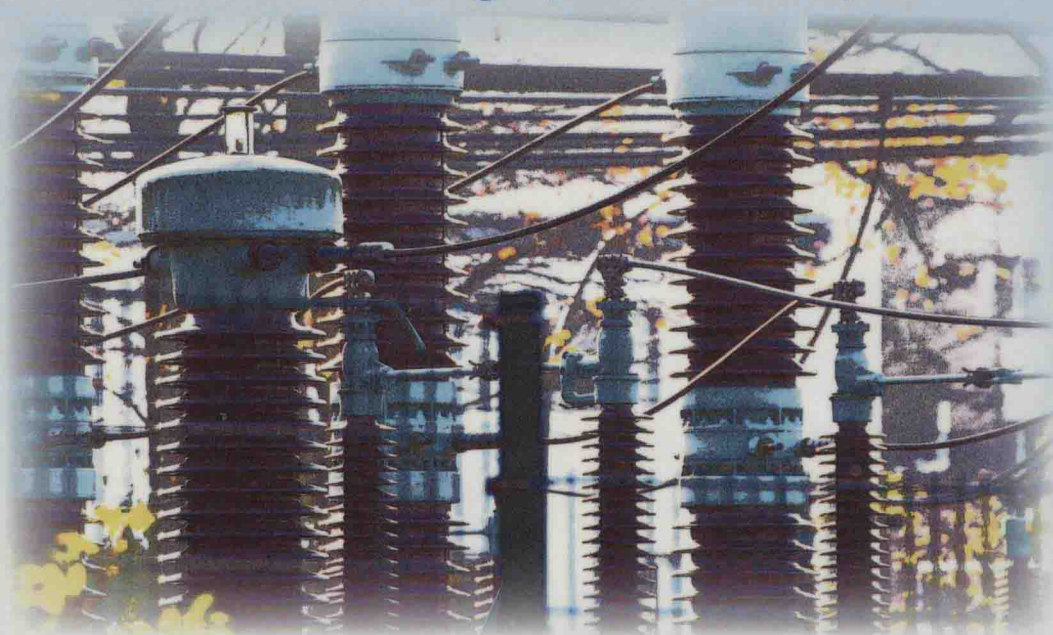


Electrical Engineering Developments

Diagnostics of Electrical Equipment Faults and Power Overhead Transmission Line Condition by Monitoring Systems (Smart Grid)

Short-Circuit Testing of Power Transformers



Alexander Yu. Khrennikov

NOVA

ELECTRICAL ENGINEERING DEVELOPMENTS

**DIAGNOSTICS OF ELECTRICAL
EQUIPMENT FAULTS AND POWER
OVERHEAD TRANSMISSION LINE
CONDITION BY MONITORING SYSTEMS
(SMART GRID)**

**SHORT-CIRCUIT TESTING
OF POWER TRANSFORMERS**

ALEXANDER YU. KHRENNIKOV, PhD



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Library of Congress Cataloging-in-Publication Data

ISBN: 978-1-63484-159-7

Published by Nova Science Publishers, Inc. † New York

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*This book is dedicated to the memory of my father.
He was an Electrical Engineer and took part in the building
of seven hydroelectric power stations.*

PREFACE

This book presents theoretical aspects of short-circuit performance of power transformers, transformer testing experiences, short current testing laboratories and high-voltage thyristor valves for electrodynamic testing. The questions of the original application experience of LVI-testing, Frequency Response Analysis (FRA) to check the condition of transformer windings, infra-red control, ultraviolet control, and Partial Discharges (PD) for the insulation monitoring of electrical equipment are examined in this book. The LVI method and short-circuit inductive reactance measurements are sensitive for detecting such faults as radial and axial winding deformations, a twisting of low-voltage or regulating winding, a loss of winding pressing, etc.

The most important elements of “intellectual networks” (Smart Grid) are the systems for monitoring the parameters of electrical equipment. Information-measuring systems (IMS), which are described in this paper, were proposed to be used together with rapid digital protection against short-circuit regimes in transformer windings. Short-circuit performance of power transformers, transformer testing experience, short current testing laboratories and high-voltage thyristor valve for electrodynamic test of power transformer are examined in this book. High-voltage electrical equipment with the SF₆ (sulfur hexafluoride) gas insulation, analysis of accident rate and service experience are represented. Estimation of the technical condition state of substation electrical equipment with the use of software and information tools allows for increasing the effectiveness of technical diagnostics and reliability of electrical equipment in service. The following diagnostic models for evaluating the technical condition state of electrical equipment are examined: model of the electrodynamic stability (mechanical state) of the transformer and reactor windings, multi-frequency diagnostic model of n-layer paper-oil insulation and model of the drift of temperatures of the bus arrangement of transformer.

Monitoring, control and analysis of breakdowns of overhead transmission lines (6 – 500 kV) in the Middle Volga region have been analyzed.

The book is based on the previous author's researches. The author has more than 200 scientific and technical publications. The main research interests concentrate on the field of transformer short-circuit testing, transformer winding fault diagnostic, Frequency Response Analysis, smart Grid and information-measuring systems.

This book is intended for the leaders and the specialists of technical service enterprises of electrical distribution networks and electrical stations, students of higher educational institutions, students enrolled in courses that will increase their qualification of power engineers, researchers and scientists in the field of electrical engineering.

Keywords: intellectual networks, smart grid, monitoring system, electrical equipment, information-measuring system, frequency response analysis, transformer winding fault diagnostic, low voltage impulse method, short-circuit inductive reactance measurement

ABBREVIATIONS

IMS	Information-measuring systems;
LVI	Low Voltage Impulse;
FRA	Frequency Response Analysis;
T	controlled power transformer;
TV	voltage transformer;
CT	current transformer;
B	high-voltage circuit breaker;
L	inductance;
ANR	accidental and non-regime;
RW	regulation winding;
DGA	Dissolved Gas Analysis;
ADC	analog-to-digital converters;
RMSD	root-mean-square deviation;
AFC	amplitude-frequency characteristic;
HV	high voltage (winding);
LV1	first low voltage (winding);
LV2	second low voltage (winding);
MV	medium voltage (winding);
HEPS	Heat Electric Power Station;
μsec	microsecond;
JSC "FGC UES"	Joint Stock Company "Federal Grid Company of Unified Energy System";
STL	Shortcurrent Testing Laboratory;
SREPS	State Regional Electric Power Station;
IR-control	infra-red control;
PD	partial discharges;
TG-	turbo-generator;
DC	direct current
DO	digital oscillograph;
GIS	gas insulated switchgear;
SAWP -	specialized automated working place;
TCS	technical condition state;
IEPS AAN	Intellectual electric power system with the active-adaptive network;

M&R	maintenance and repair;
EMF	electromotive force;
OA	operational amplifier;
EDS	expert- diagnostic system;
TREE	transformer and reactor electrical equipment;
ETCS	electrotechnical complexes and systems;
DM	diagnostic models;
DF	diagnostic feature;
ED	electrical device;
OFA	operational physical actions;
EMC	electromagnetic compatibility;
OTL	overhead transmission lines;
HVTV	high-voltage thyristor valve.

CONTENTS

Preface		xi
Abbreviations		xiii
Chapter 1	Smart Grid and Monitoring Systems for Detecting and Diagnostics Electrical Equipment Faults	1
	Abstract	1
	1.1. Introduction	1
	1.2. Smart Grid Information-Measuring System for Control of Inductance Value Transformer's Winding	2
	1.3. Algorithm of Smart Grid	3
	Information-Measuring System (IMS)	3
	1.4. Inductance Calculations of 167 MVA/ 500/220 kV Autotransformer	6
	1.5. Smart Grid Monitoring System for Short-Circuit Testing	7
	1.6. An Accuracy of Diagnostic Parameter of Smart Grid Monitoring System	9
	1.7. Determination of the Distribution Law of Measurement Random Error	13
	1.8. Calculation of Confidence of Interval of Measurement Random Error during Short-Circuit Transformer Testing	15
	1.9. Conclusion	17
	References	17
Chapter 2	Diagnostics and Transformer Testing Experience by LVI/FRA Methods	21
	Abstract	21
	2.1. Introduction	21
	2.2. LVI-Testing and FRA Method for 250 MVA/220 kV Transformer Diagnostic	22
	2.3. Algorithm of the Frequency Spectral Analysis	25
	2.4. Diagnostics of State Condition State of 125 MVA/220/110 kV Autotransformer After Failure	26
	2.5. LVI-Testing of 20 MVA/35 kV Transformer After Short-Circuit	27

2.6. Diagnostics by LVI-testing of 32 MVA/110 kV Transformer of JSC "Mogoteks," Belarus' Republic, After Damage	30
2.7. Diagnostics by LVI-Testing of TMY-43/90-90-36,6 ASEA Transformer of Oskol Electrometallurgical Plant	31
2.8. Diagnostics by LVI and FRA Method of 400 MVA/220 kV Transformer	33
2.9. Diagnostics by LVI-Testing of 63 MVA/220/ 110 kV Autotransformer	36
2.10. Study on the Dependency of LVI Oscillograms and Signal Spectra of Power Transformer Winding of One Type Manufacturing	37
2.11. Activities for The Prevention of Transformer Outages Due to Short-Circuits	39
2.12. Diagnostics by LVI and FRA Methods of 80 MVA/110 kV Transformer	41
2.13. Conclusion	44
Acknowledgment	44
References	44
Chapter 3	
Shortcurrent Testing Laboratories. Short-Circuit Performance of Power Transformers, Transformer Testing Experience	49
Abstract	49
3.1. Introduction	49
3.2. Shortcurrent Testing Laboratories	50
3.3. Short-Circuit Transformer Testing Is an Instrument for Reliability Improvement of Power Transformer Design	52
3.4. Short-Circuit Testing of 250 MVA/220 kV Transformer at Shortcurrent Testing Laboratory	54
3.5. New Shortcurrent Testing Laboratory of Russia	59
3.6. Conclusion	66
Acknowledgment	66
References	66
Chapter 4	
Infra-Red and Ultraviolet Control, Partial Discharges and Another Diagnostic Methods for Detection of Electrical Equipment's Faults, Defects	69
Abstract	69
4.1. Introduction	69
4.2. Infra-Red Control Results of Substation Electrical Equipment	70
4.3. Infra-Red Control of Turbine-Drive Generators of Heat Electric Power Stations (HEPS)	79
4.4. Ultraviolet Control Results	85
4.5. Partial Discharges (PD) for the Insulation Monitoring	89
4.6. Conclusion	96
Acknowledgment	97
References	97

Chapter 5	High-Voltage Electrical Equipment with the SF ₆ (Sulfur Hexafluoride) Gas Insulation: Analysis of Accident Rate and Service Experience	99
	Abstract	99
	5.1. Introduction	99
	5.2. Advantages and Deficiencies of High-Voltage Electrical Equipment with SF ₆ Insulation	100
	5.3. Gas-Insulated Switchgear of 500 kV for Electrical Substations	101
	5.4. Analysis of Accident Rate and Operating Experience	103
	5.5. Diagnostic Methods of Instrument Transformers with SF ₆ Insulation	105
	5.6. Conclusion	109
	References	110
Chapter 6	Estimation of the Technical Condition State of Substation Electrical Equipment with the Use of Software and Information Tools	111
	Abstract	111
	6.1. Introduction	112
	6.2. Metrological Estimation of Error in the Measurements with the Determination of the Technical State of the Electrical Equipment	113
	6.3. Results and Discussion	116
	6.4. Conclusion	119
	Acknowledgments	120
	References	121
Chapter 7	Diagnostic Models of Electrical Equipment's Technical Condition State	125
	Abstract	125
	7.1. Introduction	125
	7.2. Classification of Damage's Reasons and Forms. Fault Technical Diagnosis of the Transformer- Reactor Oil-Filled Equipment	126
	7.3. Diagnostic Models of Electrical Equipment's Technical Condition State	128
	7.4. Conclusion	138
	Acknowledgment	139
	References	139
Chapter 8	Monitoring, Control and Analysis of Breakdowns of Overhead Transmission Lines (6 – 500 kV) in the Middle Volga Region	143
	Abstract	143
	8.1. Introduction	143
	8.2. Failure Preventing Measures	
	8.3. Distribution and Seasonal Nature of Technological Breakdowns	
	8.4. Results. Analysis of Causes for the Technological Breakdowns	147
	8.5. Conclusion	152

	Acknowledgments	152
	References	152
Chapter 9	High-Voltage Thyristor Valve for Electrodynamic Test of Power Transformer	155
	Abstract	155
	9.1. Introduction	155
	9.2. High-Voltage Thyristor Valve (HVTV) for Electrodynamic Test of Power Transformers	156
	9.3. Block Scheme of HVTV, the Equivalent Circuit and Temporary Diagrams of HVTV Functioning	156
	9.4. Anode Voltage of HVTV	158
	9.5. Current Actions on Power Thyristors during Electrodynamic Tests	159
	9.6. Thermal Mode of Power Thyristors	162
	9.7. Conclusion	163
	Acknowledgments	164
	References	164
	Author's Contact Information	167
	Index	169

SMART GRID AND MONITORING SYSTEMS FOR DETECTING AND DIAGNOSTICS ELECTRICAL EQUIPMENT FAULTS

ABSTRACT

The most important elements of “intellectual networks” (Smart Grid) are the systems of monitoring the parameters of electrical equipment. Information-measuring systems (IMS), which are described in this paper, were proposed to be used together with rapid digital protection against short-circuit regimes in transformer windings. This paper presents the experience of LVI-testing application, some results of using Frequency Response Analysis (FRA) to check conditions of transformer windings and infra-red control results of the electrical equipment. The LVI method and short-circuit inductive reactance measurements are quite sensitive to be able to detect such faults as radial and axial winding deformations, twisting of low-voltage or regulating winding, losing of winding pressing, and others.

Keywords: intellectual networks, smart grid, monitoring system, electrical equipment, information-measuring system, frequency response analysis, transformer winding fault diagnostic, low voltage impulse method, short-circuit inductive reactance measurement

1.1. INTRODUCTION

Joint Stock Company “Federal Grid Company of Unified Energy System” is the operator of the United National Electrical Network of Russia. The total extent of electrical power transmission lines is 121.7 thousand km, the number of substations is 805, and the class of voltage is 220 - 750 kV. The five-year investment program of 2010 includes the construction of 73 new substations.

The switch to “clever power engineering” (Smart Grid) realized by Federal Grid Company, will make it possible not only substantially change today’s energy landscape, but also further develop the electrotechnical industry, mastering new technologies and creating

new electrical equipment. Novel methods are to be incorporated both in plants and in scientific design institutes, stimulating the professional growth of Russian scientists.

In Saint-Petersburg International Economic Forum that took place in June 2011, it was declared that one of the results of the conversions, conducted today by Federal Grid Company, must be the creation of the components of “intellectual networks” (Smart Grid), which will solve the existing tasks of the power electrical engineering providing for increase of effectiveness of its work and creating conditions for increasing the competitive ability of the economy of Russia on the basis of new innovation solutions and technologies.

**1.2. SMART GRID INFORMATION-MEASURING SYSTEM
FOR CONTROL OF INDUCTANCE VALUE
TRANSFORMER’S WINDING**

The most important elements of “intellectual networks” (Smart Grid) are the systems of monitoring of the parameters of the electrical equipment. The residual winding’s deformations of power transformers during short circuits appear practically instantly, not leaving time to analysis of the results of diagnostic measurements, demanding to switch off the transformer as fast as possible in order to avert or, at least, reduce the necessary consequent repair of the electrical equipment.

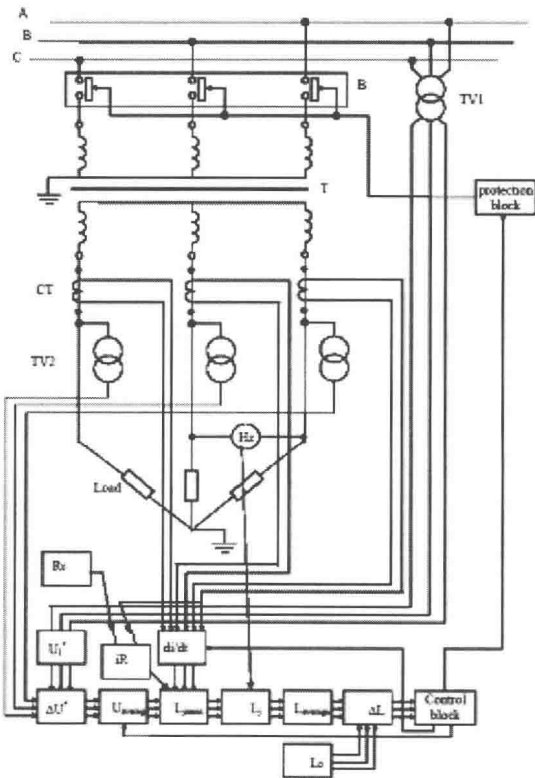


Figure 1. Information-measuring system for control of transformer’s windings state in service.