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Impact assessment of renewable generation on electricity demand characteristics

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ABSTRACT

In response to variation generation of renewable resources, it is necessary to assess the impacts on electricity demand characteristics. Renewable resources under consideration are photovoltaic, wind, small hydro, biomass, and biogas. It is proposed to treat renewable generation as negative load. Electricity demand is characterized by using peak demand, energy demand, and load factor as well as it is divided into three groups: peak, intermediate, and base. Variation of renewable generation is expressed through a concept of net load. Changes of demand characteristics can be analyzed from annual and seasonal changes of load duration curves after integrating renewable resources. The impacts on demand characteristics and load groups have meaningful implication on operating costs. Numerical results were obtained by using hourly load data and generation portfolio of Thailand.

Contents

1. Introduction

Development of renewable energy technologies, markets, and investments has been rapid in recent years. Although the world economy has slowed down, the United States, Germany, Spain, China, India, and Brazil continue to lead the world in renewable energy utilization. Renewable energy sources have been utilized to replace fossil-fuelled sources in heating and cooling, transportation, and electricity generation. It is accepted that the growth of renewable energy utilization far exceeds the growth rates of fossil fuels. Technological progress in renewable generation results in cost reduction gradually. Besides, regulatory policies, by means of subsidies and tax exemptions, play important role in driving renewable generation. Renewable power capacity worldwide reached an estimated 1320 GW in 2010 and comprised a quarter of global power capacity from all sources [1].

In rural areas around the globe, renewable energy is increasingly accessible and recognized as sustainable option for off-grid generation. This would have an impact on electricity demand

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forecasting. The forecasted demand of electricity would rather be a net value than a gross value. Besides, major concerns of using renewable resources for electricity generation are the intermittent nature of wind and solar as well as the supply availability of small hydro, biomass, and biogas. The availability of renewable generation may not match with demand variations. For instance, wind availability is high in the early morning while electricity demand is low at the moment. In summer, fuel availability of biomass is low while electricity demand is high.

On supply side, the variable generation of renewable resources could reduce fossil-fuel generation and fuel price fluctuations [2] but would require higher reserve capacity [3] and cycling operation [4]. It is questionable whether operating costs are lower. The answer is definitely dependent on renewable technologies and their penetration level. This subject has been widely studied in the literature [5–13]. On demand side, renewable generation also affects electricity demand characteristics. Because certain renewable resources, such as wind and solar, have intermittent nature so that their generation is not dispatch-able. Renewable generation may technically be considered as negative load [14–16] and its impacts are observed by using the concepts of net load and modified load duration curve [17–19]. When the penetration level of renewable resources is significant, the electricity demand characteristics would be obviously different from the original characteristics. In addition, recent work has also investigated the impacts of vehicle-to-grid and distributed generation in system operation costs and in the power demand curve [20]. By far, the comprehensive work [9] considered the impacts of only wind, photovoltaic, and biomass generation on electricity demand characteristics. The load duration curve was modified on an annual basis. The impact on load groups was only evaluated on particular hours only. The impacts on cycling operation and cost have not been mentioned.

Thus, the objective of this work is to extensively investigate the impacts of renewable generation with a time frame from seasonal basis to annual basis. Renewable resources include photovoltaic, wind, small hydro, biomass, and biogas. Electricity demand characteristics are expressed in terms of peak demand, energy demand, load factor, and load groups. Numerical model is taken from hourly load data and generation data of Thailand during 2009–2011. The main interest is on the changes of peak and energy demands as well as load factor. In addition, the impacts on load and plant groups as well as cycling operation are also subject to investigation in order to fully assess the impact of renewable generation.

2. Renewable generation in Thailand

Various renewable resources are available, but those commercially utilized for electricity generation are photovoltaic, wind, small hydro, biomass, and biogas. Renewable resources with limited potential for electricity generation are municipal waste and geothermal power. Photovoltaic and solar thermal capacities have been installed around the world and the investment trend is on the rise given that costs are falling gradually [21]. Wind power has significantly penetrated the renewable energy markets in North America and Europe for a decade and has recently driven its growth by China [1,21]. Hydroelectricity has been widely used for a long time but half of the hydro capacity in the world belongs to the United States, Canada, Brazil, Russia, and China. Typical sizes of hydro capacity are in a wide range (1–1,000,000 kW) but, by tradition, hydro power considered as renewable generation is limited to small-, mini-, micro-, and pico-hydro with capacity up to 10 MW [22]. Biomass is commonly used to produce heat and is transformed to liquid fuel. The use of biomass for electricity generation can be either direct firing or co-firing with fossil fuel. Biogas can be produced from various kinds of biological sources, mostly from animal manure and organic waste. Biogas yields vary widely depending on composition of raw material, in particular, fat content [23,24].

Table 1 shows installed capacities and investments of renewable energy resources in Thailand. Renewable energy utilization in Thailand was dominated by photovoltaic and biomass. Wind power in Thailand is limited, which is opposite to other countries, because wind speed is relatively low. Small hydro power is also limited given that the potential area is only in Northern Thailand. Biogas has been developed to saturation stage. On the other hand, waste power is considered to be at an initial stage. As of 2011, the installed capacity of renewable energy resources is approximately 8% of peak demand in Thailand. However, as shown in Fig. 1, renewable generation is less than 3% of total generation. Renewable generation was low during rainy season (July–October) and high during winter (November–February). Time-of-day energy generation in 2011 is illustrated in Fig. 2. Energy demand in Thailand peaks during 2–4 PM and 7–9 PM. But, renewable generation peaks from 9 AM to 3 PM and almost constant for the rest of the time. The generation behavior of renewable resources is coincident with the operation of production processes which utilizes biomass and biogas generations.

Fig. 3 illustrates the peak demand and renewable capacity of Thailand from 2001 to 2025. By 2015, renewable capacity would be one-third of the forecasted peak demand. But, given the data in Table 1, a realistic projection would have renewable capacity around 15% of the forecasted peak demand. As such, it can be said that renewable generation in Thailand would reach a significant level in a few years.

The generation mixes of Thailand from 2001 to 2025 sorted by fuel type and plant type are shown in Figs. 4 and 5, respectively.

Table 1
Installed capacities and investments of renewable energy resources in Thailand during 2009–2011 [25].

Resource	Installed capacity (MW)			Investment (million Baht)		
	2009	2010	2011	2009	2010	2011
PV	37.0	48.6	78.7	4644	32,788	24,472
Wind	5.1	5.6	7.3	954	17,465	139
Small hydro	55.7	58.9	95.7	301	148	330
Biomass	1618.1	1650.2	1790.2	5349	11,846	13,901
Biogas	69.8	103.4	159.2	5275	1259	3757
Waste	6.6	13.1	25.5	2169	1047	2264
Total	1792.3	1879.8	2156.6	18,692	64,553	44,863

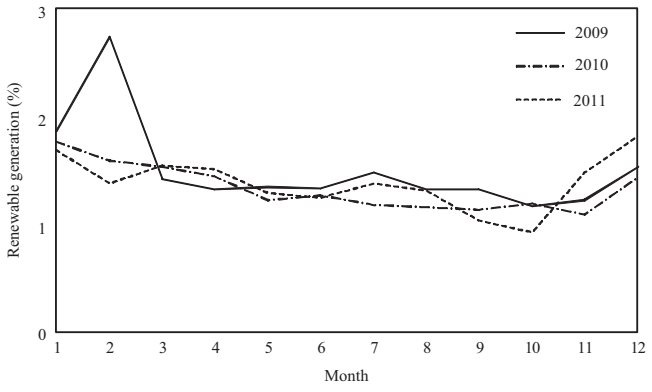

Fig. 1. Monthly generation of renewable resources in Thailand during 2009–2011.