Electric Power Systems Research 249 (2025) 112015

Contents lists available at ScienceDirect

Electric Power Systems Research

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

An accurate method for detection and compensation of current transformer saturation using unscented Kalman filter

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ARTICLE INFO

Keywords:
Current transformer (CT)
Unscented Kalman filter (UKF)
Digital protective relay
Saturation compensation
Signal processing

ABSTRACT

Current transformer (CT) saturation reduces the accuracy of current measurement, which may lead to excessive delay or incorrect operation of protective relays. In this paper, a new algorithm based on the Unscented Kalman Filter (UKF) is proposed to detect and compensate for the effect of CT saturation. In this new method, which is based on the Unscented Kalman filter theory, samples from the unsaturated regions are used to reconstruct and rectify the measured current waveform under CT saturation periods. This ensures proper compensation of the measured current, leading to correct operation of protective relays and preventing their maloperation. In particular, the proposed method significantly improves the performance of a distance protective relay by restraining any incorrect tripping signal due to CT saturation. Additionally, its high accuracy and relatively short computation time are noteworthy. This method effectively handles noise, harmonics, and restrains any relay maloperation due to a power transformer inrush current. The proposed method has been validated through simulation of numerous test cases, carried out by PSCAD/EMTDC software. In these simulations, the CT saturation compensation algorithm is implemented using MATLAB software. To assess the improvement in CT accuracy by application of this method, the simulation results of a relatively large number of case studies are analyzed. In this paper, it will be demonstrated that the method can accurately compensate for CT saturation within an acceptable time frame of 0.25–0.38 ms in a power circuit.

1. Introduction

In a power system, the current transformers (CT) are equipment for measuring the current at different circuits of the network, which play an important role in the operation and protection of the power network and the equipment connected to it. The correct and accurate transmission of the power system current to the secondary side of the current transformers causes the correct operation of the protection devices, and the saturation of the CT leads to the distortion of the current waveform and the incorrect operation of the protective relays. For example, during the occurrence of faults, large spurious differential currents may appear due to CT saturation, which may cause an unwanted trip [1,2]. Using the Unscented Kalman Filter can be a special solution to prevent this maloperation. The CT saturation solutions can be expressed as follows. In general, the diagnosis of CT saturation can be investigated in two ways, using software and using hardware [3]. In references [4–6], using neural networks, the related compensating methods for CT saturation which distorts the CT's secondary current waveforms are investigated. In reference [4], using the artificial neural network (ANN) methodology, the CT saturation is compensated for. ANN is used to learn the nonlinear behavior of a CT and reconstruct the current waveform when it is saturated. In reference [5] using ANFIS algorithm to compensate for the CT saturation, the reconstruction of current waveform using the fuzzy inference system, has been investigated. While neural networks and fuzzy inference systems are effective for CT saturation compensation, their performance is highly dependent on the quality of training data and may struggle with generalization to unseen conditions. Additionally, these methods can be computationally expensive and may be less accurate under noisy or transient conditions. In reference [7], two compensating filters are introduced to reconstruct the saturated CT output: one to compensate for CT saturation during faults, and another to suppress the DC component caused by inrush current. However, the conventional waveform-based coefficients and variables used in their approach are susceptible to noise and lack sensitivity to transient phenomena caused by faults or sudden disturbances, which limits their effectiveness in power system protection applications. In paper [8], a modeling procedure is used for CT saturation compensation, where the

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https://doi.org/10.1016/j.epsr.2025.112015
Received 19 March 2025; Received in revised form 7 July 2025; Accepted 9 July 2025