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ScienceDirect

Energy Procedia 103 (2016) 15 – 21

Energy Procedia

Applied Energy Symposium and Forum, REM2016: Renewable Energy Integration with Mini/Microgrid, 19-21 April 2016, Maldives

Cross-characterization of PV and Sunshine Profiles Based on Hierarchical Classification

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Abstract

This paper investigates the link between PV generation and the climatological indicator of sunshine duration. For the first time, an understanding of to what degree the daily sunshine duration determines the generation output profile is established, and insights into the extent of such impact at differing months of a year are provided. The new finding essentially provides a fresh new perspective on characterizing the uncertainty and variability in PV output.

Based on this correlation identified, a novel two-step hierarchical classification method is also proposed in this work to facilitate PV profiling. A case study on a practical PV plant in Great Britain is presented to demonstrate the application of this method. For each derived group, the degree of variation in PV output at different times and the confident levels of each quantity are assessed. More importantly, based on the classification results, a weather-based PV profiling guideline is created. This will facilitate PV output forecasting on a granular level, thus providing a powerful tool for the ever increasingly challenging system operation and planning.

Peer-review under responsibility of the scientific committee of the Applied Energy Symposium and Forum, REM2016: Renewable Energy Integration with Mini/Microgrid.

Keywords: Solar photovoltaic; Renewable generation; Profile characterization; Variation; Confidence level

1. Introduction

For over 100 years, the principles behind Britain's electricity sector had remained largely unchanged. The last decade has seen the beginning of a revolution: it has been grappling with the triple challenges of decarbonization, maintaining security of supply, and affordability to customers. This has triggered a paradigm shift in the way electricity is produced. In the U.K., there is currently over 4GW of solar photovoltaic (PV) generations. By the end of this decade, another 20GW will be installed on the grid, of

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Peer-review under responsibility of the scientific committee of the Applied Energy Symposium and Forum, REM2016: Renewable Energy Integration with Mini/Microgrid.

doi:10.1016/j.egypro.2016.11.242

which a significant portion will be connected on distribution levels, ranging from low-, high-, and extra high-voltage levels [1].

This will bring unprecedented level of uncertainty and variation to the future planning and operation of the national transmission grid. With small volume, generation connected to the distribution levels looks much like 'negative demand' to the power system, thus creating limited impacts that are within normal demand fluctuations. However, as these distributed sources increase in scale, they start to cause significant reverse flows across the distribution and into the transmission system, potentially beyond the design capability of the system and resulting in operational constraints.

This paper for the first time investigates the relation between PV output and daily sunshine duration (SD). Although the fact of being one of the key climatological indicators provides SD with both easy accessibility and broad public understanding, its impact on PV output characteristics has not been fully explored or quantified. To fill this gap, this work seeks to answer the question of to what degree the daily sunshine duration determines the profile of PV daily output, thus proposing a novel perspective over traditional studies on the issue of PV output characterization.

The correlation identified in this work is then extended and implemented to facilitate PV daily output profiling. A two-step hierarchical classification approach is developed and applied to a practical PV plant in Britain. Based on the results, a PV profiling guideline is finally created, which specifies PV output hourly variation and confident levels. Comparing with conventional approaches to PV profiling which tend to suffer over complexity as higher accuracy is required, the look-up table guideline created here requires neither detailed modelling of each component nor simplifying assumptions, thus achieving a well balance between method complexity and result accuracy.

2. PV Output Characterization based on Hierarchical Classification

Geographical location and climate have a significant impact on the overall PV power output variability and uncertainty. Numerous studies have evaluated the correlations between PV output and such influencing factors [2-6]. However, a review of these existing works shows that no studies have explored or characterized the relation between PV output and sunshine duration, especially given its wide public availability.

In this paper, a two-step classification method is proposed to investigate the characteristics of PV generation output. Firstly, the monitored daily output data is classified into 12 monthly groups, and for each group an averaged profile and the corresponding variation could be derived. Then the daily 'Sunshine Duration' is utilized to further classify the output profiles within each monthly group into three clusters. The overall classification has two major steps:

- Step 1: Monthly classification. The monitored PV daily profiles are firstly classified into different months. The distinguishing seasonal solar irradiance determines not only the height of the output profile curve, also it directly influences the start/end timing point of every day's PV generation.
- Step 2: Classification according to daily 'Sunshine Duration'. Within each monthly group, the relationship between the shape of daily PV profile and the examined day's meteorological sunshine duration is characterized. In this study, three groups particularly have been created, representing the situations of low, medium and high sunshine duration.

3. Example Demonstration

The proposed classification method to investigate PV output characteristics has been demonstrated on a PV plant at Cambridgeshire UK. Half-hourly monitored output data, which covers the period from 01/01/2012 to 31/12/2012, are utilized for this demonstration.