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INTEGRATED MANAGEMENT SYSTEM FOR TESTING, MONITORING AND DIAGNOSTIC OF POWER TRANSFORMER INSULATION

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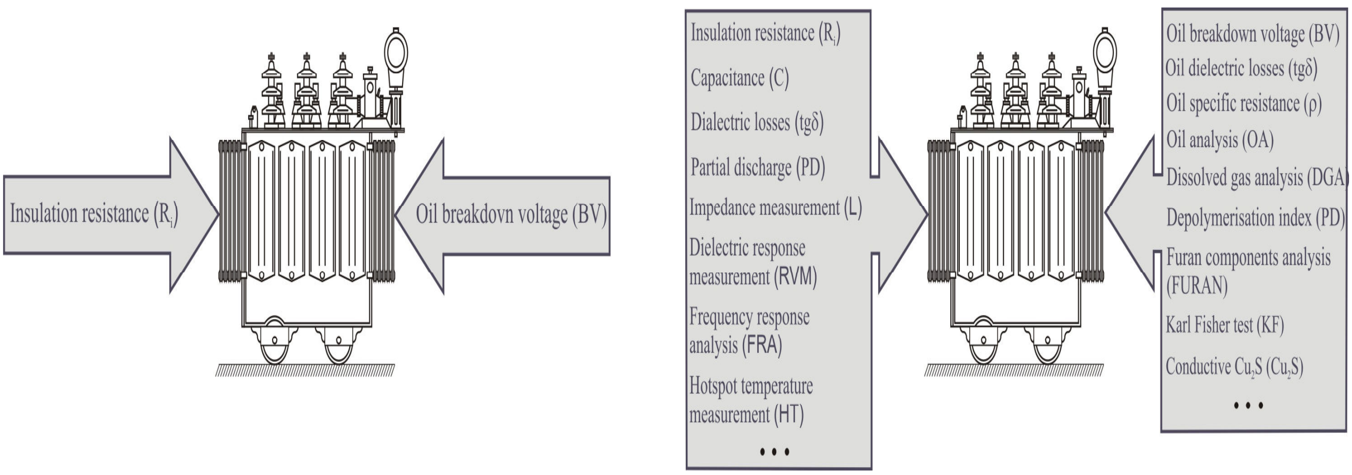
Abstract − Power transformers are the most complex, important and critical components of the transition and distribution power systems. Insulation system is the key component of life extension, better availability and higher reliability of a transformer. In order to achieve both decreasing operational cost and reliable service condition-based maintenance is needed. Monitoring and diagnostic methods and techniques, for insulation condition assessment of power transformers, are described. Data base and knowledge rules diagnostic management system, in internet oriented environment, is outlined.

Keywords: power transformer, insulation, diagnostic.

1. INTRODUCTION

Significance of testing, monitoring and diagnostic the condition of transformers insulating system is growing every year, together with the growth of production, transition, distribution and consumption of electricity [1], [2]. Historically, since Nikola Tesla's concept of alternating current has definitely won the concept of direct current, the importance of transformers for power supply system has developed commensurably. It has been a century since Nikola Tesla introduced his patents of generators, transformers and motors of alternating currents in the USA in 1888. Transformers and systems for their testing, monitoring and diagnostic have developed together with the power supply systems. Fig. 1 shows the development of methods for transformers testing and monitoring, from the first measurements which included defining the insulating resistance and oil dielectric breakdown voltage (Fig. 1a) up to modern examinations which include dozens of measuring methods and procedures (Fig. 1b).

Monitoring and diagnostic of power transformer insulation system condition is primarily directed to transformer life extension and reducing of operational costs and risks. Most diagnostic system, including laboratory measurements, off-line testing, periodical and continuous on-line monitoring, serve to detect changes in the insulation system in form of early warning system. Condition and defects that could be detected by appropriate measurement methods and techniques are: hotspots, degradation of the insulation, excess moisture in paper and oil insulation, partial discharges, localized faults, mechanical defects (partial rupture), chemical or thermal aging. Mainly, none of these defects can be detected by a singular measurement or monitoring procedure. Therefore we need to apply a multitude of different methods. Furthermore we need quite frequently a sequence of samples and measurements to identify the velocity of change, the rate of progressiveness etc.



a) b)

Fig.1. Development of measurement methods and techniques for diagnostics of transformer insulation.

2. MEASUREMENT METHODS AND TECHNIQUES

The insulation system of a transformer consists mostly of oil and paper which are subject to aging. Aging is defined as the irreversible changes of the properties of an electrical insulation system (EIS) due to action of one or more factors of influence [3]. Aging stresses may cause either intrinsic or extrinsic aging. In most EIS, extrinsic aging predominates because, in practice, they include imperfections and contaminants. The type and level of contamination and/or the level of imperfection in an EIS will significantly affect service performance.

The aging factors produce electrical, thermal, mechanical, or environmental aging mechanisms that eventually lead to failure. During aging applied stresses, which initially may not affect the EIS, can appear aging factors that, as a result, modify the rate of the degradation. When aging is dominated by one aging factor, this is referred to as single-factor aging. Multifactor aging occurs when more then one aging factor substantially affects the performance of the EIS. Aging factors may act synergistically, that is, there may be direct interactions between the stresses. Interactions may be positive or negative. The aging of a practical EIS can be complex and failure is usually caused by a combination of aging mechanisms, even though there may be only one dominant aging factor [4].

From the large number of measurement and monitoring methods and techniques we select these that are currently in use in Nikola Tesla Institute [5], [6], [7]: 1- insulation resistance/polarization index (*Ri/PI),* 2- power loss factor (*PF*), 3- partial discharge (*PD)*, 4- frequency response analysis (FRA), 5- dielectric response measurement *(RVM)*, 6- high precision impedance measurement (*Lg),* 7- low voltage no-load measurement (*Io)*, 8- DGA-Analysis (DGA), 9- Oil-Analysis (OA), 10- degree of polymerization (DP), 11- furan components analysis (FURAN), 12- Karl Fischer test (KF), 13- conductive Cu_2S (Cu_2S), 14- hotspot temperature measurement (HT).

All these methods are explained in more detail (main defect detection; availability for continuous On-line monitoring): **1-Ri/PI** (accumulation of polarizable material or contamination; No), **2-PF** (dielectric losses in the insulation system; No - except of transformer bushings), **3-PD** (deterioration of the insulation system; Yes), **4-FRA** (loosening of winding or core clamping; No), **5-RVM** (aging and water content of the paper insulation; No), **6-Lg** (winding deformation or loosening of winding clamping; No), **7-Io** (core defects; No), **8-DGA** (appearance of hot spots, PD, arcing; Yes), **9-OA** (oil contamination, PD, sparking, overheating; No), **10-DP** (aging of the insulating paper; No), **11-FURAN** (aging of paper insulation; No), **12-KF** (water content; No), **13-Cu2S** (conductive area deposition; No), **14-HT** (overheating, life extension, load regulation; Yes).

3. DIAGNOSTIC PROCEDURES

The aging of a practical EIS, as mentioned before, can be complex and failure is usually caused by a combination of aging mechanisms, even though there may be only one dominant aging factor. Mainly, none of these defects can be detected by a singular measurement or monitoring procedure. Therefore we need to apply a multitude of different methods together with diagnostics procedures like fingerprinting and trend analysis to identify the velocity of change, the rate of progressiveness etc. Data and knowledge base are the key elements of modern IT use in planning, exploitation and managing the power supply system in technical and business sense. Using the benefits of modern IT-technology, the closed loop, up-to date and high effective testing-monitoring-diagnostic management system, presented in Fig. 2, is realized.

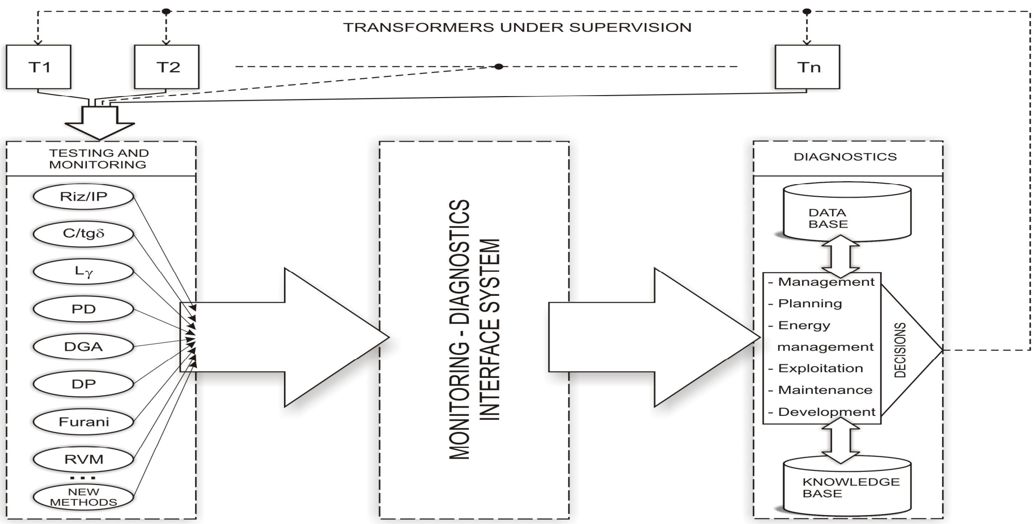


Fig. 2 Testing-monitoring-diagnostics management system.

In this project's phase testing-monitoring-diagnostic management system is primarily designed for prophylactic diagnostic of insulation conditions of transformers under supervision [5]. The Institute's clients have an opportunity to connect the data base to their information system. Thus, they can effectively assess the technical condition of their objects and machines for the purpose of production planning, investments, repairs and other activities.

The basis major objects are transformer's data. Each transformer is uniquely marked and has its own code in the data chart. Structural parts of the base are data charts with measuring results for each transformer and they include factory measuring, start-up measuring as well as periodic and any extra measuring. Depending on the enquiry and report concepts, reports are generated from the chart data, which may vary from one case to another.

Server base carrier and web server, as can be seen in Fig. 3, are the area in which the whole system works. MySQL server has been chosen for its ability of multiple clients' assessing through local network and internet. It also allows storing a lot of data, it is efficient and free of charge. Client's Access application enables data registration into the basis as well as change of existing data and report generation. This application is interface between laboratory users and the base (Fig. 3), which is accomplished by local computer network through ODBC (Open Data Base Connectivity). This application sends standard SQL enquiries to the base through MySQL-ODBC driver so that the communication between Access application and MySQL is successfully performed. Users of Access application are analysts who do the measuring and have the access level that enables them to register the measuring results to the base.

Depending on the access level, client may get the required data about an object, measuring or diagnosis through internet Web server. Chosen Web server is IIS (Internet Information Service), which is installed into Windows XP. Web browser (e.g. Internet Explorer) sends an enquiry about certain base data to the Web server address. The Web server processes the enquiry and sends back the HTML text with required measuring data, objects and diagnosis from the base (Fig. 3). Users who access the base through the internet have minimum level of authorization and access only to some data base information.

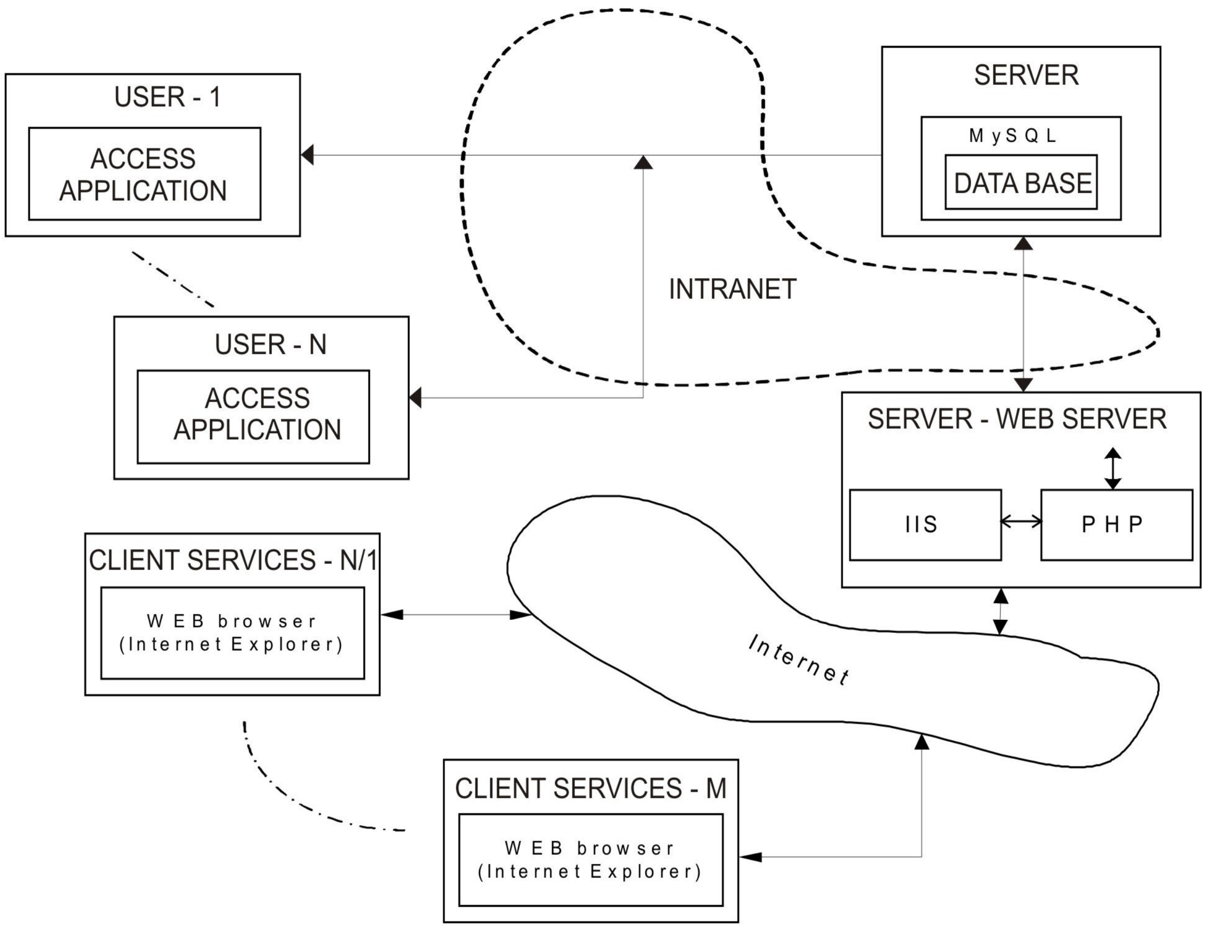


Fig. 3 Data-knowledge base and client services.

4. CONCLUSIONS

Competitive electric energy market drives utilities to adapt to a lot of changing technical and economical requirements, so transformers and systems for their testing, monitoring and diagnostic have developed together with the power supply systems, as shown on Fig. 1. To meet these challenges, the electrical power company in the world is now making the transition from the conservative corrective and time based strategies toward condition based maintenance (CBM). This need for CBM has encouraged the development of adaptable and cost-effective diagnostic.

Using the benefits of modern IT-technology the closed loop up-to date and high effective testing-monitoring-diagnostic management system, presented in Fig. 2, is realized. The distribution of information about the condition of transformer insulation can easily be done by means of standardized web browser technology, as shown in Fig. 3.

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