50 hydro and thermal units in testing and readjustment of existing turbine governing systems, whose ultimate goal is to achieve a response of the unit that is in accordance with the requirements of the grid code.

REFERENCES (*last 10 years)

1. HPP „Đerdap 2“ A1, A2, A4, A5, A9 i A10, Pg=27,5MVA, Site acceptance test (SAT), 2009.-2010.
2. HPP „Đerdap 2“ A10, Pg=27,5MVA, Guarantee test, 2009.
3. Testing the quality of unit work in Load-frequency control, study, 48 hydro & thermo units were tested in power range from 12 to 700MVA, 2011.-2016.
4. HPP „Piva“ A1, A2 i A3, Pg=120MVA, Test for determination of existing condition, 2016.
5. SP HPP „Bajina Bašta“ R1, Pg=315MVA, Site acceptance test (SAT), 2016.
6. HPP „Đerdap 1“ A4, Guarantee test, Pg=211MVA, 2017.
7. HPP „Bočac“ A1, A2, Test for determination of existing condition, Pg=58MVA, 2019.
8. HPP „Pirot“ A1 i A2, Test for determination of existing condition, Pg=44,5MVA, 2020.

Electrical Engineering Institute Nikola Tesla

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SITE ACCEPTANCE AND GUARANTEE TEST OF THE GENERATOR COMMISSIONING OF THE UNIT

CONTROL AND AUTOMATION DEPARTMENT

SITE ACCEPTANCE TEST

Electrical Engineering Institute Nikola Tesla a. d. Belgrade (Institute) has decades of experience in conducting acceptance tests of synchronous generators (generators) in the space of the generator Purcheser, i.e. in the power plant where the generator is installed. (Site Acceptance Test - SAT).

After complete or partial revitalization of the synchronous generator or delivery of a new synchronous generator, acceptance tests are performed in the power plant (SAT). The scope of acceptance tests is defined by the Contract between the Purchaser, usually the owner of the production capacity and the Supplier of goods and services. The Institute has such professional and technical capacities that it can meet the specific requirements of the Purchaser and conduct generator tests using the test procedures defined in the international standards from the group IEC 60034.

In the basic division, entrance examinations consist of:

- Tests of generator electrical insulation system
- Testing of basic properties and characteristics of generators
- Vibration tests
- Heating generator tests, heat runs

Based on the results of acceptance tests, a decision is made to put the generator into operation.

COMMISSIONING

Acceptance tests of the generator in the power plant (SAT) take place in parallel with the commissioning of the generator. The commissioning of the generator, in the broader sense commissioning of the unit, is performed in several phases. The transition from one to the next phase of commissioning of the unit is conditioned by the results of acceptance tests of parts that are integral part of the unit.

The commissioning of the generator and the production unit as a whole, implies coordination between different parts of the main and auxiliary equipment of the unit and the system of protection of the unit. It also implies coordination with the execution of all acceptance tests on parts of the main and auxiliary equipment of the unit. Commissioning of the unit means that all main and auxiliary systems of the generator and turbine have been tested to the level required for each phase of the commissioning process and that they have proper functionality. Systems like:

- Hydro-mechanical protection system of the unit,
- Electrical protection systems of the generator,
- Unit emergency stop system,
- Turbine governing system,
- Excitation system,
- Unit control system,
- Unit cooling system,
- Hydraulic pressure unit,
- Compressed air system,
- Fire protection systems, etc.

must be tested and functionally ready and mutually harmonized and coordinated. Our experts have extensive experience in performing such a complex and responsible task as putting a new unit into operation after complete or partial revitalization. The Institute can provide you with the services of acceptance tests of generators and commissioning of units, that are practically inseparable from each other and form the basis for trial run of the unit.

GENERATOR EFFICIENCY

One of the most important features of the generator as a basic part of the production unit is it efficiency. The efficiency of a generator is a measure of its usefulness during electromechanical energy conversion. When determining the generator efficiency by applying the procedure of measuring of separate losses, the following are measured and determined:

- Friction and ventilation losses
- Losses in the magnetic core, iron losses
- Coil losses, Joule losses in copper
- Additional losses due to stray flux
- Losses in the excitation system
- Losses in bearings

These losses are measured directly from electrical quantities or by applying a calorimetric method when measuring the power of losses which are taken away by coolant.

The Institute provides the service of determination of the generator efficiency by applying test procedures described in the standards IEC 60034-1, 60034-2-1, 60034-2-2, 60034-4, taking into account the procedure and test conditions agreed between the Purchaser and the Supplier. When conducting tests, the Institute uses its own test equipment and technical capacities.

So far, the Institute's experts have successfully determined the efficiency of generators from several world-renowned manufacturers as a part of the tests which were conducted during preparation for the revitalization of the unit or as part of a tests which were conducted with the aim of determining fulfilment of contractually guaranteed properties and parameters of the generator.

GUARANTEE / PERFORMANCE TEST

After the expiration of the trial operation of the unit it is usual to test the properties and parameters of the generator and compare them in qualitative and quantitative terms with the properties and parameters specified in special technical conditions which are an integral part of the contract between Purchaser and Supplier.

The scope of guarantee test is significantly wider than the scope of acceptance tests. The scope of test as well as the conditions for execution of test are defined by the contract between the Purchaser and the Supplier. The applied test equipment must be calibrated and with appropriate metrological characteristics and appropriate accuracy.

All applied test procedures must be in accordance with the international technical standards from the family of standards IEC60034. Both the Purchaser and the Supplier must agree with all procedures and with the schedule of the guarantee test. Also, during the test, the presence and testimony of the representatives of both contracting parties is usually obligatory.

Guarantee test of generators due to its specificity, testing properties and parameters of generators that have a long-term impact on the quality and durability of generator operation, and in this regard direct or indirect financial consequences for the Purchaser and / or Supplier, is very complex test that require exceptional test equipment and engineers who possess significant experience, skill, and unquestionable impartiality.

The Institute has engineers who meet the above criteria. Our experts can provide you with a complete service of guarantee test quality assurance. Our experts can provide you with consulting services during formation of special technical conditions which are part of tender documents that are binding on the Supplier. During formation of special technical conditions, all properties and parameters of the generator are defined, allowed deviations of measured and determined properties and parameters from the guaranteed ones are defined, and very importantly, the scope of guarantee test and conditions under which test will be performed are defined. Finally, our experts will conduct guarantee test, provide you with all the necessary information before, during and after the test and will prepare a detailed report with the test results, which is an ID card of the generator and a reference document for future operation of the generator.

REFERENCES (*last 10 years)

HPP „Đerdap 1“ A6 211MVA – Site Acceptance Test of the generator and Commissioning of the unit after revitalization, 2011. god.

HPP „Đerdap 1“ A4 211MVA – Site Acceptance Test of the generator and Commissioning of the unit after revitalization, 2013. god. Guarantee test of the generator, 2014. god.

HPP „Đerdap 1“ A5 211MVA – Site Acceptance Test of the generator and Commissioning of the unit after revitalization, 2015. god.

HPP „Zvornik“ A1 37,5MVA – Guarantee test of the generator, 2016. god.

TPP „Nikola Tesla B“ B2 727,5MVA– Guarantee test of the generator, 2016. god.

HPP „Đerdap 1“ A1 211MVA - Site Acceptance Test of the generator and Commissioning of the unit after revitalization, 2017. god.

HPP „Zvornik“ A2 37,5MVA – Guarantee test of the generator, 2017. god.

HPP „Đerdap 2“ A7 27,6MVA – Testing before revitalization, fingerprint test of the generator 2018. god.

HPP „Zvornik“ A3 37,5MVA – Guarantee test of the generator, 2018. god.

HPP „Đerdap 1“ A1 211MVA - Site Acceptance Test of the generator and Commissioning of the unit after revitalization, 2019. god.

HPP „Zvornik“ A4 37,5MVA – Guarantee test of the generator, 2019. god.

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Power supply and control systems for electrostatic precipitators

Automation and Control Department

BASIC CHARACTERISTICS

Application

Power supply and control systems for the electrostatic precipitators (**ESP**) were designed to supply power and control applied voltage on the electrodes and to control functionality of the concomitant devices of the electrostatic precipitators

Primary features

- ESP voltage and current regulation or
- regulation of number of sparks

Additional functions

- Opacity monitoring in function of power saving
- Reduction of voltage at rapping
- Reduction of voltage at starting/stoping of boiler
- Back corona detection
- ESP short circuit detection

Current asymmetry detection

Operating modes of the automatic regulator

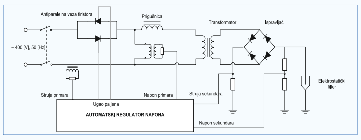
- test, manual, continuous, intermittent

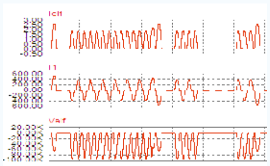
Single-phase digital control units for electrostatic precipitators

This is a typical solution for voltage control using antiparallel thyristors.

Basic parameters:
Input voltage: 400V, 690V
Input current: < 500A

Block diagram of the control system



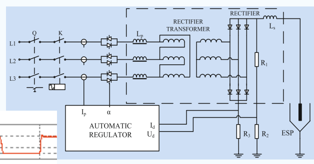


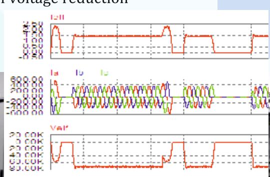
Three-phase digital control units for electrostatic precipitators

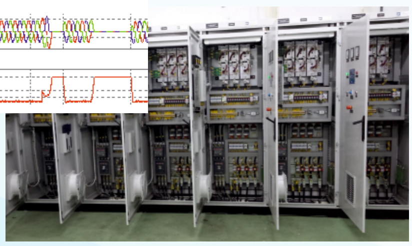
Benefits

- early corona detection and prevention of arcing
- power saving in intermittent mode
- efficient cleaning
- modular application
- increasing of form factor
- efficient rapping because of voltage reduction

Block diagram of the control system







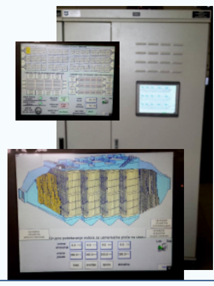
Single-phase and three-phase transformer/rectifier units for electrostatic precipitators

Basic parameters

- DC voltage peak: 95kVp, 105kVp, 115kVp, 125kVp, 150kVp
- DC average current: <2500mA

Control and monitoring system of ESP

Device designed for control and monitoring of entire ESP system.
Basis of the system is a PLC with corresponding I/O modules.
480 digital inputs, 160 digital outputs, 52 analog inputs, 2 analog outputs and 2 communication channels are realized using I/O modules.
Data communications protocol used is Modbus (RTU).
Remote control, monitoring and data archiving are realised using SCADA system.



Power supply system for rappers and heaters on ESP

This device supplies:

- Rapping motors of discharge and collector electrodes,
- Motors of dust rotary valves,
- Insulator heaters and hopper heaters.

Main references for electrostatic precipitators

1. Single-phase power supply control unit for ESP in TPP Kostolac, unit A1, 4 pcs, 1997.
2. Single-phase power supply control unit for ESP in TPP Kostolac, unit A2, 1 pcs, 2004.
3. Single-phase power supply control unit for ESP in TPP Kostolac, unit B1, 1 pcs, 2005.
4. Single-phase power supply control unit for ESP in TPP Nikola Tesla, unit A1, 4 pcs, 2005.
5. Single-phase power supply control unit for ESP in TPP Kolubara, unit A5, 4 pcs, 2006.
6. Single-phase power supply control unit for ESP in TPP Nikola Tesla, unit A1, 8 pcs, 2006.
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8. Single-phase power supply control unit for ESP in TPP Kolubara, unit A5, 8 pcs, 2009.
9. Single-phase power supply control unit for ESP in TPP Nikola Tesla, unit A6, 16 pcs, 2010.
10. Medium-frequency power supply for reconstruction of existing single-phase power supply, prototype, 1 pcs, 2013-2014.
11. Three-phase power supply control unit for ESP in TPP Nikola Tesla, unit A3, 16 pcs, 2014.
12. Three-phase transformer/rectifier unit for ESP in TPP Nikola Tesla, unit A3, 18 pcs, 2014.
13. Three-phase transformer/rectifier unit for ESP in TPP Nikola Tesla, unit A3, 2 pcs, 2015.
14. Single-phase power supply control unit for ESP in TPP Kolubara, unit A3, 4 pcs, 2015.
15. Single-phase power supply control unit for ESP in TPP Kolubara, unit A1, 2 pcs, 2015.
16. Contol and monitoring system for ESP in TPP Ugljevik, 1 pcs, 2017.
17. Three-phase power supply control unit for ESP in TPP Nikola Tesla, unit A4, 2 pcs, 2018.
18. Single-phase power supply control unit for ESP in TPP Gacko, 4 pcs, 2020.
19. Power supply and control unit for heaters in ESP in TPP Kostolac, unit B1, 2 pcs, 2020.
20. INCREASING THE EFFICIENCY OF THE ELECTROSTATIC PRECIPITATOR ON UNIT B2 IN TE „KOSTOLAC B“ BY IMPROVING POWER SUPPLY UNITS, Research study, 2019.

Total:

- 1 ph control unit = 64 pcs
- 3 ph control unit = 18 pcs
- 3 ph T/R unit = 20 pcs
- Control system = 2 pcs

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Analysis of influence of electromagnetic field on living and working environment and mitigation techniques

Maja Grbić, Aleksandar Pavlović, Dejan Hrvić, Momčilo Petrović

Testing of electromagnetic field in living and working environment

DC field

- The testings are performed in the vicinity of HVDC power lines, MRI equipment, permanent magnets and other sources of DC magnetic field, as well as inside industrial and power facilities etc. [1].

- Testings performed in the vicinity of power lines are based on both measurements and calculations.

LF field

- The testings are performed in the vicinity of overhead and cable power lines, substations and other sources of low-frequency electromagnetic field, as well as inside power plants, substations, switchyards, industrial facilities etc. [2].
- The testings are based on both measurements and calculations of electric and magnetic fields.

VF field

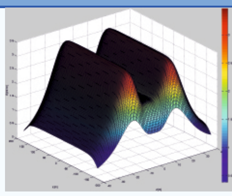
- The testings are carried out in the vicinity of base stations, radio and TV transmitters, radars and other sources of high-frequency electromagnetic field [3].

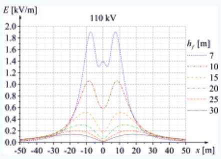
Projects and studies

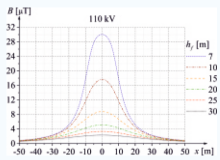
Living environment

Expert evaluation studies

- Expert evaluation studies are carried out when it is necessary to evaluate the influence of new/reconstructed electromagnetic field source (overhead or cable power line, substation etc.) on the environment [4]. The study contains the results of measurements of existing level of electromagnetic field in the environment as well as the results of field calculations for the situation after the construction/reconstruction of the source.







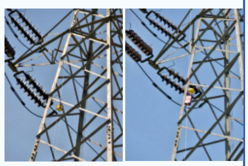
Projects

- Research projects are conducted in order to determine the influence of power lines, substations and switchyards on the environment.
- The project "Analysis of results of non-ionizing radiation testing in the vicinity of 110 kV, 220 kV and 400 kV overhead power lines" [5] analyzes the levels of electric and magnetic fields obtained by measurements and calculations in over 400 increased sensitivity areas located in the vicinity of the aforementioned power lines.

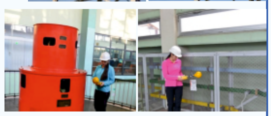
Working environment

Projects

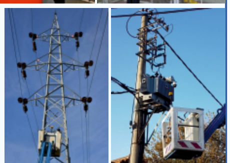
- Research projects are carried out in order to assess the exposure of workers to electric and magnetic fields.
- The "Study on influence of electromagnetic field on workers during work in the vicinity of high voltage on 110-400 kV double-circuit overhead power lines" [6] analyzes the exposure of workers to electric and magnetic fields during work on double-circuit overhead power lines in the case when work is done on de-energized line while the other line on the same towers is in operation.



- In the project "Analysis of exposure of workers to non-ionizing radiation in Limske power plants and proposition of protection measures" [7] the assessment of exposure of workers inside Potpeć, Bistrica, Kokin Brod and Uvac power plants is conducted.



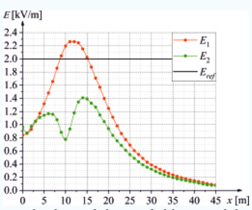
- In the project "Exposure of workers to electromagnetic fields during works in electric power facilities" [8] a detailed analysis of exposure of workers during work in the vicinity of 0.4 kV, 10 kV, 20 kV and 35 kV overhead and cable lines, as well as inside 10/0.4 kV, 20/0.4 kV, 35/x kV and 110/x kV substations is conducted.



Measures for protection from electromagnetic field in living and working environments

Overhead power lines

220 kV OHL

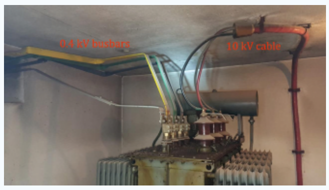


Measured values of electric field strength before and after the implementation of measures

- In the case when the testing shows that the reference levels of electric and/or magnetic field are exceeded it is necessary to apply certain measures in order to reduce the field levels [9].
- In order to select the most adequate technique for reducing the values of electric and/or magnetic field and predict the field values that will occur after the application of the technique, studies are carried out for each particular case [10].
- Mitigation techniques are most often applied to transmission overhead power lines and 10(20)/0.4 kV substations located in buildings.

Substations

10/0.4 kV substation



Maximum values of magnetic flux density in the apartment located above the substation before and after implementation of measures:

B = 124,9 μT (before)

B = 4,6 μT (after)

References

[1] Testing of DC magnetic field inside Kotor converter station and along the route of 500 kV cable line, 2020, commissioned by: Terna Crna Gora d.o.o.

[2] Testings of low-frequency electric and magnetic fields inside and in the vicinity of substations and switchyards and in the vicinity of power lines, commissioned by: Serbian Transmission System and Market Operator "Elektromreža Srbije", Electric Power Industry of Serbia etc.

[3] Systematic testings of high-frequency electromagnetic fields in the environment in the vicinity of base stations and radio and TV transmitters, 2018, commissioned by: Ministry of environmental protection.

[4] Expert evaluation studies regarding influence of new/reconstructed electromagnetic field sources (overhead and cable lines, substations etc.) on the environment, commissioned by: Serbian Transmission System and Market Operator "Elektromreža Srbije", Electric Power Industry of Serbia etc.

[5] "Analysis of results of non-ionizing radiation testing in the vicinity of 110 kV, 220 kV and 400 kV overhead power lines", 2018-2019, commissioned by: Serbian Transmission System and Market Operator "Elektromreža Srbije".

[6] "Study on influence of electromagnetic field on workers during work in the vicinity of high voltage on 110-400 kV double-circuit overhead power lines", 2016-2018, commissioned by: Serbian Transmission System and Market Operator "Elektromreža Srbije".

[7] "Analysis of exposure of workers to non-ionizing radiation in Limske power plants and proposition of protection measures", 2018-2019, commissioned by: Electric Power Industry of Serbia, Limske power plants.

[8] "Exposure of workers to electromagnetic fields during works in electric power facilities", 2019-2020, commissioned by: Electric Power Industry of Serbia.

[9] "Techniques for reducing electric and magnetic fields", 2013-2014, commissioned by: Serbian Transmission System and Market Operator "Elektromreža Srbije".

[10] Studies regarding measures for reducing the levels of electric field strength and magnetic flux density in the vicinity of overhead power lines and substations, commissioned by: Serbian Transmission System and Market Operator "Elektromreža Srbije", ODS „EPS Distribucija", d.o.o. etc.

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Numerical calculation of electromagnetic transients- Insulation coordination -

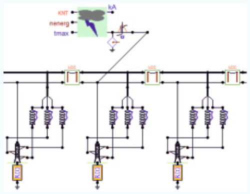
Electrical Engineering Institute Nikola Tesla a. d. Belgrade (Institute) has decades of experience in developing research methods, calculations and analysis of phenomena on medium and high voltage facilities and networks that are focused on transient processes of voltages and currents in the power grid, primarily to solve problems in the field of overvoltages and insulation coordination. Within the coordination of insulation, the problems of choosing the dielectric strengths of insulation for high voltage apparatus, ie their corresponding withstand voltages with regard to stresses caused by voltages and overvoltages that occur in networks during operation and with regard to the required reliability and the effect of applied protective measures. The objectives of numerical simulations and research are that the selection of insulation of equipment, facilities and lines, as well as the choice of protective measures and means to limit overvoltages, under operating conditions and expected voltages and overvoltages, is done so that continuity of work is achieved within economically and technically acceptable proportions.

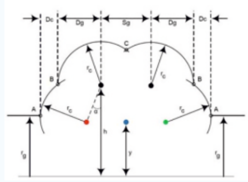
LIGHTNING OVERVOLTAGES

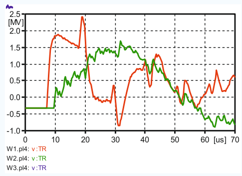
Lightning discharges are one of the most common causes of overvoltages in the power system, which have a great impact on the quality of delivered power, which is reflected in the increased number of interruptions, violation of network reliability parameters and failures of expensive equipment such as power transformers.

The application of software tools for the analysis of electromagnetic transients (EMTP) allows:

- **Formation of an adequate simulation model,** which takes into account frequency-dependent and nonlinear properties of components, suitable for calculation of overvoltages caused by lightning discharge in transmission line tower, shielding wire or phase conductor or lightning protection of facilities, substations, PV power plant or exposed parts of wind turbines.
- **Statistical analysis** (Monte-Carlo simulations) aimed at taking into account the stochastic nature of the occurrence and calculating the risk of destructive insulation discharges, mean number of years without equipment failure (MTBF), annual number of failures of overhead lines…
- **Deterministic analysis** whose goal is to calculate the maximum values of voltage or maximum values of energy of surge arresters, for given parameters of lightning discharge.





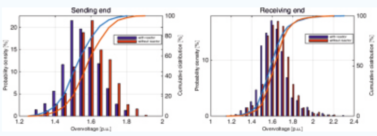


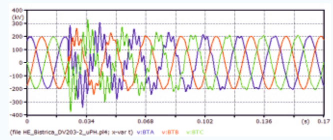
SWITCHING OVERVOLTAGES

Power electric equipment is exposed to overvoltages caused by switching manipulations on a daily basis. Depending on the power grid configurations, switching overvoltages can reach high levels and seriously endanger the insulation of the equipment, if there is no adequate overvoltage protection. Surges occur both when the circuit breaker is closing and when the circuit breaker is opening either in usual operations or during the faults.

Switching On

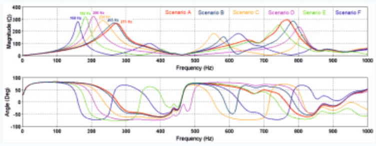
- Statistical analysis (Monte Carlo simulations) provides the consideration of the random moment of the contacts closing and the time dispersion between the poles of the switch. As a result of the analysis, the distribution of overvoltage is obtained (probability of overvoltage occurrence).
- Commonly simulated are switching-on of the:
  - Powel lines (overhead, cable mixed);
  - Transformers (taking into account the residual flux in the magnetic circuit);
  - Reactors and capacitor banks…
- Possible types of switching-on operations:
  - "Classic" switching-on;
  - Auto-Reclosing (AR) on OHL;
  - *Out-of-phase* switching;
  - Sympathetic switching of transformers;
  - *Back-to-back* switching of capacitor banks;
  - Point-of-Wave switching;





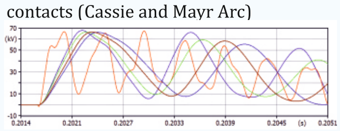
Frequency scan

- Frequency scan simulations provides identification of resonant points and potentially dangerous configurations.



TRV (RRRV) analysis

- When the switch is opened, a transient recovery voltage (TRV) is established between its contacts).
- The switch has successfully cleared the fault if the TRV is less than the dielectric strength in the inter-contact gap.
- Numerical tools are allowing the simulations of the:
  - Terminal, long line and short line failures;
  - Different types of faults (LG, LLLG, LLL);
  - Out-of-phase switching;
  - Presence of the electric arc between contacts (Cassie and Mayr Arc)

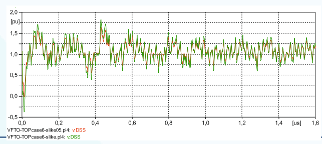


VERY FAST OVERVOLTAGES

VFFT in GIS

Switching manipulations with earthing switch, disconnector and circuit breaker in gas-insulated plants can cause very fast front overvoltages that can cause problems in primary and secondary circuits.

With detailed GIS data, credible models can be considered.

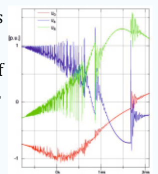


Vacuum Circuit Breaker

Switching operations of vacuum switches, due to the occurrence of multiple arc reignition and restrikes, can be the source of very fast overvoltages, endangering the inter-winding insulation of the equipment in the facility.

Numerical simulations make possible to:

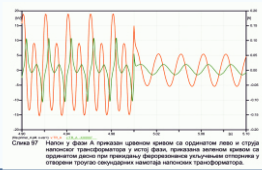
- Check the efficiency of overvoltage protection,
- Select the optimal RC snubber values.

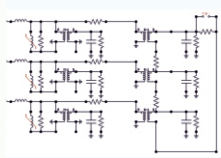


TEMPORARY OVERVOLTAGES

Temporary overvoltages are undamped or weakly attenuated surges of oscillatory shape and relatively long duration, from several periods of industrial frequency to several hours. They usually do not endanger the insulation of the equipment, but can cause problems in the operation of certain devices, such as surge arresters, voltage transformers, etc.

- Oscillatory transients can occur during :
  - Resonance
  - Ferrroresonance
  - SLG fault
  - Load rejection
  - Phase missing





MOST SIGNIFICANT REFERENCES(last 10 years)

[1] Study of switching overvoltages in GCCIA interconnection network, , 2020.

[2] Study of very fast overvoltages caused by the operation of a vacuum circuit breaker, within the OMAN LNG debottlenecking project, 2020.

[3] Lightning and switching surge study, within ADNOC Onshore's BAB Integrated Facilities, beneficiary: *China Petroleum Engineering & Construction Corporation, 2019*.

[4] CB Transient Recovery Voltage Analysis Study, SEWA Layyah PS, 2019.

[5] Electric arc hazard assessment study, done for Adient Setings d.o.o. 2019.

[6] Insulation Coordination and Arc Protection Studies, done for Lim HPPs, 2019.

[7] Studies of Lightning, Switching, Very Fast Surges in GIS and Frequency Scanning, within the *Saudi Aramco Marjan Development Program*, 2018.

[8] Insulation Coordination Study, conducted for *Abu Dhabi Gas Industries (GASCO) - Taweelah Gas Compressor Station*, 2017.

[9] Study of Transient voltage and current regimes in the transmission system of Serbia 110kV, 220kV and 400kV, user EMS, 2014.

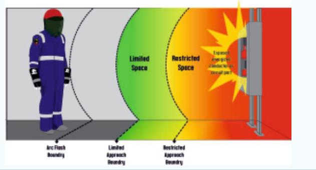
[10] Study of Overvoltage protection of generator transformers in EPS power plants, 2012.

ELECTRIC ARC HAZARD

The possible occurrence of an electric arc is endangering everyone who works on or near energized electrical equipment, so it is very important to be aware of the hazard of electric arc and to wear appropriate PPE.

The arc risk assessment is performed in order to:

- Recommend appropriate work procedures;
- Determine boundary distances;
- Defines the necessary protective equipment.



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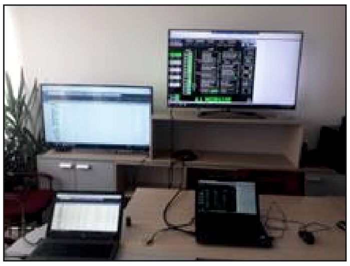
REMOTE MONITORING AND DIAGNOSTICS CENTER - RMDC

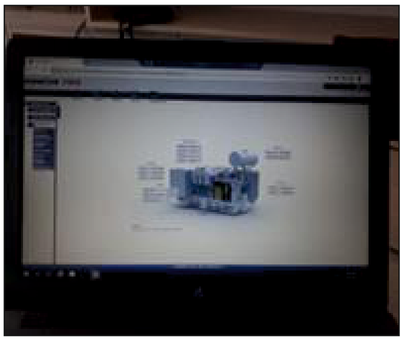
Reasons to start the project

- Asset management improvement in the power sector,
- power sector digitization,
- centralization of the monitoring system of capital high voltage power equipment (HVPE),
- centralization of the system for acquisition and analyzing data on capital equipment,
- updating the database for generators, power transformers and other HVPE.



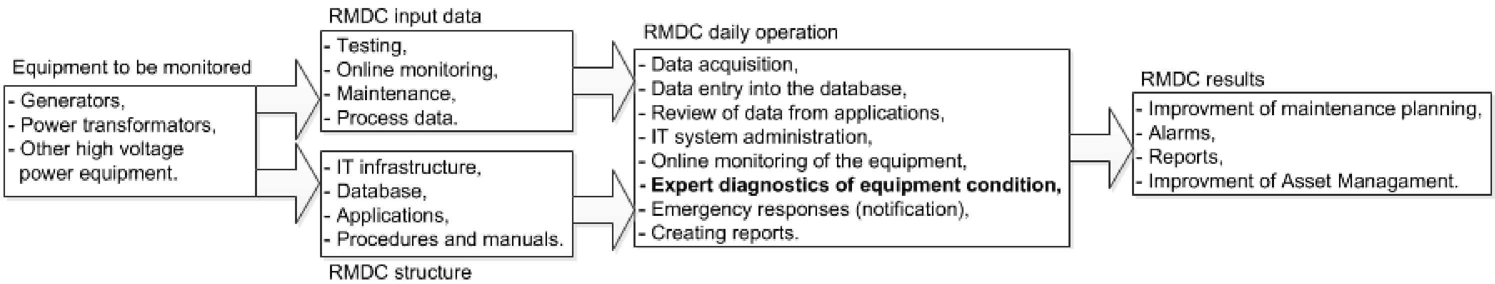
Diagnostic center job description

- data acquisition and analysis on a daily basis ,
- expert diagnostics of equipment condition,
- reporting to the clients of significant changes in real time.



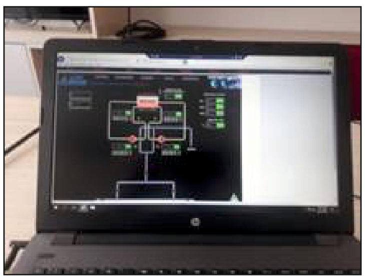
Establishment of the Diagnostic center

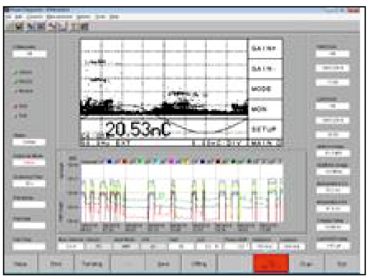
- development of a unique conceptual solution matching all users specifics (Conceptual design of the system),
- development of the database and supporting applications,
- acquisition of process data, data from monitoring systems, testing data and maintenance data,
- system security.



Diagnostic center results

- centralization of diagnostics of capital and other HVPE,
- Annual report on the status of HVPE as a significant input for optimizing total maintenance costs,
- introduction and implementation of Condition based maintenance (CBM) policy,
- improved risk management,
- improvement of Asset management.





Conclusion

- improvement of Asset management,
- improving maintenance planning, increasing equipment availability, risk management and cost optimization,
- centralized expert access to all HVPE data from a remote location during emergencies - remote monitoring (e.g. COVID-19 virus pandemic),
- tendency to the Industrial Internet of Things concept.

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Decontamination of PCB contaminated equipment using INT patented technology for simultaneous dechlorination, desulphurization and regeneration of mineral insulating oils

PCB in electrical equipment

PCB decontamoination process aligned with **Nationalplan for the implementation of Stockholms Convention to eliminate** PCB in Republic of Serbia.

INT patent (RS 53510): PCB removal down to 1 ppm, oil regeneration and removal of corrosive sulphur, in accordance to IEC standards.

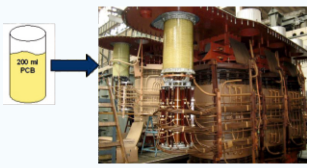
Stockholm convention

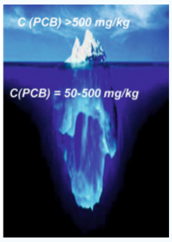
PCB limit - 50 mg/kg uin electrical equipment in service
New electrical equipment and oil – PCB free

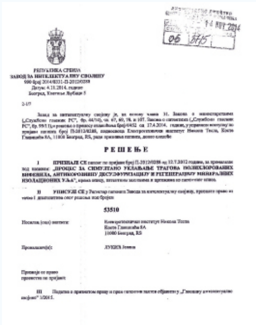
Sources of PCB contamination

Treatments and oil change (common tanks, machines for oil treatment)

Transformer repair (workshops, factories, tanks)

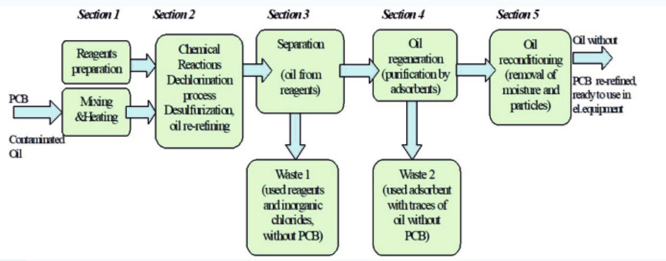






Mobile unit for PCB decontamination and process flow diagram

capacity: 1500-2000 kg/day



Sections
Section 1: heating&reagent preparation
Section 2: Chemical conversion
Section 3: Separation
Section 4: Regeneration with adsorbents
Section 5: Final treatment (oil reconditioning) – drying, filtration, degassing

Reactor and separator

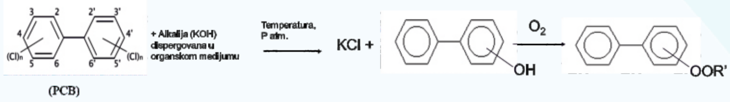
Adsorbent and columns

Oil reconditioning machine

Removal of PCB, corrosive sulphur and oil ageing products
Improval of oil properties after treatment

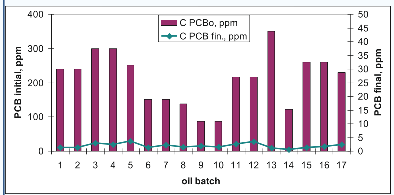
Implementation period: 2015-2022
More than 2600 tons of equipment decontaminated
Location: Republic of Serbia, Power sector, Industry

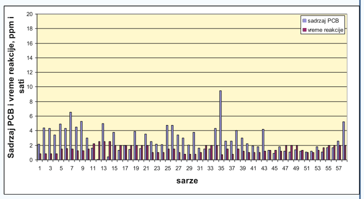
Chemical reactions



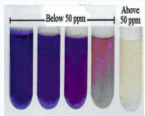
PCB conversion

PCB conversion and reaction time was otpmized through continous on-site measurements

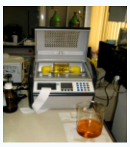




PCB on-site measrurements

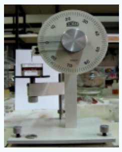


PCB test kit – Chlrine content in the oil LDX Analyzer



Breakdown voltage

Dielectric dissipation factor

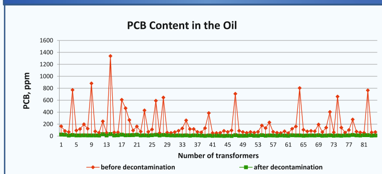


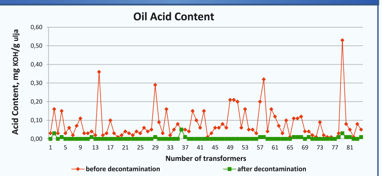
Interfacial tension

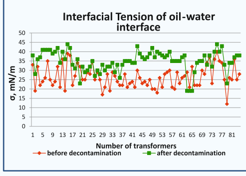
PCB measurements in the laboratory

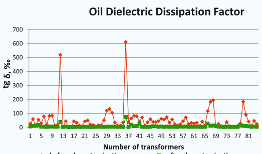
GC ECD - acc. to IEC 61619

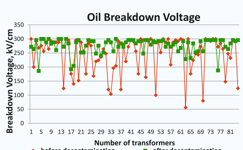
PCB decontamination results











CONCLUSION

- INT process is efficient in the removal of PCB, corrosive sulphur and oil ageing products from mineral insulating oils and can be used for efficient decontamination of PCB contaminated equipment, aged oils oil regeneration and desulphurizaction, i.e. Removal of corrosive sulphur for the risk mitigation of power transformers
- After treatment power transformers have extended life
- INT process can be used for PCB contaminated waste oil and equipment treatment for final disposal

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MEASURING SYSTEMS FOR INSTRUMENT TRANSFORMERS ACCURACY TESTING

DRAGANA NAUMOVIC-VUKOVIC[1)], SLOBODAN SKUNDRIC, ALEKSANDAR ZIGIC, DEJAN MISOVIC, DUSAN BOLIC, SRDJAN MILOSAVLJEVIC, NIKOLA MILADINOVIC, VLADIMIR POLUZANSKI, NIKOLA CAKIC

Developing and production of measuring systems for accuracy testing of instrument transformers in the Electrical Engineering institute Nikola Tesla (EEINT) have been last for more than 60 years. The measuring systems for accuracy testing and calibration of current and voltage transformers are based on methods and devices that are developed in the EEINT. These systems are used for calibration of high accuracy standard transformers, as well as for ratio and phase displacement measurement of instrument transformers installed in the power and distribution utilities. The concept of these measuring systems fulfils the requirements of international standards: IEC, IEEE, ANSI and CAN/CSA. In the EEINT new generation of various devices and systems for the wide variety of instrument transformers testing application have been developed and built from 2002. to 2020.

SPECIFICATION

Standard Current Transformers	Standard Voltage Transformers
Rated primary currents: from 1 A to 10 000 kA	Rated primary voltages: from 10 kV to 110 kV
Rated secondary currents: 5 A, 1 A and 0.1 A	Rated secondary voltages: 100V/3, 100V/√3, 110V/√3, 110V, 120V, 200/√3, 200V
Best accuracy: ± 0.001% (10 ppm) for ratio error and ± 0.05min (~15 ppm) for phase displacement	Best accuracy: ± 0.05% for ratio error and ± 0.2 min for phase displacement

Measuring devices for instrument transformers accuracy testing

Measuring range: from1% to 200% of rated current, and form 20% to 200% of rated voltage	
Best accuracy for ratio error measurement: ± 0.002% (20 ppm)	Best accuracy for phase displacement measurement: ± 0.1 min (~30 ppm)

SYSTEM COMPONENTS

STANDARD CURRENT TRANSFORMERS

STANDARD CURRENT BURDENS

STANDARD VOLTAGE TRANSFORMERS

ELECTRONIC MEASURING DEVICES FOR RATIO ERROR AND PHASE DISPLACEMENT MEASUREMENT OF INSTRUMENT TRANSFORMERS

MEASURING METHODS

- D. Naumovic-Vukovic, S. Skundric, D. Kovacevic, S. Milosavljevic, *"On Site Accuracy Testing of Instrument Transforers"*, Proc. of 3rd International Symposium on High Voltage and High Power Tests, Measurement and Certification of Electrical Power Equipment, Baile Olanesti, Romania, 2007.
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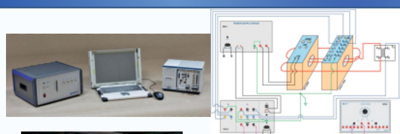
- D. Numović-Vukovic, S. Skundric, P. Nikolic, D. Belonic, *„The Application of Standard Current Transformer up to 10kA for Accuracy Testing of Bushing Generator Current Transformers"*, Proc of 34. CIGRE Serbia,R A3 05, ISBN 978-86-82317-85-2, http://www.cigresrbija.org

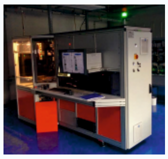
SOFTWARE

USER FRIENDLY SOFTWARE THAT ENABLE ACQUISITION, MATHEMATICAL PROCESSING AND VARIOUS PRESENTATION FORMS OF MEASURING RESULT

APPLICATION



HIGH ACCURACY MEASURING SYSTEMS FOR NATIONAL METROLOGY INSTITUTES LABORATORIES [11, 16]



ROBOTIZED SYSTEM FOR ROUTINE TEST OF 6 CURRENT TRANSFORMERS IN THE INTERMEDIATE AND FINAL CONTROL – THE MEASURING SYSTEMS FOR ACCURACY TESTING OF CURRENT TRANSFORMERS, MADE BY ELECTRICAL ENGINNERING INSTITUTE NIKOLA TESLA, ARE PART OF IT [10]

THREE CHANNEL'S MEASURING DEVICE FOR RATIO ERROR AND PHASE DISPLACEMENT MEASUREMENT, SIMULTANEOUSLY TESTS 3 CURRENT TRANSFORMERS IN THE FINAL FACTORY CONTROL [12]

LABORATORY FOR ON SITE ACCURACY TESTING OF INSTRUMENT TRANSFORMERS (HIGHEST VOLTAGE FOR EQUIPMENT OF 110 KV) IN THE POWER UTILITY AND DISTRIBUTED SUBSTATIONS [1]

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