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Operation Unified Energy System (hub) to consider the reliability indices

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Abstract:.In this paper, then introduction of integrated energy systems, with regard to reliability indices as statically due to the development of societies, the growth of energy consumption and optimal and simultaneous of energy use have been studied. As well as, using with Genetic Algorithm (GA), the best state installed elements at different times in the form of statically model and the exact amount of input energies according to the value of electrical and thermal energies is determined. And using various efficiencies and prices of energy carrier in different hours in a year is considered. Finally, with extension period time of operation system in a prototype system is evaluated.

Keywords: Integrated Energy Systems, Integrated Energy Systems Operation, Multiple Energy Carrier, Statically, Genetic Algorithm.

1.Introduction

Many of today's energy infrastructures evolved during the second half of the twentieth century and it could be questioned if they meet the requirements of tomorrow. Besides congested transmission systems, many facilities are approaching the end of their prospected life time. In addition to that, other issues such as the continuously growing demand for energy, the dependency on limited fossil energy resources, the restructuring of power industries, and the general aimof utilizing more sustainable and environmentally friendly energy sources raise the question whether piecewise changes of the existing systems are sufficient to cope with all these challenges or a more radical change in system design be needed. Various scientific studies have investigated future scenarios based on boundary conditions given by today's structures, such as standardized electric voltage and gas pressure levels. Although these studies provide important insights, they often result in solutions that comply with the existing systems; possibly interesting and more long-term oriented solutions are "hidden", as they lie beyond system-given boundaries. In contrast to these studies, a project named Vision of Future Energy Networks was initiated at ETH Zurich together with partners2 that aims at a greenfield approach for future energy supply systems. Restrictions given by the existing systems are basically neglected in order to determine "real" optima. The consideration of multiple energy carriers, not only electricity,
represents one of the key characteristic of this project. It is believed that synergies among various forms of energy represent a great opportunity for system improvements. Besides the possibilities of
modern information technology, state-of-the-art as wellas emerging and looming energy technologies,
e.g. fuel cells, are taken into account. The time horizon for implementation is set to 30 to 50 years from now. Thus, the basic question to be answered is: "How should energy systems look like in 30 to 50 years, and what can be expected from them?"
Under these conditions, two key approaches are reasonable: transformation, conversion, and storage of various forms of energy in centralized units called energyhubs, and combined transportation of different energy carriers over longer distances in single transmission devices named energy interconnectors. It was soon realized that only a few established tools are available for the integrated analysis of multiple energy carrier systems, thus the project focused in a first phase on developing a modelling and analysis framework. In the

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second phase, which recently started, optimal system structures and operation strategies are determined and compared with conventional infrastructures using the developed tools. The result of this phase is the greenfield approach. The final phase of the project is dedicated to identifying transition paths and bridging systems leading from today's systems to the identified optimal structuresIn the remaining part of this paper, the key approaches, some developments as well as some results from the project Vision of Future Energy Networks will be presented[1].

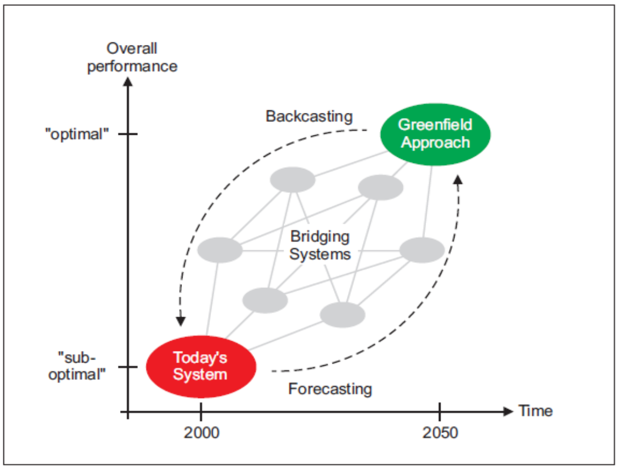


Figure 1: Transition from today's system to the greenfield approach via bridging systems

2. Combining Energy Infrastructures

Industrial, commercial, and residential consumers require various forms of energy services provided by different infrastructures. In the industrialized part of the world, coal, petroleum products, biomass, and grid-bound energy carriers such as electricity, natural gas, and district heating/cooling are typically used. So far, the different infrastructures are most often considered and operated independently. Combining the systems can result in a number of benefits. Synergy effects among various energy carriers can be achieved by taking advantage of their specific virtues: Electricity, for example, can be transmitted over long distances with comparably low losses; chemical energy carriers such as natural gas can be stored employing relatively simple and cheap technology. With so-called line packing techniques compressible fluids can be stored in pipeline networks, even if there are no designated storage devices installed. Combining the infrastructures means to couple them, thereby enabling exchange of power among them. Couplings are established by converter devices which transform energy into other forms. The question to be answered is of course where to put which devices and how to operate them. Answering this question is essential for the system layout and therefore one of the central issues in the project. Therefore models and methods have been developed to find the optimal coupling and power exchange among multiple energy carriers based on various criteria such as cost, emissions, energy efficiency, availability, security, and other parameters.[1-2]

3. The Energy Hub Concept

A key element in the Vision of Future Energy Networks project is the so-called energy hub. An energy hub is considered as a unit where multiple energy carriers can be converted, conditioned, and stored. It represents an interface between different energy infrastructuresand/or loads. Energy hubs consume power at their input ports connected to e.g. electricity and natural gas infrastructures, and provide certain required energy services such as electricity, heating, cooling, compressed air, etc. at the output ports. Within the hub, energy is converted and conditioned using e.g. combined heat and power technology, transformers, power-electronic devices, compressors, heat exchangers, and other equipment. Real facilities that can be considered as energy hubs are for example industrial plants (steel works, paper mills), larger buildings (airports, hospitals, and shopping malls), rural and urban districts, and island energy systems (trains, ships, and aircrafts).[2]

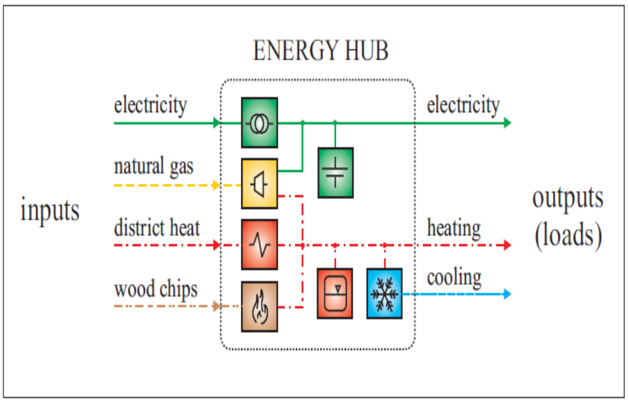


Figure 2: Example of an energy hub that contains a transformer, a micro turbine, a heat exchanger, a furnace, absorption cooler, a battery, and hot water storage.

The components within the hub may establish redundant connections between inputs and outputs. For example, the electricity load connected to the hub in Figure 2 can be met by consuming all power directly from the respective grid or generating part or all of the required electricity from natural gas. This redundancy in supply results in two important benefits which can be achieved using energy hubs. First, reliability of supply can be increased from the load's perspective because it is no longer fully dependent on a single network. Alternatively, reliability of the individual infrastructures could be reduced (e.g. by reducing maintenance) while availability for the load remains high. Second, the additional degree of freedom enables the optimization of the supply of the hub. Energy carriers offered at the hub's input can be characterized based on their cost, related emissions, availability, and other criteria; the inputs can then be optimally dispatched based on these quantities. Besides that, utilizing energy storage represents an opportunity for increasing the overall system performance therefore storage is already taken into account in the planning phase. Especially when energy sources with stochastically available primary energy (e.g. wind, solar) are considered, storage becomes important since it makes it possible to affect the corresponding power flows. Compensation of fluctuating power flows is possibly the most evident application of energy storage technology. However, investigations have shown that storage can be utilized in such a way that it positively affects all of the aforementioned criteria, especially when considering a liberalized market environment.[3]

4. Power Flow

For general investigations on the system level, steady state flow models are appropriate and commonly used. The flows through power converter devices can be analyzed by defining their energy efficiency as the ratio of steady state output and input. With multiple in- and outputs, a conversion matrix, or coupling matrix, can be defined which links the vectors of the

corresponding power flows. Figure 3 outlines this modelling concept. The coupling matrix describes the transformation of power from the input to the output of the hub; it can be derived from the hub's converter structure and the converter's efficiency characteristics. Describing the behaviour of storage devices requires the consideration of time and energy as additional variables. Various flow models are available for hydraulic and electric networks, from general network flow to more detailed steady state power flow models. The appropriate degree of approximation depends on the kind of investigation. Combined transmission links (interconnectors) can be modelled similar to energy hubs via coupling matrices. This is further elaborated in reference [3].

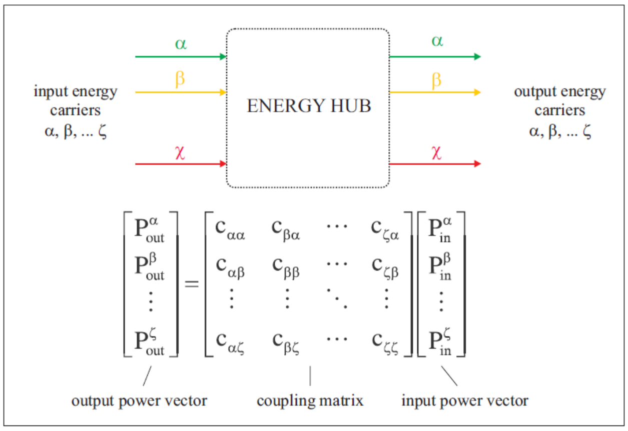


Figure 3: Modelling the transformation of power through an energy hub.

5. Reliability

Reliability and availability of energy supply is an important issue, therefore models have also been developed for this kind of investigations. Failure and repair rates can be defined for all components in the system. Considering an energy hub, failure and repair rates of the coupling elements can be stated in matrices similar to the mentioned coupling matrix in Figure 3, and this has been elaborated in . It is out of the scope of this paper to go into the details of such an analysis, but the general conclusions can be illustrated by an example. Figure 5 shows the German standard weekday electrical load profile for a small business, scaled to a total annual consumption of 20 MWh. The electrical load can be supplied by:

Direct electrical connection, capacity

$$C_{ee} = 10 \text{ kW} \quad (1)$$

Conversion chemical to electrical, capacity

$$C_{ce} = 2 \text{ kW} \quad (2)$$

Conversion thermal to electrical, capacity

$$C_{te} = 0.5 \text{ kW} \quad (3)$$

As can be seen from Figure 4 the load can during different time intervals be supplied through different combinations of the three supply channels given above.

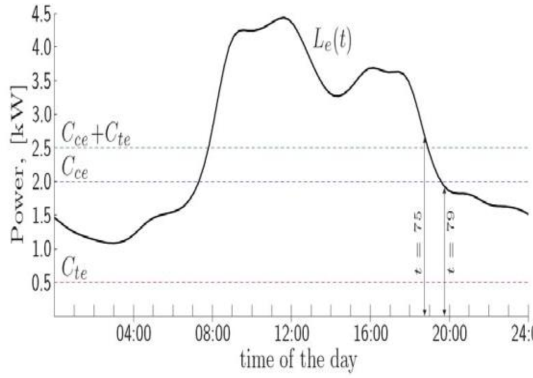


Figure 4: Electrical load curve of a small business of total annual consumption of 20 MWh. Indicated are the capacities of the different converters as given in text.

Obviously the load can be supplied by the electrical connection alone, but during different time intervals the load or part of the load can be supplied by the chemical to electrical connection alone or in combinationwith the thermal to electrical connection. This will increase the reliability indicators of the system, e.g. the availability and the Expected Energy Not Supplied, EENS. The detailed modelling using Markovtechniquesandnumerousapplication examples can be found in [3].

6.System Optimization

Various optimization problems can be identified when considering integrated multi-carrier systems. The basic question of combined optimal power flow is how much of which energy carriers the hubs should consume and how should they be converted in order to meet the loads at their outputs. This is an operational problem. In the planning phase, the optimal structure of the hub may be of interest, which can be found by determining the optimal coupling matrix which describes the conversions within the hub. Converters can then be selected in order to establish this optimal coupling, and missing technology can be identified. These and other optimization problems have been formulated and analysed using various criteria such as energy cost, system emissions, transmission security measures, etc. Bi- and multi-objective optimization can be performed by combining different criteria in composite objective functions. In reference [4] the details of the optimization procedure have been described. Here only one interesting result will be highlighted. The relationship between the outputs, i.e. the load vector **L**, and the input vector, **P**, in Figure 5can in matrix form be written as:

$$L=Cp \quad (4)$$

where **C** is the coupling matrix in Figure 4. A general optimality condition of the hub can then be written as:

$$\Psi\Lambda=C \quad (5)$$

where is the vector of system marginal prices and Λ the vector of hub marginal prices. This latter equation is the equivalent to the well-known economic dispatch rule for generators in electrical systems, the so called "equal incremental cost rule" as illustrated in Figure 5.

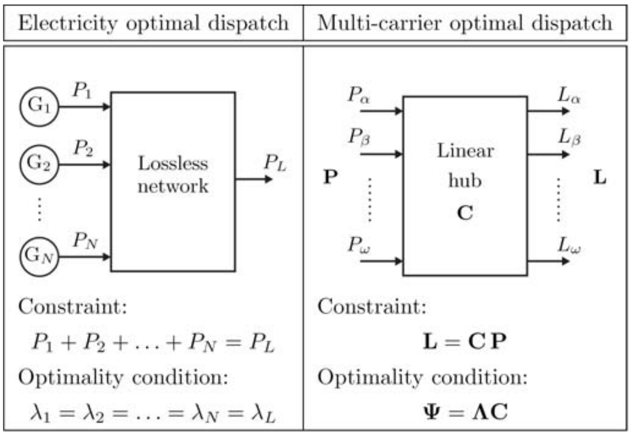


Figure 5: Electricity and multi-carrier optimal dispatch.

7. The objective function

$$F = Operation\ cost + Emission\ cost + cost(Ens) \tag{6}$$

That objective function consists of three parts. The first part is related to the cost of installing equipment in one year's time:The first part of the energy costs and the cost of operation of the equipment, including the cost of buying electricity from the grid .hzynh production at prices determined by the network, the cost of energy produced by the plant is the simultaneous production of electricity and heat.

$$Operation\ cost = 365 \times \sum_{t=1}^{24}\left(\sum_{i=1}^{Ni}[c_1 + c_2 P_i(t) + c_3 P_i^2(t)] + \sum_{\alpha=1}^{N\alpha}[P_\alpha(t) \times \cos t\, P_\alpha(t)]\right) \tag{7}$$

In the above passage c_ (1) the fixed cost maintenance and c_2 and c_3 represents the variable costs and exploit are chp, α type and i-type fuel energy input to the system integrated components installed.Cost P (t) electric In energy prices according to pu be purchased from the grid.
The second part of the cost of offenses pollution and emissions of toxic carrier of change

$$Emission\ cost = 365 \times \sum_{t=1}^{24}\sum_{\alpha=1}^{N\alpha}[E_1 + E_2 P_\alpha(t) + E_3 P_\alpha^2(t)] \tag{8}$$

E_3 and E_2 E_1 coefficients and coefficients are apply the cost of pollution and air quality are determined by the controller.Here factor θ is added to the system of power sharing between the boiler and the inlet gas chp defines the value of θ is between zero and one
Equations describing the system can be expressed as a matrix:

$$L(t) = CP(t) \tag{9}$$

$$\begin{bmatrix} L_e(t) \\ L_h(t) \end{bmatrix} = \begin{bmatrix} \eta_T & \vartheta \times \eta_{chp_e} \\ 0 & \vartheta \times \eta_{chp_h} + (1-\vartheta)\eta_B \end{bmatrix} \begin{bmatrix} P_e(t) \\ P_g(t) \end{bmatrix} \tag{10}$$

In the above passage coefficients Pe and Pg by express carrier power and carrier gas are also η_T efficiency of trans-η (chp (e)) electrical efficiency chp and η (chp (h)) thermal efficiency chp and η_B efficiency heat Boilers are [5]
The fourth part of the cost of supply of energy is not cost Reliability

$$cost(ENS) = ENS_i \times Rens_i \tag{11}$$

In the above passage coefficient r Ens and Ens are not represents cost and lack of energy not supplied
The importance of an integrated system to optimize the use of energy carriers according to the constraints is that the current system, it becomes clear. Thus, the constraints to specify some of the variables are used such the limitations include the following

$$0 \le P_i(t) \le P_{i_{max}} \tag{12}$$

$$i \in e, g \tag{13}$$

And of the the limitations is that the variable values in the relationship between input and output connection and apply a matrix parameters

$$L_e(t) = \eta_T P_e(t) + \vartheta \eta_{chp_e} P_g(t) \tag{14}$$

$$L_h(t) = \vartheta \eta_{chp_h} P_g(t) + (1-\vartheta)\eta_B P_g(t) \tag{15}$$

At this stage, in addition to the proposed constraint must be considered in the limit θ.[6]

8. The introduction of an integrated system of exploitation:

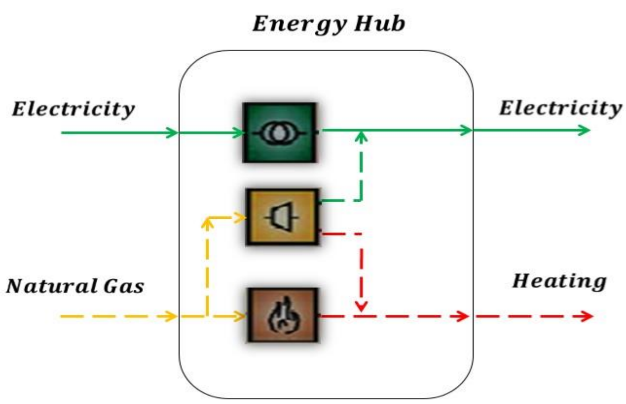


Figure 6: The model is intended for hub Energy Systems

The demand for electricity and heat at different times of day charts are as follows:

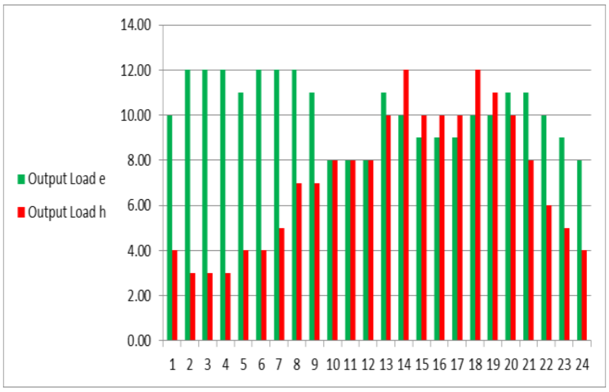
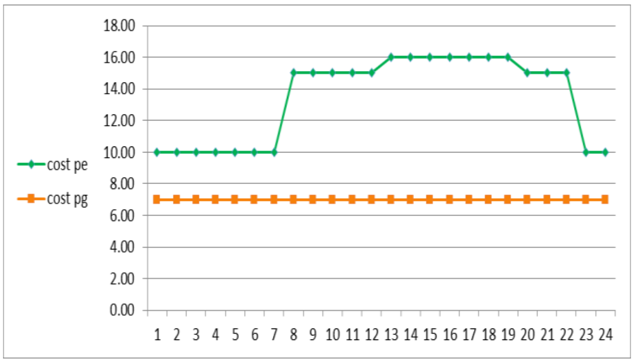


Figure 7: The question of electricity and heat

In energy prices in the calculation and determination of the amount of gas and electricity is very effective input, this model in energy prices is evaluated according to the following diagram:



Figue8: The cost of electricity and gas energy input to the system

After the simulation and run the software according to the demand of electricity and heat, the system of transformers 2, Chp 2 and boiler 1 usesElectric and gas input is calculated by the optimization software in the following diagram:

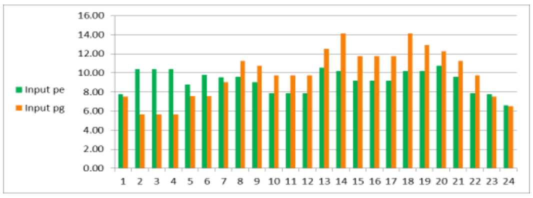


Figure 9: The amount of electrical energy input to the system in the first scenario study

Electricity and gas energy input to the systemIn this model, taking into consider the amount of gas boiler in the hub energy input by a factor θ is divided between the boiler and Chp Gams is determined by optimization software, the following diagram to determine the value of θ[7].

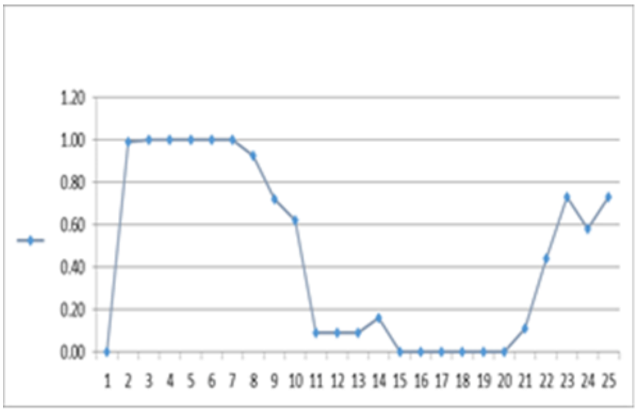


Figure 10: The division of power between the inlet gas,chp,boiler

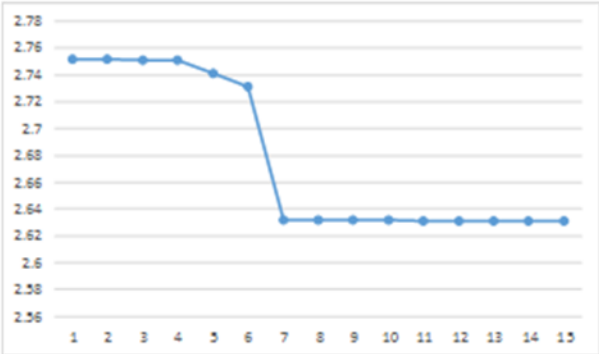


Figure 11: The results of the objective function reliability for multiple repeat

8. Conclusion

With respect to total static models to evaluate energy system with genetic algorithm achieved thefollowing results:an integrated system capable of optimizing the energy input required according to the desired output capable. static model of innovation in the operation of the energy system. In the simulation shown when the input carrier tariffs will The value of reliability is an important area of economic assessment and design philosophy of operation cantilever conside Evaluation of reliability (lolE) with the help of this model when times greater benefits can be accepted studies Due to the genetic algorithm used in this model, we have the most efficient response It is possible to optimize the input power requirements according to the required output power drill.In the simulation shown when the input carrier tariff system the most optimal solution for the operation of the integrated energy system offers.

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