Outage data analysis of utility power transformers based on outage reports during 2002–2009

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ABSTRACT

Statistical analysis of failures and forced outages of power transformers constitute an important basis for asset management of these transformers. Results of the statistical analysis can be used, for example, to enhance utility reliability, influence transformer design and technology, and improve maintenance and condition monitoring practices. In addition, various methods for transformer reliability evaluation require that the expected values of component outage rates, outage durations, and repair durations be known. In this paper, outage data are obtained from the Egyptian Electricity Transmission Company (EETC). This work presents outage data analysis over eight years, from 2002 to 2009, for 1922 (average number) transformers in voltage populations ranging from 33 kV to 500 kV and MVA rating from 5 MVA to 500 MVA. Forced outages due to correct and false action of transformer's protection systems are carefully considered. Outage data analysis is conducted according to two basic phases. In the first phase, failure and repair analysis of transformers is performed while in the second phase impact of transformer outages on customers is assessed. Percentage average number of failures (%AANF) and annual average repair time (AART) per transformer are used to represent the failure and repair data of power transformers. Two indicators are used to represent the impact of transformer outages on customer interruptions. These indicators are the annual average interrupted MW (AAIMW) and annual average customer-interruption duration (AACID). A summary of the main outcomes of the work presented in this paper is provided in the conclusions' section; however, it is worthy to be mentioned here that the fire-fighting systems are responsible for the highest number of false trips in all voltage subpopulations except the 220 kV subpopulation where the dominant cause of false trips is the busbar protection. Therefore, it is recommended to improve the maintenance and design of this protection equipment to reduce the failure rate of power transformers.

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1. Introduction

Based on ANSI/IEEE C57.117-1986 [1], a transformer is a static electric device consisting of a winding, or two or more coupled windings, with or without a magnetic core, for introducing mutual coupling between electric circuits. The transformer includes all transformer-related components, such as bushings, Load Tap Changers (LTCs), fans, temperature gauges, and excludes all system-related components, such as surge arresters, grounding resistors, high-voltage switches, low-voltage switches, and house service equipment. Transformers can be classified to many types such as power transformers, autotransformers, regulating transformers. Based on their application, transformers are classified to substation transformers, transmission tie transformers, unit transformers, etc. The study in this paper considers power transformers for utility applications. For the purpose of abbreviation in this paper, the term 'transformer' refers to 'power transformer'.

Transformers are an integral part of power systems, and their reliability directly affects the reliability of the whole network. Outage of transformers is a failure, since a transformer outage is the termination of the ability of a transformer to perform its specified function [1]. Transformer outages are either forced or scheduled. Both types of outages are caused by switching operations. Forced outages of transformers are mainly due to automatic switching operations performed by protection systems [1–3]. They are caused by either external causes (such as transmission line faults) or internal causes (such as core failure, and winding failure). Refs. [4,5] give more details about failure statistics of transformer subassemblies. For the purpose of abbreviation in this paper, the term 'outage' refers to 'forced outage'.

The Egyptian Electricity Transmission Company (EETC) purchases bulk power from all generation entities and sells bulk

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power to the distribution companies and EHV & HV consumers [6]. Based on Fig. 1, in 2008–2009, the total transformer capacities were 7765 MVA, 29688 MVA, 3467 MVA, 36222 MVA, and 1774 MVA for the 500 kV, 220 kV 132 kV, 66 kV, and 33 kV networks, respectively [7].

In this paper, outage data analysis of power transformers in Egypt's power network is performed. The data are obtained from the Egyptian Electricity Transmission Company (EETC). This work presents outage data analysis over eight years, from 2002 to 2009, for 1922 (average number) transformers in voltage populations ranging from 33 kV to 500 kV and MVA rating from 5 MVA to 500 MVA. Forced outages due to correct and false action of transformer's protection systems are carefully considered.

2. Outage data preparation

Outage reports of transformers in the voltage range of 33–500 kV from 2002 to 2009 are obtained from EETC. The collected data per outage includes the transformer location, date and time, transformer outage duration, protection action, transformer restoration (or repair) time, interrupted MW and duration. The total number of transformers in service was 1717 and 2124 in 2002 and 2009 respectively. Table 1 shows the actual and average

numbers of transformers per voltage subpopulation in various geographical zones for years 2002–2009. Table 2 shows the number of transformers per voltage subpopulation for years 2002–2009, and their average numbers. It is depicted from Fig. 1 that the installed capacity of the 33 kV transformers in comparison with the 66 kV transformers is small. In addition, based on Table 1, the 33 kV transformers are available only at Middle and Upper Egypt. Therefore, the 33 kV and 66 kV transformers are combined into a single voltage subpopulation, a situation that is accepted and recommended by EETC because both the 66 kV and 33 kV transformers belong to the same authority. As shown in Fig. 2, the population of transformers is split up into subpopulations based on the voltage level, geographical zone, and year of reporting.

The outage causes of transformers in different voltage subpopulations are different. This is mainly due to the differences in operating conditions, maintenance strategies, and environmental conditions. Table 3 lists the outage causes of transformers in various voltage subpopulations. The outage causes listed in Table 3 are further classified into five outage categories according to the type of the outage causes. These outage categories are transformer related outages, power system related outages, environmental related outages, human factor (or human mistakes) related outages, and unclassified/other outages. The marks inside the table indicate types of outages causes associated with various voltage subpopulations.
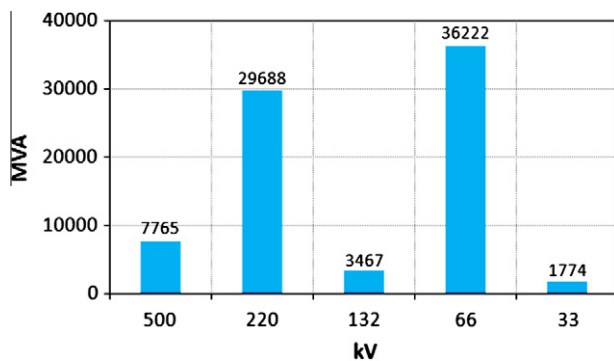

Fig. 1. The EETC's total Transformers Capacities in 2008–2009.

Table 2
Number of transformers per voltage subpopulation during 2002–2009.

Year/subpopulation	500 kV	220 kV	132 kV	66–33 kV	Total
2002	30	223	85	1379	1717
2003	30	230	85	1422	1767
2004	30	234	83	1492	1839
2005	30	247	83	1541	1901
2006	30	251	87	1594	1962
2007	30	262	80	1633	2005
2008	30	274	81	1672	2057
2009	32	292	79	1721	2124
Average	30	252	83	1557	1922

Table 1
Number of transformers per voltage subpopulation in various geographical zones during 2002–2009.

Zone	Subpopulation (kV)	2002	2003	2004	2005	2006	2007	2008	2009	Average
Cairo	500	8	8	8	8	8	8	8	8	8
	220	51	56	57	61	63	69	70	74	63
	66	389	405	450	467	486	506	515	528	468
Alexandria	500	2	2	2	2	2	2	2	2	2
	220	29	29	30	30	30	30	30	30	30
	66	146	151	155	158	161	163	167	168	159
Canal	500	4	4	4	4	4	4	4	4	4
	220	48	50	51	55	59	61	66	77	58
	66	201	209	218	230	240	244	251	256	231
Delta	500	4	4	4	4	4	4	4	4	4
	220	48	48	49	49	46	48	51	53	49
	66	299	306	318	327	335	344	349	360	330
Middle Egypt	500	7	7	7	7	7	7	7	8	7
	220	21	21	21	26	26	25	25	26	24
	132	24	24	23	23	25	23	23	23	24
	66–33	157	160	160	162	163	170	170	179	165
Upper Egypt	500	5	5	5	5	5	5	5	6	5
	220	26	26	26	26	27	29	32	32	28
	132	61	61	60	60	62	57	58	56	59
	66–33	187	191	191	197	209	206	220	230	204
Total		1717	1767	1839	1901	1962	2005	2057	2124	1922