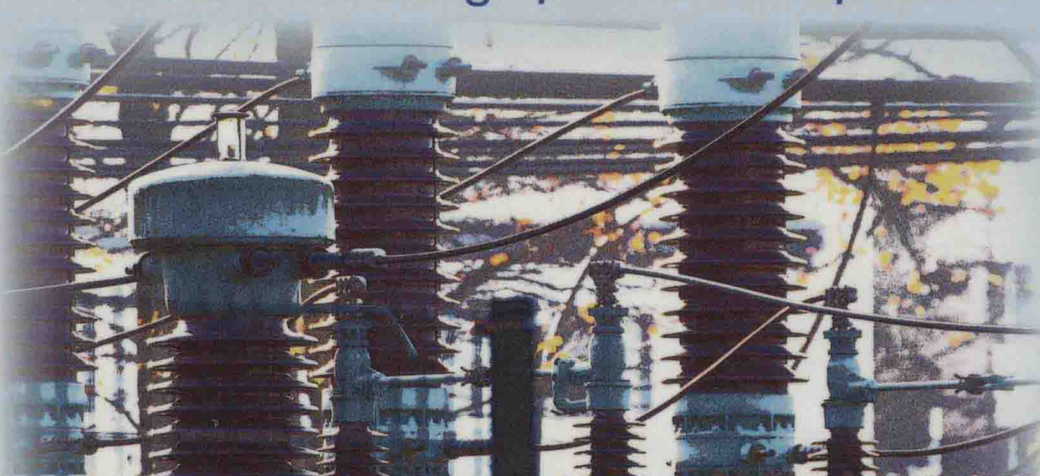
Electrical Engineering Developments

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

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

SHORT-CIRCUIT TESTING OF POWER TRANSFORMERS

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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 кV) 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, mart 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

Chapter 1

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.

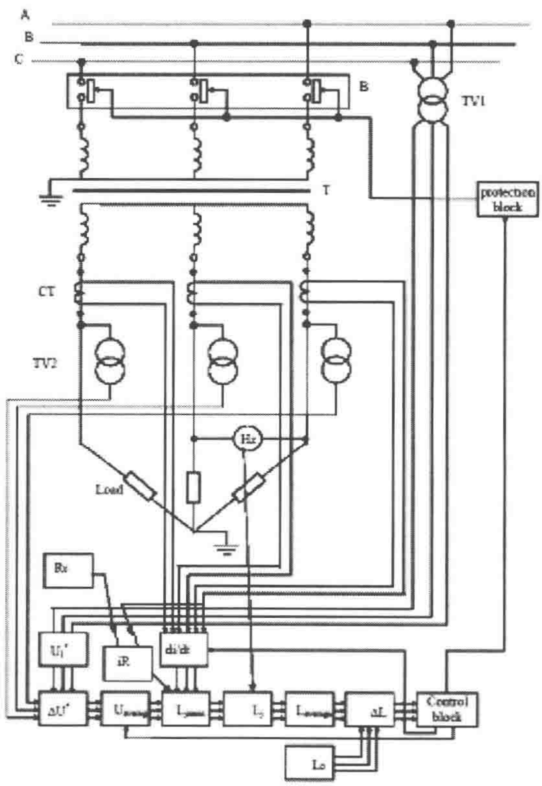

Figure 1. Information-measuring system for control of transformer’s windings state in service.