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Applying Hidden Markov Processes to Optimizing Power Systems Maintenance

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Abstract

Failure identification and prediction in a power system are essential components that are prerequisites for optimizing the maintenance of the system. The incidences of power system failures have increased dramatically in recent times due to the uncertainties inherent in the advent of both man-made and natural disasters. This problem is further exacerbated due to the increasing demand for higher operational efficiency in power systems. Currently, there is a paucity of studies that predict and identify failure in a distribution power system. In this paper, we propose an integrated methodology for selecting the optimal maintenance plan based on predicting and identifying failure modes with the aid of Hidden Markov Models (HMM) and a probabilistic decision-making tool. While the model parameters of previous studies were determined utilizing observable prior knowledge, the use of HMM offers a different approach especially in the absence of such observable prior distributions. Thus, we determine the status of health of a power system by using an HMM to capture the relationship between unobservable degradation state and observed parameters. The preliminary outcome is instructive for the management of power systems especially in response to fortifying the system against aging and degradation.

Nomenclature

A. Sets

N	The number of hidden states.
M	The number of observations in hidden state.

B. Parameters

λ	Hidden Markov Model parameter (Hidden States, Observations, Transition Probability, Emission Probability, Initial Probability)
S_N	N^{th} hidden state
q_t	Hidden state at time t
O_M	M^{th} Observation.
π_i	Initial probability for i^{th} state.
a_{ij}	Transition probability from j^{th} to i^{th} state.
$b_j(k)$	Emission probability of an observation k in state j.
$\alpha_t\ (j)$	Forward probability at t
β_t	Backward probability at t
$Cost^{i}_{total,t}$	Total cost at time t in health state i
$R_{CI,i,t}$	Customer interruption rate in state i at time t
$R_{LR,i,t}$	Loss of revenue rate in state i at time t
$Cost_{PM,i,t}$	Preventive maintenance cost in state i at time t
$Cost_{CM,i,t}$	Corrective maintenance cost in state i at time t

Keywords

Hidden Markov Model (HMM), Probabilistic Decision Making, Economic Energy management

1. Introduction

The fundamental objective of an electronic power system is to reliably supply electrical energy to the customers with a continuous and acceptable quality. However, electronic power system catastrophe can originate from the failure of any electronic component [1]. According to the State of Commercial and Industrial Power Reliability Report, in 2018, almost half of U.S. commercial and industrial (C&I) customers experienced a power outage at least once, and 21%