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# 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.



## 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.

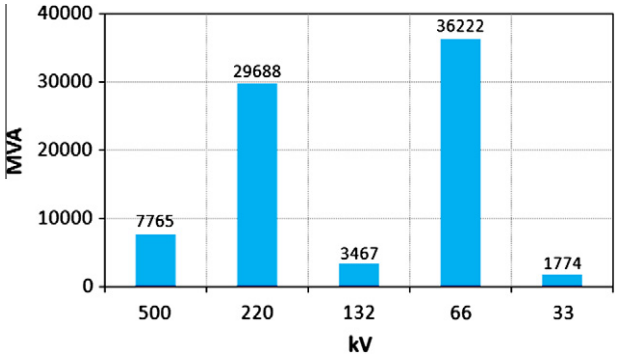


**Fig. 1.** The EETC's total Transformers Capacities in 2008–2009.

**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 |