DATA-BASED MODELLING, SIMULATION AND OPTIMIZATION OF THE OPERATION OF PRODUCTION PLANTS

VIENNA young SCIENTISTS SYMPOSIUM

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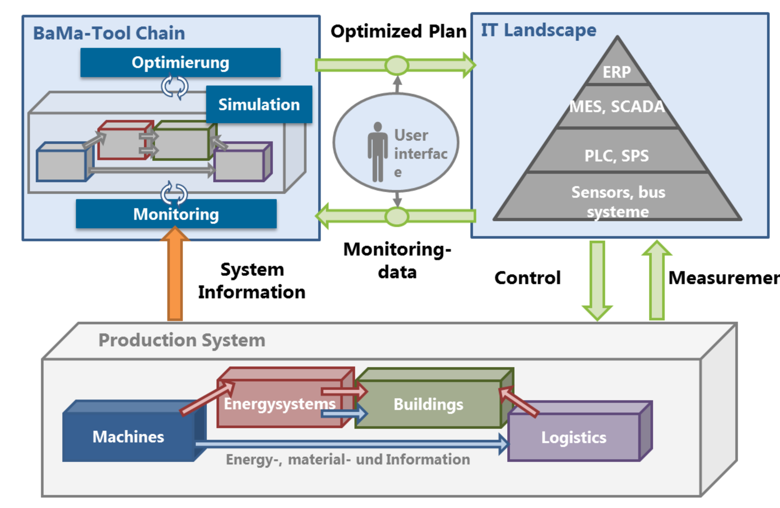
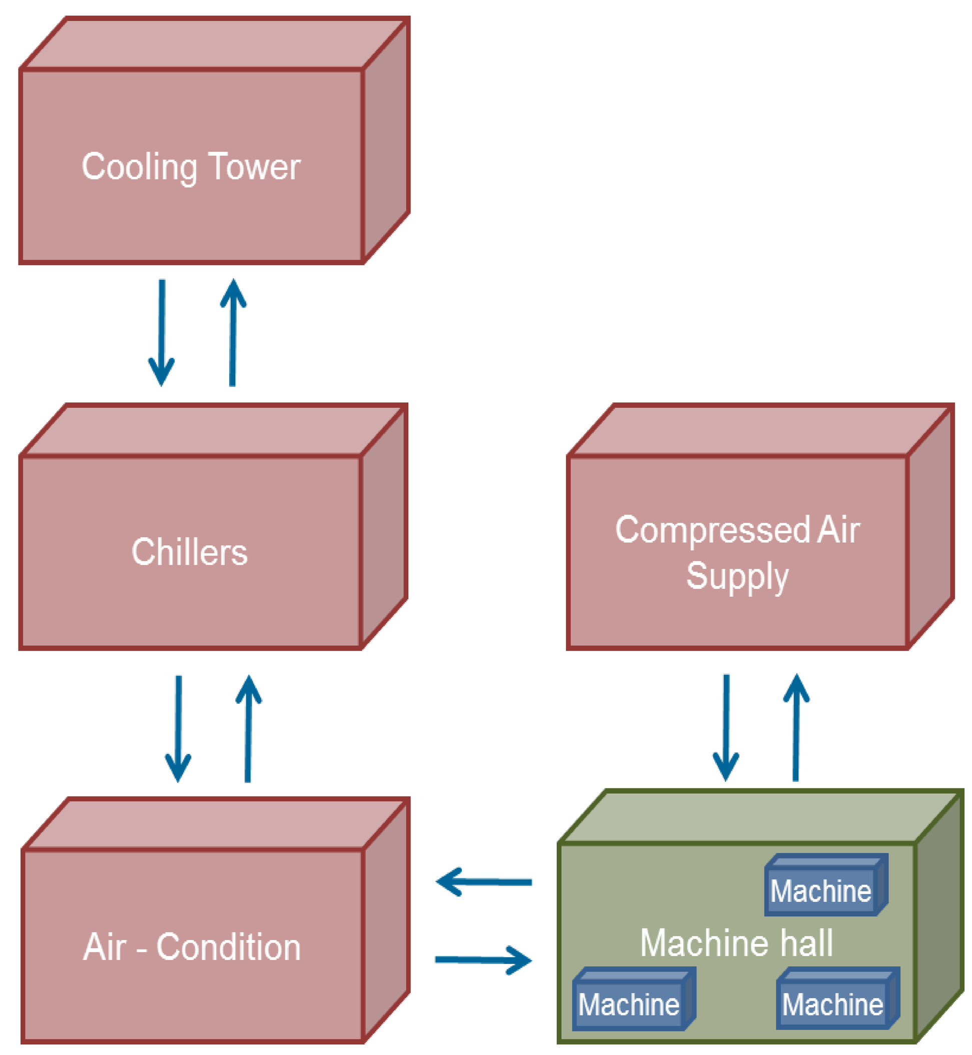
Introduction

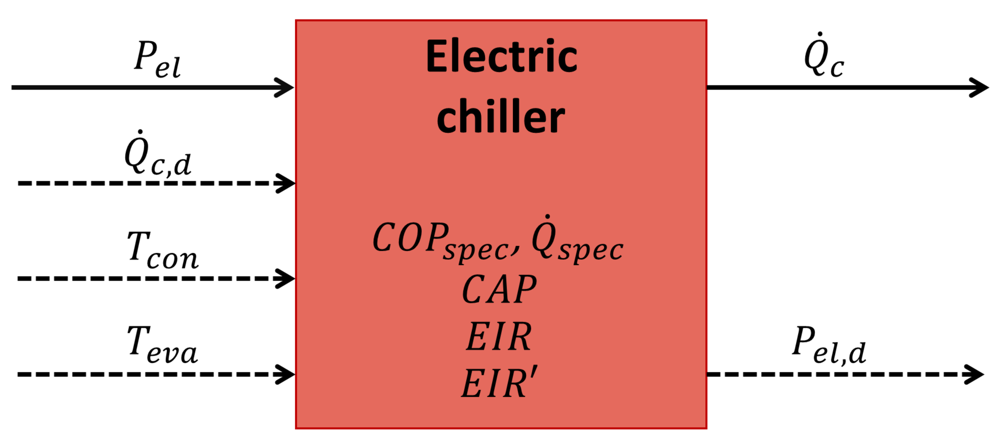
The goal of the research project BaMa (Balanced Manufacturing) is to increase energy efficiency of industrial production sites. A toolchain, consisting of the three main parts monitoring, simulation and optimization, is developed to optimize the operation strategy and production plan of a given production facility. Additionally to usual parameters such as production time and delivery reliability, energy consumption and CO2-emissions are taken into consideration. In order to illustrate the method, the development of an energy-optimized operation strategy for a refrigeration plant, consisting of four electric chillers, supplying a semiconductor production plant is presented. Several different methods for modelling, as well as optimization were identified and applied to the problem. Without any additional measurement equipment or interruption in the operation of the plant, it was possible to build sufficient models. The results of the application are propitious and indicate the feasibility of the BaMa-method in general.



Material and Methods

By measuring relevant input- and output signals, a model can be parameterized. This model makes the prediction of the behaviour of the electric chillers possible. [1]. The generation, preprocessing and aggregation of data results in models that can be used to optimize the underlying plant's operation. Figure 1 shows how an electric chiller is modelled according to the BaMa-method. Relevant input parameters are electrical power P_{el}, the cooling demand $\dot{Q}_{c,d}$ and condensator and evaporator return temperatures T_{con} and T_{eva}. Based on those inputs, the cooling power $\dot{Q}_c$ and the electrical power demand $P_{el,d}$ is calculated. A model proposed by Monfet and Zmeureanu [2] which is based on the work of Hydeman et al [3] was used. For each individual chiller unit, the values for $\dot{Q}_{spec}$, COP_{spec}, as well as the coefficients a_i, b_i and c_i were determined based on the available monitoring data.





$$\dot{Q}_{avail} = \dot{Q}_{spec} \cdot CAP \qquad PLR = \frac{\dot{Q}_c}{\dot{Q}_{avail}}$$

$$\dot{Q}_c = min(\dot{Q}_{avail}, \dot{Q}_{c,d}) \qquad P_{el,d} = \frac{\dot{Q}_{avail}}{COP_{spec}} \cdot EIR \cdot EIR'$$

$$CAP = f(T_{con}, T_{eva}) = a_1 + a_2 T_{con} + a_3 T_{eva} + a_4 T_{con}^2 + a_5 T_{con} T_{eva} + a_6 T_{eva}^2$$

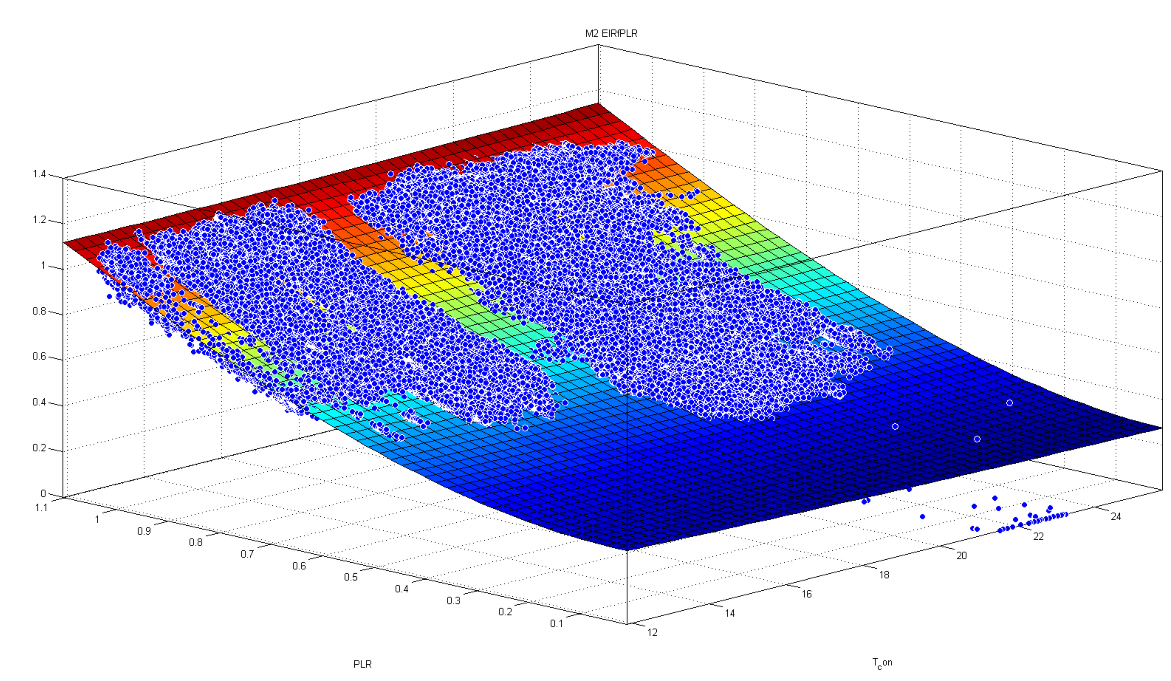
$$EIR = g(T_{con}, T_{eva}) = b_1 + b_2 T_{con} + b_3 T_{eva} + b_4 T_{con}^2 + b_5 T_{con} T_{eva} + b_6 T_{eva}^2$$

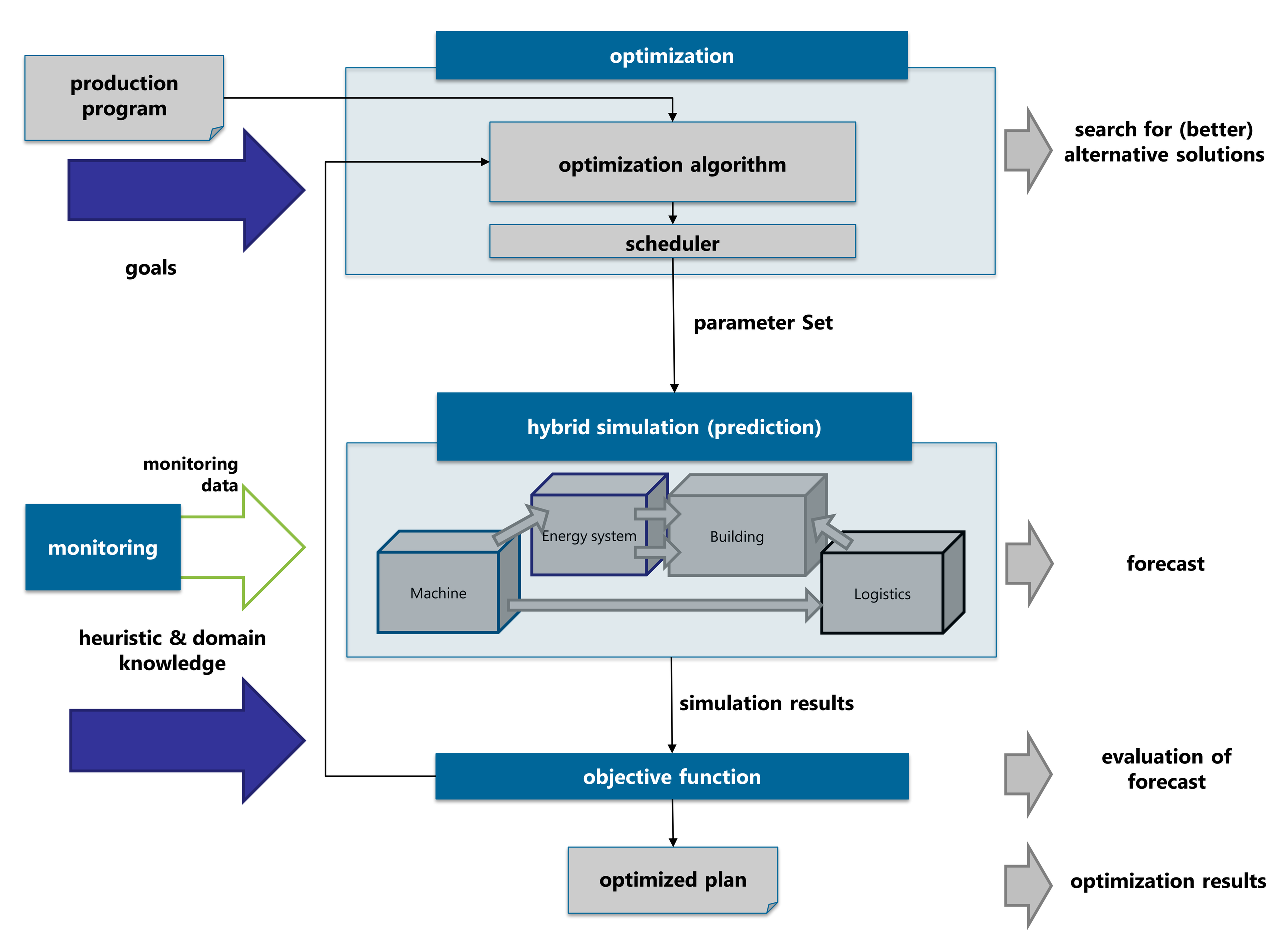
$$EIR' = h(T_{con}, PLR) = c_1 + c_2 T_{con} + c_3 T_{con}^2 + c_4 PLR + c_5 PLR^2 + c_6 T_{con} PLR + c_7 PLR^3$$

Results and Discussion

	Machine 1	Machine 2	Machine 3	Machine 4
Rel. Error	10%	3%	3.8%	2%
R^2	0.46	0.97	0.99	0.99

The root mean square model prediction errors for the electrical energy demand of the four electric chillers are 10%, 3%, 4% and 2%, respectively. Apart from the first value, those errors are in the same order of magnitude as those presented by Monfet and Zmeureanu.
The differences in model performance between the machines can be described by the poor data quality. Currently, new datasets are collected.
The presented approach demonstrates that considering energy efficiency in the operation of existing refrigeration plants can reduce overall energy demand significantly. As a next step, the developed model will be combined with other cubes in order to locate optima in a broader set of possible solutions. Furthermore, the optimized operation strategy should be adapted in order to validate the predicted saving potential. For additional improvements of the model and the optimization results, the existing monitoring system needs to be expanded to the remaining chillers.
Using the chiller models, a simulation of the underlying chiller plant consisting of four electric chillers can be set up. As a baseline for the assessment of the optimized operation strategy, chiller operation states for a period of 80 days in 2015 were used. Together with the information about the corresponding temperature signals T_{con} and T_{eva} in that period, alternative chiller operation states were found by choosing the optimal chiller unit (i.e. the one with the lowest electrical energy demand at a given time). First simulation results indicate, that energy savings of up to 10% are realistic.
The BaMa optimization framework consists of two optimizations stages. Those can work independently and aim at the optimization of different parts of the production facility. Within the first stage, the sales plan and production program for a given planning period are used to generate an optimized production plan. The second optimization stage takes an production plan (either the result of stage one, or generated externally) and optimizes the operation of the building equipment. The quantities for every product are being translated - via a scheduler - to a preliminary production plan. Similar to the production program there are parameters in the form of schedules and variables for machines and equipment in the periphery of the production, including building services. The simulation results are performance indicators that are evaluated in an objective function. The implementation of building equipment optimization (such as the presented chillers) is developed.





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