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Reactive Power Planning and Its Cost Allocation for Distribution Systems with Distributed Generation

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***Abstract*--This paper addresses some of the modeling and economic issues pertaining to the optimal reactive power planning of radial distribution systems with distributed generation. When wind power generation (WPG) units are installed in a distribution system, they may cause reverse power flows and voltage variations due to the random-like outputs of wind turbines. To solve this problem, we introduce Static Var Compensator (SVC) into distribution systems, and combine the reactive power support from distributed diesel units for voltage control. An optimal reactive power planning model is proposed in this paper. Monte-Carlo simulation is used to simulate the uncertainty of wind power generation. The locations and the outputs of SVCs and distributed diesel units are determined using our proposed optimal reactive power planning model. Genetic Algorithm (GA) is used to solve the optimization problem. Furthermore, we apply the Shapley Value Axiom in cooperative game theory to allocate the reactive power cost of SVC among wind power turbines, which have caused voltage variations. Finally, we discuss the allocation results from an economic point of view.**

***Index Terms*—Distributed Generation，SVC， Monte-Carlo simulation，optimal allocation， cost allocation**

I. Nomenclature

t	Wind power generation units output status;
T_t	The time duration of status t;
K	The energy cost per unit;
$P_t(x)$	Active power loss for wind power output status t;
i	System node;
e_i	Binary variable, the value depends on whether SVC is installed at bus i or not;
r_i	Marginal cost of SVC at bus i;
Q_{ci}^0	The maximum required capacity of SVC placed at bus i for all the WPG output statuses;
c_i	Fixed installation cost of SVC at bus i;
P_{DGi}^t, Q_{DGi}^t	Diesel unit active and reactive power outputs at node i for WPG output status *t*;
a_i, b_i, c_i	The coefficients of production cost function for the diesel unit at node i;
e_{iWPG}	Binary variable, the value depends on whether wind turbine is installed at bus i or not;
e_{iDG}	Binary variable, the value depends on whether diesel unit is installed at bus i or not;
P_{WPGi}^t, Q_{WPGi}^t	The active and reactive power outputs of the wind power generator at node i for status t;
P_{DGi}^t, Q_{DGi}^t	The active and reactive power outputs of the diesel unit at node i for status t;
V_i^t	Voltage magnitude at node i for WPG output status t;
Q_{ci}^t	Reactive power injection by SVC at node i for WPG output status t;
$Q_{ci}^{\max}$	The maximum reactive power output of the SVC at node i;
$P_{DGi}^{\max}, Q_{DGi}^{\max}$	The maximum active and reactive power outputs of the diesel unit at node i.

II. Introduction

With the deregulation of electric power systems and the development of new generation technologies, distributed generation (DG) is becoming more and more important in the future power systems. One of the benefits of DG sources is deferring or avoiding transmission and distribution expansions. In general, DG can be defined as small-scale electric power generation sources (roughly 30MW or less). They are usually connected to distribution networks or located at the customer side. The distributed generation sources include those generators with traditional power technologies, such as, diesel and combustion turbines, and power sources of renewable technologies, such as, photovoltaic and wind power.

Wind power generation has become one of the most

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