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Optimal sizing of distributed generation in gas/electricity/heat supply networks

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Abstract

Multi-energy supply systems are expected to play an important role in smart grids. Today's energy supply systems are large nodes networks, and different types of energy are needed at each node to satisfy the different energy demands. These different types of energy can then be converted to each other through specific devices. How to decide the ratings of these devices at each node to make the system cost-effective is addressed in this paper. The focus is set on a gas/electricity/heat hybrid network. A hydrogen storage system (fuel cell, electrolyzer, and tanks) is used as electricity storage system, a combined heat and power device is used to produce heat and electric power, etc. A mixed integer linear programming algorithm is used to determine the optimal operation schedule of the system, where the goal is to minimize shed load. A genetic algorithm is also used to search for the best size of each component, where the goal is to minimize the total investment costs. In order to resist to contingency events, betweenness centrality (describing the relative importance of each node) is then used to find the worst case under contingency events. This worst case scenario is used to research about the influence of contingencies on the sizing results. At last, two cases (modified 13-node network and IEEE 30 + Gas 20 + Heat 14 nodes system) are tested using the proposed sizing method. The results show that the renewable energy location, investment cost of components, and the structure of the whole system influence the sizing results. When the installed capacity of photovoltaic panels is reduced by 50%, the capacity of the electrolyzer decreases by 3%, the capacity for the hydrogen tanks increases by 2%; when the investment cost of the fuel cell and electrolyzer decreases by 50%, the capacity of photovoltaic increases by 14%, the electrolyzer increases by 13%, and hydrogen tanks increase by 2%. After considering the worst case contingency event, for case I, the capacity of photovoltaic and fuel cell increase by 12% and 11%, and the electrolyzer increases by 34%; for case II, the capacity of photovoltaic and fuel cell increase by 8% and 11%, and the electrolyzer increases by 57%.

Keywords: sizing, multi-energy system, gas/electricity/heat, hydrogen storage system, optimization

1 Nomenclature

2 Acronyms

3	CCHP	combined cooling heat and power
4	CHP	combined heat and power
5	DG	distributed generation
6	EA	evolutionary algorithm
7	EH	energy hub
8	GA	genetic algorithm
9	MG	microgrid
10	MILP	mixed integer linear programming
11	MINLP	mixed integer nonlinear programming

12 Parameters

13	α	penalty values for load shedding of gas demands
14	β	penalty values for load shedding of electricity demands
15	γ	penalty values for load shedding of heat demands
16	C_{inv}	investment cost of each component
17	eff_{CHP}	gas utilization efficiency of CHP to consume gas
18	eff_{ch}	efficiency to produce H ₂ through the electrolyzer
19	eff_{ETH}	efficiency of ETH to produce heat
20	eff_{GTH}	efficiency of GTH to produce heat
21	eff_{heat}	fuel cell efficiency to produce heat
22	eff_{re}	heat recovery efficiency of CHP
23	$L_{el}^{i,t}$	electricity load demands at node i and time t (MW)
24	$L_{gas}^{i,t}$	gas load demands at node i and time t (MW)
25	$L_{heat}^{i,t}$	heat load demands at node i and time t (MW)

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