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# Stochastic Modelling of Weather-Related Transmission Line Outages

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## ABSTRACT

The physical environment around transmission lines plays a major role in the resulting reliability of the power network. The inclusion of weather in the failure and repair process will lead to realistic modelling of the power network. This article suggests a modelling methodology to take into account weather-related failures. Besides a maintenance management strategy using dynamic programming, it is suggested to minimizing the cost of maintenance while accounting for weather-related failures. The data obtained from 220kV Transmission lines from Goa, India, is used to stochastically model the phenomenon. A three-state weather model is suggested, and accordingly the failure and repair phenomenon are segregated and stochastically modelled. Time-varying expressions for computing the availability in each weather condition is computed. This model can be used by the power utilities to realistically model weather-related failures.

## KEYWORDS

Condition Based Maintenance, Maintenance Management, Markov Model, Power System, Power Utility, Reliability of Power Systems, Stochastic Process, Transmission Line Outage

## 1. INTRODUCTION

In India, the unavailability of power based on weather is a cause of outrage and bitter criticism from the public against the power utilities. For example, during the rainy season, the frequency of power failure and down time is high leading to protest against the Government and power utilities (Gauree, 2018; Saini, 2018; Sony & Mekoth, 2014, 2015). Among the other reasons of power failure, the weather is one of the most important factors affecting the reliability of power systems (Panteli, Pickering, Wilkinson, Dawson, & Mancarella, 2017; Zhou, Pahwa, & Yang, 2006). The supply chain model of the power system from Generation, Transmission, and Distribution has to work together to cater the reliable power to consumers (Pabla, 2012). The transmission and distribution lines are affected by weather-related failures. Analysis of transmission line is important because the failure of transmission lines will lead to the power outage of several distribution lines leading to blackouts (Sony Michael & Mariappan, 2012). The failure rates are dependent on the weather conditions around which the transmission line operates. Increased failure rates are reported in different types of weather condition (Wu, Gao, Tang, & Huang, 2016).

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Not only the failure rates the downtime are also influenced by the weather conditions (Tavner et al., 2013). For an overhead transmission system, the weather environment can severely impact the performance of the transmission lines leading to the power utility's operational ability due to enhanced line failure and repair rates during bad weather periods (Billinton & Singh, 2006). Therefore, estimating reliability by utilities without incorporating weather conditions can be quite optimistic and erroneous. In addition, it may also affect planning and design decisions for maintenance activities for the power utilities, which will result in the financial loss (Fanucchi, Bessani, Camillo, London, & Maciel, 2016). By recognizing the impact of various weather contributions to the total system performance indices will help to pinpoint the situations, where investment may be provided for maximum reliability improvement. A transmission and distribution system usually consists of overhead lines, underground and combination of both (Pabla, 2012). In utilities like India, which is a developing country, the ratio of overhead transmission lines to underground transmission lines are very high (Saini, 2018). Hence, assessing the reliability of systems without incorporating, weather-related outages would lead to erroneous conclusions resulting in bad policy and maintenance strategies. In other words, for cash-starved utilities, incorporating weather-related outages will lead to optimum allocation of available resources. Another aspect to consider in a developing country is that the repair process is also dependent on weather (Sony Michael, Mariappan, & Kamat, 2011). Thus, failure rate and repair rate are a continuous function of weather conditions. It is difficult to describe failure rate and repair rate as a continuous function of weather-related failures. However, a set of discrete states could be used to describe the variable failure and repair rates. Previous researchers have used the concept of failure bunching to model storm related failures (Billinton & Singh, 2006; Gaver, Montmeat, & Patton, 1964). Markov models were used in the evaluation of transmission system availability if the rate of failure and repair followed exponential distribution (Michael et al., 2009).

Besides failure modelling of storm-related failure were also modelled as a two-state process (Billinton & Bollinger,1968). A three-state weather process model was proposed by Billington and Singh (2006) to account for weather-related faults. However, this model cannot be used when repair process is weather-related. Nevertheless, due to the practical impact of weather-related failure on repair rates, it makes the problem, further complex in a developing country power utility and the three-state model will not be able to capture its complexity (Michael, Amonkar, Mariappan, & Kamat, 2009). In addition, classification of failure rates into monsoon, winter, and summer, further improves the modelling complexity and actuates the system to its reality. In this paper, it is proposed to stochastically model the weather-related outages in a transmission line. A mathematical model is proposed for its evaluation and a case study is presented on the failure of the 220kV Transmission system in Goa, India. In addition, a maintenance strategy for taking into account weather-related failure as also suggested. The model can be used readily by power utilities for evaluating its availability and maintenance strategy designed.

## 2. WEATHER RELATED FAILURE-REPAIR MODEL

Modelling failure related to weather conditions like the heavy storm, freezing rains, tornados etc. can have a great impact on the reliability of power systems (Billinton & Acharya, 2006; Trakas, Hatziargyriou, Panteli, & Mancarella, 2016). The IEEE Standard 346 further suggests that the weather environment should be divided into the three classes of normal, adverse and major storm disaster (Wang & Billinton, 2002). As such we propose a weather based three- state model. In order to model first state, we classify the weather during Summer. For modelling adverse state, we consider the weather during winter where fog deposits on the insulators are created failures (Gorur, Cherney, & Hackam, 1986). To model major storm disaster, we model the weather as Monsoon (Liu, 2015).

In addition, it is further proposed from our practical discussion with power utility Engineers in India, that repair process is also affected by these three weather conditions. To ascertain this fact, three focus group discussion (Morgan, 1998) was conducted. A thematic conclusion which transpired from

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