DESSLib – Benchmark Instance Structure, Component Models and Parameters

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Abstract. DESSLib provides benchmark instances obtained by real world data for synthesis problems of decentralized energy supply systems (DESS). This paper contains information about name convention, structure and generation of the DESSLib benchmark instances. Moreover, all parameters and functions needed to describe the component models and the overall system parameters are defined. See [2] for the description of the considered optimization problem.

Benchmark Instances for Synthesis of DESS

DESSLib contains categorized problem instances for synthesis problems of decentralized energy supply systems based on the original real world example stated by Voll et al. (2013) [6]. The raw data is given in hourly power demand levels. In order to reduce the computational complexity, the historical data was divided into representative load cases. Those cases represent the most common loads occuring per year. Moreover the peak load demands of the thermal energy demand are added as seperate loads. Note that peak load cases have a duration of zero. Thereby, the energy system will be designed to meet all occuring energy demands.

The instances are characterized by two dimensions: (i) the number of considered components in the superstructure S and (ii) the number of considered load cases L. A file representing an DESSLib instance is named, e.g., as follows:

`insS8L12_5.csv`

The number behind `S` represents the total number of components in the superstructure. The distribution amongst different component technologies is symmetrical, thus `S8` stands for a superstructure with two components of each of the four component types (c.f. [2]). Following this logic `L12` denotes an instance with twelve load cases plus two peak load cases. Within each `S`/`L`-category, the absolute values of the energy demands are randomly varied by a small factor. As a result, we obtained ten instances (index `0,1,...,9` at the end of filename) for each category. All instances in a category are structurally identical but vary numerically in their demands. The instance files are sorted into subdirectories with respect to their superstructure and load case category. Each .csv instance file is structured as follows:

i) parameters of all components in the superstructure
ii) energy demands of all load cases
iii) general parameters

The given component models and overall system parameters are valid for all benchmark instances of DESSLib. In the following, these parts of the instance file are described in detail.

i) parameters of all components in the superstructure

The file includes a description of the components performance ranges and parameters. $\dot{V}_s^{\mathrm{N,min}}$ and $\dot{V}_s^{\mathrm{N,max}}$ are given by `N_min` and `N_max` in the csv file, the parameters η^{N} (or $\mathrm{COP}^{\mathrm{N}}$), m_s and $\alpha_s^{\min}$ by `eta_N`, `m_l` and `alpha_min`. The parameters are listed in table 1.

	$\dot{V}_s^{\mathrm{N,min}}$ `N_min`	$\dot{V}_s^{\mathrm{N,max}}$ `N_max`	η^{N} `eta_N`	m_s `m_l`	$\alpha_s^{\min}$ `alpha_min`
Boiler $s \in B$	0.1 MW	14 MW	0.9	1.5	0.2
CHP engine $s \in C$	0.5 MW	3.2 MW	0.87	10	0.5
Absorption chiller $s \in A$	0.05 MW	6.5 MW	0.67	1	0.2
Turbo chiller $s \in T$	0.4 MW	10 MW	5.54	4	0.2

Table 1: Size ranges, efficiency, maintenance cost factors and minimum part-load factors of considered component types.

ii) energy demands of all load cases

Each instance file contains the energy demands for each timestep $\ell \in L$: `E_cold` for cold, `E_heat` for heat and `E_el` for electricity demand. The entries in `part` define the proportion Δ_ℓ of a load case of a period's duration.

iii) general parameters

The indices `gamma_CF`, `i`, `p_gas_buy`, `p_el_buy` and `p_el_sell` in a file denote the model parameters γ^{CF}, i, $p^{\mathrm{gas,buy}}$, $p^{\mathrm{el,buy}}$ and $p^{\mathrm{el,sell}}$. The parameters are taken from [6] and listed in table 2.

$p^{\mathrm{el,buy}}$ `p_el_buy`	$p^{\mathrm{el,sell}}$ `p_el_sell`	$p^{\mathrm{gas,buy}}$ `p_gas_buy`	i `i`	γ^{CF} `gamma_CF`
0.16 ct/kWh	0.10 ct/kWh	0.06 ct/kWh	0.08	10 a

Table 2: Economic parameters of DESS synthesis problem.

Part-load Performance and Investment Cost Functions

The nonlinear component models for part-load operation and investment cost curves used in this paper are stated below. The part-load performance of CHP units is based on measured data-points for several existing components. Moreover we assume that the part-load operation is not depending on the size of equipment, thus scaling to a normalized output power is possible. The part-load efficiency for boilers and adsorption chillers is modeled in analogy to [3]. The part-load performance behavior is modeled in analogy to [3] and additional correspondence with turbo compression manufacturers. The nominal efficiency of the CHP engines was taken from [1]. Maintenance-cost is based on [5], the investment cost curves consider are composed on information from [5] and data-base of industrial partners.

Part-load Performance: (1) – (5)

$s \in B$ (Boiler)

$$\dot{U}_s(\dot{V}_{s\ell}, \dot{V}_s^{\mathrm{N}}) = \frac{1}{\eta^{\mathrm{N,B}}} \left(C_1^{\mathrm{B}} \cdot \frac{\dot{V}_{s\ell}^2}{\dot{V}_s^{\mathrm{N}}} + C_2^{\mathrm{B}} \cdot \dot{V}_{s\ell} + C_3^{\mathrm{B}} \cdot \dot{V}_s^{\mathrm{N}} \right) \tag{1}$$

$$\eta^{\mathrm{N,B}} = 0.9,\ C_1^{\mathrm{B}} = 0.1021,\ C_2^{\mathrm{B}} = 0.8355,\ C_3^{\mathrm{B}} = 0.0666$$

$s \in A$ (Absorption chiller)

$$\dot{U}_s(\dot{V}_{s\ell}, \dot{V}_s^{\mathrm{N}}) = \frac{1}{\mathrm{COP}^{\mathrm{N,A}}} \left(C_1^{\mathrm{A}} \cdot \frac{\dot{V}_{s\ell}^2}{\dot{V}_s^{\mathrm{N}}} + C_2^{\mathrm{A}} \cdot \dot{V}_{s\ell} + C_3^{\mathrm{A}} \cdot \dot{V}_s^{\mathrm{N}} \right) \tag{2}$$

$$\mathrm{COP}^{\mathrm{N,A}} = 0.67,\ C_1^{\mathrm{A}} = 0.8333,\ C_2^{\mathrm{A}} = -0.0833,\ C_3^{\mathrm{A}} = 0.25$$

$s \in T$ (Turbo chiller)

$$\dot{U}_s(\dot{V}_{s\ell}, \dot{V}_s^{\mathrm{N}}) = \frac{1}{\mathrm{COP}^{\mathrm{N,T}}} \left(C_1^{\mathrm{T}} \cdot \frac{\dot{V}_{s\ell}^2}{\dot{V}_s^{\mathrm{N}}} + C_2^{\mathrm{T}} \cdot \dot{V}_{s\ell} + C_3^{\mathrm{T}} \cdot \dot{V}_s^{\mathrm{N}} \right) \tag{3}$$

$$\mathrm{COP}^{\mathrm{N,T}} = 5.54,\ C_1^{\mathrm{T}} = 0.8119,\ C_2^{\mathrm{T}} = -0.1688,\ C_3^{\mathrm{T}} = 0.3392$$

$s \in C$ (CHP engine)

$$\dot{U}_s(\dot{V}_{s\ell}, \dot{V}_s^{\mathrm{N}}) =$$

$$C_1^{\mathrm{C}} + C_2^{\mathrm{C}} \cdot \frac{\dot{V}_{s\ell}}{\dot{V}_s^{\mathrm{N}}} + C_3^{\mathrm{C}} \cdot \dot{V}_s^{\mathrm{N}} + C_4^{\mathrm{C}} \cdot \left(\frac{\dot{V}_{s\ell}}{\dot{V}_s^{\mathrm{N}}}\right)^2 + C_5^{\mathrm{C}} \cdot \dot{V}_{s\ell} + C_6^{\mathrm{C}} \cdot \left(\dot{V}_s^{\mathrm{N}}\right)^2 \quad (4)$$

$$C_1^{\mathrm{C}} = 550.3,\ C_2^{\mathrm{C}} = -1328,\ C_3^{\mathrm{C}} = -0.4537,$$
$$C_4^{\mathrm{C}} = 668.3,\ C_5^{\mathrm{C}} = 2.649,\ C_6^{\mathrm{C}} = 9.571e-05$$

$$\dot{V}_s^{\mathrm{el}}(\dot{V}_{s\ell}, \dot{V}_s^{\mathrm{N}}) =$$

$$C_7^{\mathrm{C}} + C_8^{\mathrm{C}} \cdot \frac{\dot{V}_{s\ell}}{\dot{V}_s^{\mathrm{N}}} + C_9^{\mathrm{C}} \cdot \dot{V}_s^{\mathrm{N}} + C_{10}^{\mathrm{C}} \cdot \left(\frac{\dot{V}_{s\ell}}{\dot{V}_s^{\mathrm{N}}}\right)^2 + C_{11}^{\mathrm{C}} \cdot \dot{V}_{s\ell} + C_{12}^{\mathrm{C}} \cdot \left(\dot{V}_s^{\mathrm{N}}\right)^2 \quad (5)$$

$$C_7^{\mathrm{C}} = 518.8,\ C_8^{\mathrm{C}} = -1203,\ C_9^{\mathrm{C}} = -0.5361,$$
$$C_{10}^{\mathrm{C}} = 579.3,\ C_{11}^{\mathrm{C}} = 1.464,\ C_{12}^{\mathrm{C}} = 7.728e-05$$

Investment cost: (6) – (9)

$s \in B$ (Boiler)

$$I(\dot{V}_s^{\mathrm{N}}) =$$
$$1.85484 \cdot \left[\left(11418.6 + 64.115 \cdot \dot{V}_s^{\mathrm{N}\ 0.7978}\right) \cdot 1.046 \cdot \left(1.0917 - 1.1921 \cdot 10^{-6} \cdot \dot{V}_s^{\mathrm{N}}\right)\right] \quad (6)$$

$s \in A$ (Absorption chiller)

$$I(\dot{V}_s^{\mathrm{N}}) = 0.50401 \cdot 17554.18 \cdot \dot{V}_s^{\mathrm{N}\ 0.4345} \quad (7)$$

$s \in T$ (Turbo chiller)

$$I(\dot{V}_s^{\mathrm{N}}) = 0.8102 \cdot \dot{V}_s^{\mathrm{N}} \cdot \left(179.63 + 4991.3436 \cdot \dot{V}_s^{\mathrm{N}\ -0.6794}\right) \quad (8)$$

$s \in C$ (CHP engine)

$$I(\dot{V}_s^{\mathrm{N}}) = 9332.6 \cdot \left(\dot{V}_s^{\mathrm{N}} \cdot \frac{\eta_s^{\mathrm{N,el}}(\dot{V}_s^{\mathrm{N}})}{\eta_s^{\mathrm{N,th}}(\dot{V}_s^{\mathrm{N}})}\right)^{0.539} \quad (9)$$

$$\eta_s^{\mathrm{N,th}}(\dot{V}_s^{\mathrm{N}}) = 0.498 - 3.55 \cdot 10^{-5} \cdot \dot{V}_s^{\mathrm{N}}, \quad \eta_s^{\mathrm{N,el}}(\dot{V}_s^{\mathrm{N}}) = \eta_s^{\mathrm{N}} - \eta_s^{\mathrm{N,th}}(\dot{V}_s^{\mathrm{N}}), \quad \eta_s^{\mathrm{N}} = 0.87$$

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