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Wind power variation identification using ramping behavior analysis

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Abstract

Harvesting energy from renewable sources has become prominent since the use of fossil fuels became unsustainable. Traditional practice for mitigating the energy demand around globe majorly consists of utilizing conventional sources and injection of renewables as and when available. The continuous and exponential growth in consumption alongside the need to reduce the carbon footprint and to counter the climate change has paved the way for Renewable Energy Sources (RES). Availability and maturity in technology made wind and PV (photo-voltaic) the most prominent among others. Per contra, the inherent variations in the weather in form of wind speed, solar irradiance act as a barrier in utilizing the full potential. The variations, ramp events, in case of wind energy have adverse effects on determining the reliability, economical profitability, and flexibility. Accurate recognition of the wind ramp events can improve energy management, forecasting and causality. This paper proposes a data analysis oriented approach exploring the pre-processing technique of wind power variations using moving average filter, followed by noise extraction and separating the power swings. Further clustering the power swings utilizing K-means clustering technique. The proposed technique improves the power swings identification process by reducing the noise content.

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Keywords: Power swings; Renewable energy resources; data clustering; ramp event detection;

1. Introduction

The systems are static, quasi-static or dynamic with respect to time. An event in a system can be a continuous or discrete time process. Ramp is used to explain an event where a sudden positive or negative swing occurs within a period. Harvesting energy from every possible source before the conventional sources run out of reserve pushed us for the change in regime. Now that the energy requirement is foreseeing a rapid growth over time, the challenge became multi objective – manage consumption, increase production from alternative sources and ICT (Information and Communication Technologies) integrated smart controlling of the overall system. Most renewable sources of energy are non-deterministic owing to the factor of random availability as in wind speed, solar irradiance. This unreliability acts as the major hindrance apart from the economic standpoint in wide scale implementation. Today's

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practice consists of majority of production and reserve from conventional sources and penetrative renewable energy. The ramp events in power conversion from RES have adverse effects on reliability, economical profitability and flexibility. Characterizing the ramp behavior of renewable sources fosters the chances for better management and thus improving the system operation. Inherently RES have multi-level time varying uncertainty. In wind energy, ramp-ups are usually caused by intense low pressure systems, low level jets, thunder storms, wind gusts, climatic variations [1]. Again, the statistical model presented providing insights to the ramping events- frequency of occurrences and severity levels. The study of ramp events are utilized in system control and day-ahead forecast. Sevlian and Rajgopal et. al. used a dynamic programming recursion to analyze ramp events by virtue of a statistical model [2]. Wherein Florita et. al. used swinging door algorithm and indicated the fine tune required to improve the ramping event analysis in solar and wind energy [3]. Ouyang et. al. illustrated the current forecast models based on ramping events. Then extended suggestions in contrast with numerical weather prediction [4]. Bianco et al. presented wind ramp detection, time forecast, observed ramp and impact of the up-down events on the grid operation [5]. In [6] ramping behavior analysis technique was elaborated for the ramp detection in RES. In [7] a time series simulation for the large wind farm in turbulent scenario was described. In [8] a spacio-temporal model for the short-tern wind power forecast model was developed. However, the wind power variations are highly dependent on the precise peaks identification and a setting a proper threshold. The noise in the dataset often lead to misclassification or over-estimation of the ramp events. In this paper, the focus was on the pre-processing of wind power data that give rise to precise time-series data removing the noise content and preserving the swing property of the original data. Consecutively identifying the peaks and clustering the peaks into groups classified the variations accurately. This article is divided into four sections- first the wind power variations explaining the ramp events, second wind power data filtering method, followed by clustering the data sets to emphasize the significance and finally the conclusion.

2. Wind power variations

The Ramping Behavior Analysis (RBA) is a relatively recent field of study in the domain of RES. The causality of the ramp events are not clearly traced. In wind energy, sudden oscillation of output power from wind turbine and high input power injection with notable pace is an identifier of ramping. Performing the ramping analysis on both the input and output is a key point. There exists no particular increment in magnitude or oscillation ranges in literature for the RES to characterize the events. As a result, there are multiple ramp events in various sets of thresholds. The second fold of problem is based on reliability statement in agreement with magnitude and times of occurrences in the period of analysis. Various levels of system with multiple time steps, intermediate delays, and the instantaneous weather changes make the system highly random. Statistical model requires iterative investigations with multiple thresholds, data sets and time stamps to make an inference, setting aside the Hybrid Renewable Energy Sources (HRES). The traditional definitions for the wind ramp events are distinguished by the pre-determined threshold values. The four equations of threshold values below are widely used definitions in literature. [4].

$$\left|P(t+\Delta t)-P(t)\right| > P_{thr} \tag{1}$$

$$\left|\max\left(P\left[t,t+\Delta t\right]\right)-\min\left(P\left[t,t+\Delta t\right]\right)\right| > P_{thr} \tag{2}$$

$$\frac{\sum_{n=1}^{m}\left(P_{t+h}-P_{t+h-N}\right)}{N} > P_{thr} \tag{3}$$

$$\frac{\left|P(t+\Delta t)-P(t)\right|}{\Delta t} > P_{thr} \tag{4}$$

Where P, t, Δt, P_{thr} stand for power generated, time, time interval and power threshold respectively. The yardstick of the analysis depends on the threshold, and change in magnitude of wind power production over a period. Considering only the ends or difference between maximum or minimum power productions including end approach has a disadvantage in the form of special case inclusion or exclusion [3].

Setting up a threshold depends on multiple factors as in grid topology, size of turbine, placement and region. Ramp refers to significant increase or decrease in wind power within a set time period. A swing can at times be a special case, as in the wind speed drops below the limit or sudden increase due to untraceable factors. RBA consists of a) ramp-up b) ramp-down c) rise-time d) fall-time e) ramp-up/down rate [6]. The objective is to identify the set of significant ramps considering the time as a reference and the difference between two consecutive high and low