Engineering Failure Analysis 86 (2018) 158–167

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Short Communication

Reliability, availability and maintainability study for failure analysis in series capacitor bank

Ricardo Manuel Arias Velásquez*, Jennifer Vanessa Mejía Lara

Pontificia Universidad Católica del Perú (PUCP), Perú

ARTICLE INFO

Keywords:
Asset management
Availability
Maintainability
Overhead lines
Series capacitor

ABSTRACT

In this research, the objective is introducing the fundamentals of reliability analysis, it has been applied to the planning and design of Series Capacitor (SC) Bank, applied for power lines. It considers the cost of power outages, the decision process for new and existing power equipment in several systems, as well as the ability to make quantitative analysis "Cost – Vs. - Reliability" trade-off studies. The lack of credible data concerning equipment reliability and the cost of power outages has hindered engineers in making such studies.

The study case considers a Reliability, Availability, and Maintainability (RAM) calculations, it has been performed for the series capacitor banks to be located at Cotaruse 220 kV, 4500 m over sea level (mosl) in a substation, located in Peru. The calculations are divided into forced and scheduled outages. A crew delay (for example: travel time) of 2 h, as well as 1 h for switching, have been included in calculations.

The results are divided into forced and scheduled outages with a reliability calculation and spare parts are listed in this research.

1. Introduction

Transmission substations are composed of a wide range of equipment and systems, subject to the occurrence of failures compromising the performance of the electrical power system, their high availability results from combination of operating with reliable equipment and adequate maintenance procedure [1]. Reviewing the literature related to reliability studies in power system identifies the combination of maintenance tasks that achieve the best reliability within a limited financial budget [2,3]. Besides in the Ref. [4] explains that the guarantee of non-occurrence of unscheduled shutdowns depends on the monitoring of the algorithms used in the data analysis and decision making, there are many research in the power transformers diagnosis [5], besides, some methods as fuzzy logic has been implemented in the inductive assets for power system [6]. According Ref. [7], in a modern substation associated an overhead line, a priority equipment is a SC, it allows to obtain an optimal power flows according to the stability; the most important failure is associated to lightning failures, in long transmission lines, it should be considered the reliability analysis as Ref. [8] and the second failure priority is isolation [9], the SC should operate in an adequate reliability, availability and maintainability, finally the reliability model for redundant protective systems has been developed in many research with double control and protection systems [10].

The series capacitor banks are designed according to the following main principles:

- Each series capacitor bank comprises one segment per phase.

* Corresponding author.
E-mail addresses: ricardoariasvelasquez@hotmail.com, rarias@rep.com.pe (R.M. Arias Velásquez).

https://doi.org/10.1016/j.engfailanal.2018.01.008
Received 1 September 2017; Accepted 23 January 2018

Table 1
RAM key values.

RAM key values	Expected
Forced outage frequency	0.04 f/y
Forced outage duration	17.52 h/f
Forced outage unavailability (FOU)	0.01%
Forced outage availability (FOA)	99.99%
Scheduled outage frequency	1 outage/year
Scheduled outage duration	10.73 h
Scheduled outage unavailability	0.12%
Annual availability	99.87%

- Each series capacitor bank is equipped with a protective scheme comprising a MOV, a bypass switch and a current limiting damping circuit.
- Each SC can be disconnected from the line by two isolating disconnect switches and one bypass disconnect switch.

For the study case, the Reliability, Availability, and Maintainability (RAM) calculations have been performed for the series capacitor banks to be located at Cotaruse 220 kV substation in Peru. The calculations are divided into forced and scheduled outages. A crew delay (e.g. travel time) of 2 h, as well as 1 h for switching, have been included in calculations. The expected key values for the proposed series capacitor bank have been summarized in the Table 1.

The relevant parameters are: Nominal system voltage (rms) is 220 kV, max continuous system voltage (rms) is 245 kV, system frequency is 60 Hz, finally, swing current (rms) are 2,253A.

The expected values in the Table 1, it represents corresponding mean values and shall, therefore, not be taken as guaranteed values. The predicted figures above are single point estimates for three phases [11]. The reliability calculations are limited to the equipment supplied. It has been defined in the Single Line Diagram, Fig. 1 including the control and protection systems and the auxiliary systems as recommended the Ref [12].

The spare parts used for the calculations are listed in this research, it can be useful for the engineers and technical expert in this kind of equipment.

Thus, it is hard to accurately model the interior failures in substations [13], it has been proposed a reliability assessment method for multi-level grid considering planned outages, but in this method they have some problems with SC for power lines, it have some special considerations as RAM study.

An adequate handling of Reliability, Availability and Maintainability is of strategic importance to equipment manufacturer and utilities companies as customers. RAM is therefore continuously considered and improved upon by several manufacturers during both new development and system design in order to ensure that contractual requirements are met and exceeded.

In this research, it has an established RAM program that includes:

- Defined responsibilities, tasks and allocated resources
- Defined objectives and goals
- Methods, tools and procedures for RAM
- Systematic collection and utilization of historical data
- Prediction of RAM data for equipment and plants
- Definition of RAM requirements towards providers' internal and external suppliers

The equipment requirements are evaluated regarding system complexity, system RAM requirements, equipment complexity, degree of standardization and proven design. Deviations from standard practices which may, for example, occur due to a particular customer's specification are the subject of special scrutiny in the design review. National and industrial codes are used in combination with standards whenever they are relevant. The design process also considers maintenance aspects with the aim to minimize repair and maintenance efforts, and the need for special skills and tools. Historical data is collected through failure reports from the failure reporting system database or data from the RAM calculation database from participating suppliers and independent sources. This research solves a reliability assessment method based on the reliability equivalent law of series system, in contrast with traditional methods and others approach [11].

2. Methodology

2.1. Objective

The main objective has been to create a simple and highly reliable design, which will give high availability and low maintenance costs. In order to achieve this, the design process has evolved to have the following steps:

- Design to minimize the number of components needed to fulfil the functional requirements by applying