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ScienceDirect

Energy Procedia 105 (2017) 427 – 432

Energy Procedia

The 8th International Conference on Applied Energy – ICAE2016

# Optimal Planning of High Penetration Distributed Photovoltaic with considering Grid Reinforcement

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**Abstract**

With the continuous strong supportive policies, distributed photovoltaic have developed rapidly in a high penetration in some regions, which requires grid reinforcement and is imposed to the curtailment risks. In response to the grid reinforcement costs, reduced losses, delayed grid investment and other costs or benefits associated with the access of high penetration distributed photovoltaic; this paper proposes a comprehensive cost-benefit analytical method in consideration of grid reinforcement. Analytical results of 8760h power flow are acquired for optimized planning of the access of high penetration distributed photovoltaic. The research results may be valuable references for the scientific planning of high penetration distributed photovoltaic.


Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.

*Keywords:* high penetration; distributed photovoltaic; optimal planning; cost-benefit

## 1. Introduction

At the end of 2014, China launched the second catalog of pilot zones for distributed photovoltaic and determined six provinces as the pilot provinces for photovoltaic-based poverty relief, including Anhui, Hebei and Shanxi, etc. With the progress of the pilot projects of photovoltaic system and poverty relief, some regions already have a high penetration of distributed photovoltaic. In some regions, the distributed photovoltaic presents the feature of high penetration and intensive access; in special regions, the Penetration of distributed photovoltaic has even exceeded 200% (the ratio of installed capacity of distributed photovoltaic to maximum local user load). The optimized planning of high penetration distributed photovoltaic has become the key issue focused by all circles.

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Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.
doi:10.1016/j.egypro.2017.03.336

The key to the optimized planning of distributed photovoltaic lies in cost-benefit assessment in scenarios. Nearest access of distributed photovoltaic and their direct supply to consumers help to reduce power transmission and distribution losses, delay grid investments, save energies, reduce consumptions and pollutions and bring other economic and social benefits. However, developments and constructions of distributed photovoltaic require massive initial investments. Meanwhile, high penetration access to the grid may result in grid reinforcement costs and curtailment losses. Therefore, scientific quantitative assessment of the various costs and benefits of distributed photovoltaic may provide scientific basis for the optimized planning of distributed photovoltaic and promote the coordinated planning of distributed photovoltaic and the grid. Many literatures have studied the optimized planning of distributed power supplies. However, current researches focus on low penetration scenarios ignoring the grid reinforcement costs and curtailment losses arising from high penetration scenarios. Meanwhile, the benefits of distributed power supplies are not fully considered [1] - [4].

This paper firstly analyzes the grid reinforcement costs, reduced losses, delayed grid investments and other costs and benefits arising from access of distributed photovoltaic, proposes the quantitative assessment method of various costs and benefits, proposes multiple typical planning scenarios for the photovoltaic-based poverty relief, performs the 8760h technical and economic analysis and raises some basic viewpoints on the optimized planning of high penetration distributed photovoltaic.

## 2. Quantification of costs and benefits of access of distributed photovoltaic

Generally speaking, the access of distributed photovoltaic will bring multiple costs and benefits.

### *2.1. Quantification of costs*

(1) Initial investment cost. The initial investment cost of distributed photovoltaic is normally the installed capacity multiplied by unit cost of installed capacity.

$$C_{\mathrm{g}} = \sum_{i=1}^{n} C_{\mathrm{kw}_i} P_i \tag{1}$$

Where, $C_{\mathrm{kw}_i}$ is the cost of unit installed capacity of distributed photovoltaic $i$ ; $P_i$ is the installed capacity of distributed photovoltaic $i$ ; $n$ is the quantity of distributed photovoltaic units.

(2) Grid reinforcement cost. The grid reinforcement cost calculation is comparatively complicated and need to perform 8760h analysis and it is also related to the grid reinforcement strategy. For calculation of the reinforcement costs herein, the restricted power at various given time points is determined according to the curtailment strategy applicable for excess of grid capacity on the basis of the grid operational stability analytical results on a typical day or in the year. Thereafter, the necessity of grid reinforcement is determined by judging if the cumulative daily or annual restricted power exceeds the standard and also the lines to be renovated and the corresponding costs are also determined.

$$C_{\mathrm{r}} = \sum_{i=1}^{m} C_{\mathrm{km}_i} L_i R_i \tag{2}$$

Where: $C_{\mathrm{km}_i}$ is the unit length cost of line $i$ ; $L_i$ is the length of line $i$ ; $R_i$ indicates if line $i$ needs reinforcement, or it shall be 1 if reinforcement is required and 0 if not required; $m$ is the lines quantity.

(3) Maintenance cost. Maintenance cost primarily includes the maintenance cost of project and renovated grid equipment which is normally estimated at a certain ratio of the investment cost. The maintenance cost of distributed photovoltaic is calculated as per its capacity and the maintenance cost of renovated grid equipment is estimated at a ratio of the reinforcement costs.