1

Current and Future Challenges for Production Planning Systems

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Summary. This article elaborates on the coming challenges production planning departments in utilities are facing in the near and remote future. Firstly, we will motivate the complexity of production planning, followed by a general solution approach to this task. The development of a new generation of energy management tools seems necessary to fulfill the need to handle uncertainty and eventually cover stochastic processes in energy planning. These new energy management systems have to include complex workflows and different methods and tools into the planning process.

Key words: Energy management, Uncertainty in energy planning

1.1 Introduction

Energy planning can be complicated. Due to its techno-economic nature it was already complex in monopolistic times and has gone from 'complex' to 'very complex' thereafter.

First of all, it is important to explain what production planning in the energy industry or energy planning, respectively, means. Production planning is the commercial and technical organization that uses power plants to generate income. It is the key organizational function that translates production capacity into commercial value. In a nutshell, this means that without production planning, power plants are not generating any income.

The objective for production planning is clearly to maximize the profits that can be created by running power plants. As power plants inherently produce more than electricity, the maximization of profits is typically subject to a number of restrictions. These restrictions are particularly heat supply but also technical restrictions and ancillary service commitments. Experience shows that production planning becomes very complex as soon as power plants produce more than just straight power.

1.2 Production Planning – History and Present

A good example for how complex production planning really is and what significant commercial impact it can have is depicted in Fig. 1.1. The producer's every day production capacity of his power plants is offered to the Nord Pool exchange. When it is profitable, production is sold. The set of assets consists of a number of smaller and larger production units using different fuels. Furthermore, heat is supplied to a stretched-out heat grid and different steam grids. This example of production planning shows very clearly that even small improvements in performance can have a significant impact on results. Moreover, small planning mistakes can have very serious commercial and operational consequences.

In Fig. 1.1 actual hourly production in December 2004 is depicted. At first glance, it can be difficult to understand how this can be an optimal production plan. However, there are some good explanations. The variation in production is a function of many factors such as weekend stops, ancillary services delivery, and commercial production. In the chart, one can see the 'coal-minimum' and the 'oil-minimum' situations where reserves are delivered automatically and manually. On closer examination, it is even possible to see that different on-duty crews have different views of what is maximum and minimum production capacity.

The deregulation of energy markets has had a very significant impact on production planning: Firstly, the purpose of planning has changed from minimizing cost of delivery to maximizing profits. Secondly, new markets have emerged, like spot power, gas, and CO_2. Thirdly, the roles of market

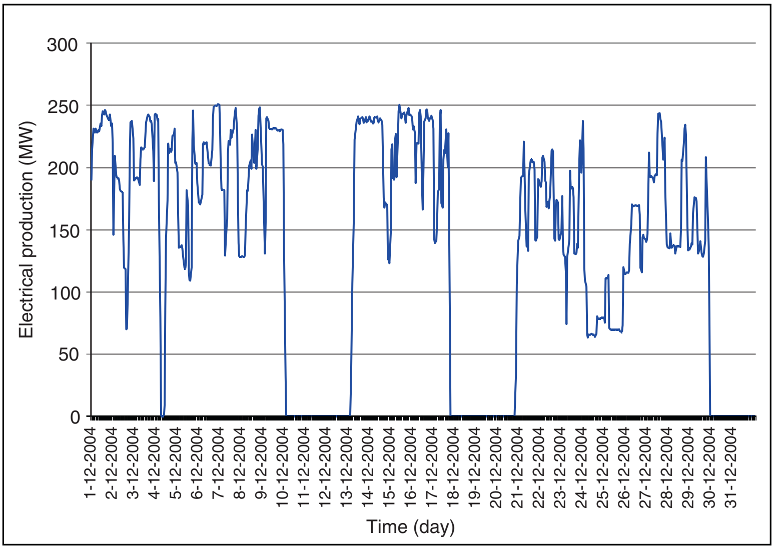

Fig. 1.1. Production planning in practice

participants have changed. Consequently, as a result of this, the production planning workflow has changed as well.

In order to understand where production planning and production planning tools are today, it makes sense to look at the historical framework. The European energy markets have been deregulated in the past 10 years and this had a considerable impact on how energy companies behave in the market and organize themselves, see [1]. Firstly, deregulation meant that the purpose of an energy company changed. Today, companies very much strive to make profits for their owners whereas prior to deregulation, the objective was to minimize delivery costs to consumers. In the past, very often the result of a year was decided when the annual budget was drawn up. Secondly, deregulation has opened new markets. Today, it is possible to trade spot power and gas, imbalances and CO_2 emission rights – all products that were not even known a few years ago. Lastly, deregulation changed the roles of market participants. In some countries, this led to new players entering the markets, yet in other countries, this resulted in the emergence of a few and very large energy giants.

To illustrate how much all these factors have influenced production planning, taking a look at an illustration of production planning work processes prior to deregulation makes sense.

Prior to deregulation, production planning consisted of the forecasting of load and later the computation of the optimal production plan, see Fig. 1.2. While this looks like a relatively simple task, it can be a difficult calculation, especially if the production system is complex. Previously, the focus of attention was mostly on technical power plant availability and how to meet production requirements. In those days fuel prices were relatively stable and hence there was no need for daily calculations. Instead, calculations were made weekly or even less frequently. For shorter periods, a prioritization of production units was sufficient. Deregulation and the emergence of new markets changed all this radically.

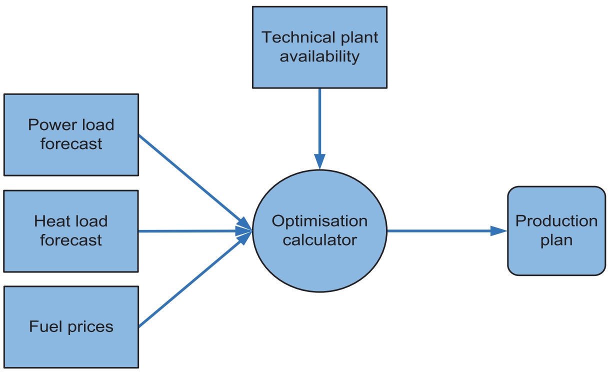

Fig. 1.2. Production planning before deregulation

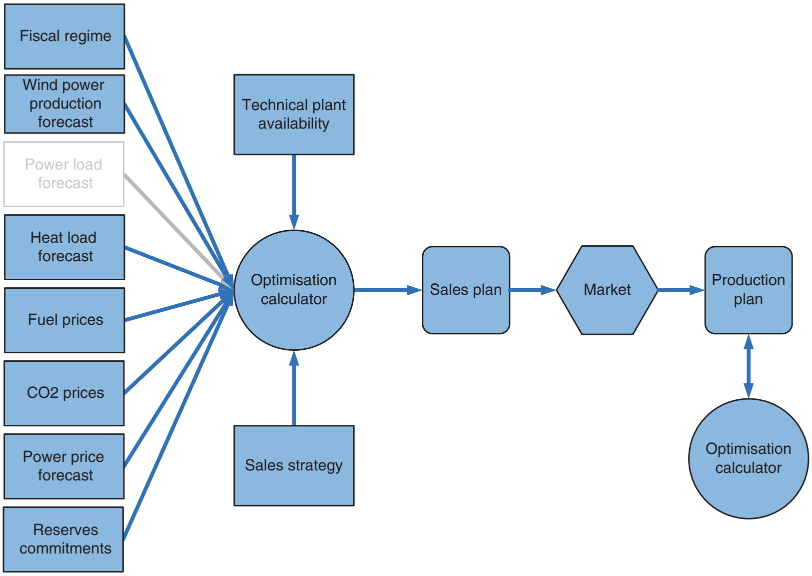

Fig. 1.3. Production planning work process today

Today, however, the amount of input data is not only much larger but inputs are also much more volatile, see Fig. 1.3. This means that production planners have to work very efficiently day in and day out to compile information, do the necessary analysis and planning and then submit these to the exchanges before noon. That means they have complex workflows, many methods, lots of data and less time for it all. At the same time, the new deregulated environment called for the development of new systems for effective data management and shorter calculation time for optimization. The good news is that power load forecasting is no longer a task for production planning. Today, this is the task of the retail manager. Furthermore, there are now several new trading platforms, like exchanges, over the counter trading, cross border trading and intraday trading. This is why sales strategies play an important role. All in all, nowadays, production planning has very much become a task of optimizing sales in an environment of volatile power and fuel prices.

1.3 The Coming Challenge: Handling Uncertainty

"It's hard to predict, especially the future". This well-known saying attributed to Winston Churchill proves to be valid in production planning as well. In fact, production planning is very much exposed to risks and uncertainties, although not much attention has been paid to this aspect for quite some time. One of the most volatile commodities in the world is power, even more volatile than fuel oil prices. As a comparison, in the period April 2006-March 2007, the fuel oil price has varied from US $50 to 75 per barrel, while the Nord Pool price showed much larger variations and German EEX prices have been even more volatile. This makes it very difficult to predict power prices a day ahead.

Fig. 1.4 depicts the base load prices for 2006 in the Nord Pool area DK2.

But it is even harder to predict hourly prices and profiles, which is shown in Fig. 1.5 for Nord Pool DK2.

While hourly spot prices are so difficult to predict, they are one of the most important parameters in a production plan. Wrong forecasts of spot prices can lead to wrong decisions. If you base heat planning on a wrong spot price profile, you could end up with power production in low price hours and heat production in high price hours. Generally, you have to optimize the combined heat, steam and power production portfolio regarding your forecasts

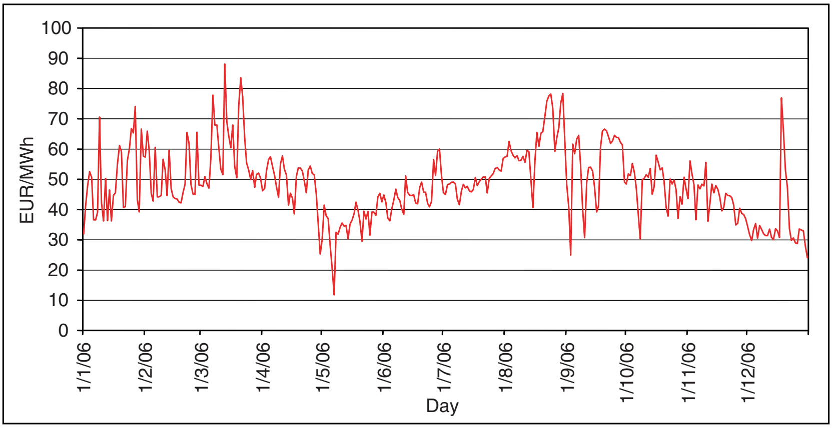

Fig. 1.4. Spot prices (Nord Pool DK2)

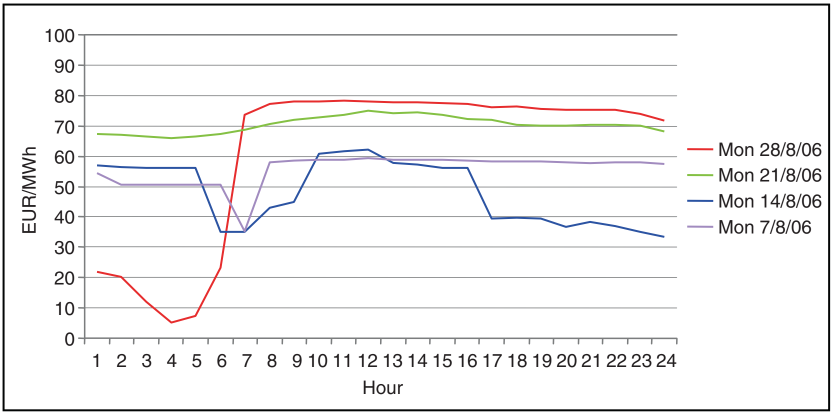

Fig. 1.5. Hourly spot prices (Nord Pool DK2) on 4 Mondays in August 2006

of district heating, steam production and spot prices. This is naturally always prone to errors resulting in imbalances between your day-ahead planning and the required and delivered customer load.

While it is yet impossible to forecast exact values, in fact sometimes it is possible to forecast the direction of imbalances. One example can be found in the field of wind power forecasting.

The graph in Fig. 1.6 shows the forecasting of wind power production at a Baltic Sea wind farm and the actual production curve. It shows that the prediction for wind power production a day-ahead is very accurate.

However, the problem is that predictions are not always as good. As can be seen in Fig. 1.7, which shows said wind farm on another day. This time, the forecast results in notable imbalances which are priced with different imbalance costs for each hour. The graph illustrates also the commercial risk attached with such a wrong prediction regarding the exact time of the wind load curve.

Forecasts of power prices and wind power production are by far not the only sources of uncertainty and of commercial risks. There is uncertainty in heat load forecasts, fuel prices, unit failures and many more. Basically, uncertainty cannot be avoided. Uncertainty about input parameters leads to imbalances – and even wrong decisions. This is especially true for virtual power plants, see [5]. Also, one can forecast some effects in a short time horizon. The key to this problem is handling the risks effectively. This is important because the commercial implications can be very substantial. So, how do you do production planning under uncertainty? One approach is to ignore it, because

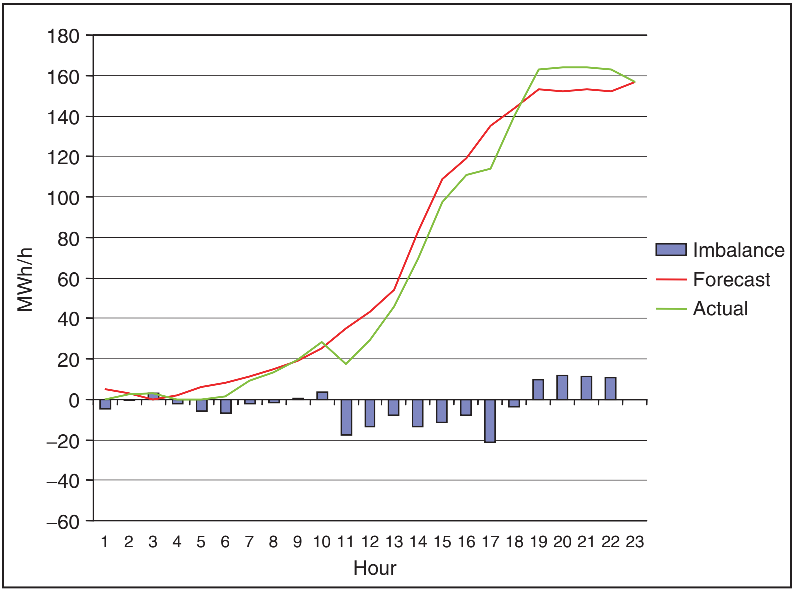

Fig. 1.6. Forecasting wind production and little imbalances

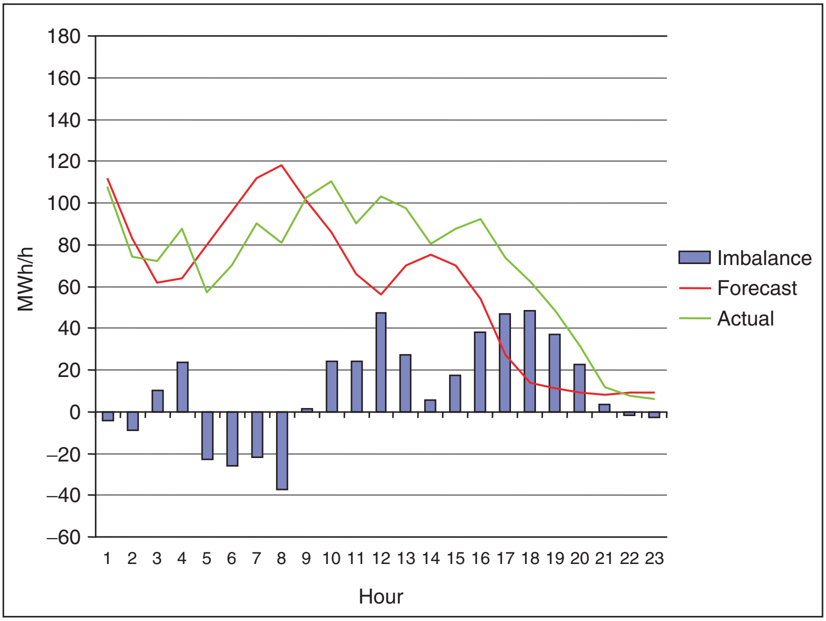

Fig. 1.7. Forecasting wind production with time error and big imbalances

production planning is complex enough, already. Another approach is to deal with it. This means to start acknowledging that input parameters to production planning are uncertain. Rather than avoiding it, it makes sense to accept it, work with it and even to exploit the opportunities it brings. The good thing is that sometimes being wrong does not have serious consequences. It also means to acknowledge that input parameters are not always symmetrical and that it is sometimes possible to predict the shape of the distributions.

There are many reasons why markets will become even more volatile in the future. One reason is the increasing share of renewable production capacity. Moreover, the deregulation of the gas markets will be another source of uncertainty. The effect of global warming will lead to shortages of cooling water and cause additional volatility in the market. How politicians will respond to this also causes concern. Furthermore, CO_2 quotas are predicted to come in short supply.

1.4 Requirements for Future Production Planning Systems

Overall, the energy management systems as they exist today form a strong basis. The last 10 years have shown great achievements: Despite enormous changes in the market environment, the industry has been able to adapt without market failures leading to blackouts. The market participants have been able to cope with very large changes in the commercial, legal and regulatory environment. User-friendly tools for modeling power plant systems and for solving complex optimization problems have been developed. Production planning has developed from being a technical activity to being a commercial core competence.

To exemplify the latter, Fig. 1.8 depicts the BoFiT modeling environment. BoFiT is a production planning solution suite widely used in German and European utilities, e.g. Vattenfall Europe [3] and Stadtwerke Munich [6]. It features among other things a graphical user interface that facilitates the development of the features of a model and explain its results within teams. It also helps to explain the results to the business staff using their own language.

Now, it is time to face the next challenge: Efficient handling of uncertainty and automation of time-consuming business processes. In future, energy management tools will have to be developed further, much in the way that risk management systems have developed with a far stronger focus on strategies and trading opportunities.

With the deregulation of energy markets, uncertainty became a key feature of the commercial management in many energy companies, like risk management and hedging, financial trading portfolios, new end-user products with fixed price components. Production planning is very much exposed to risks now, however, for some reason this had received less attention in the field of multi-commodity systems.

So what could a future production planning solution look like?

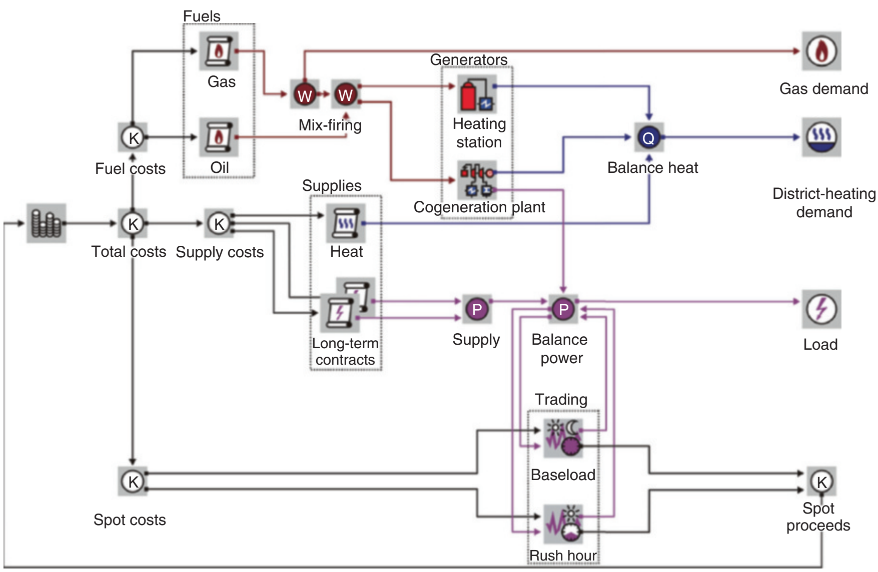

Fig. 1.8. BoFiT model building environment

First of all, planning tools should be bridges between mathematical methods and the user. Hence, they should provide a comfortable way to use a graphical modeling environment. Furthermore, planning tools should be easy to integrate and to adapt in an IT system environment. Planning tools should support relevant user decisions. They should deliver reliable results and offer a quick response time. Classical decision horizons are long-term, medium-term, day-ahead, and intraday. They should be supported by the planning tool see Fig. 1.9. This overall frame covers the period from 15 min to 60 months. Long-term covers several years to one or two decades. Medium-term reaches from 1 week to 60 months. Day-ahead covers the period from 24 h to 1 week and intraday concerns 15 min to 30 h. Optimizing these planning horizons requires corresponding grid load forecasts, sales forecasts, market forecasts, demand forecasts of clients and client groups.

On top of the above-mentioned requirements, new production planning systems need to support a different approach of choosing a market strategy. Figure 1.10 shows the basic modules of future production planning systems. There exist various input parameters which are put in order of decreasing volatility. Hence, the most volatile parameter is the "imbalance price forecast" and the least volatile are "reserves commitments". The input to the planning are not just single-point forecasts but some form of uncertain or stochastic data. These inputs enter into a trading strategy analysis module where it is possible to evaluate different strategies with different combinations of input data. Part of this calculation can be an optimization calculation that is integrated in the trading strategy analysis tool. The result of the trading strategy analysis is a sales plan which in turn leads to a production plan.

The benefits of such a new type of energy management system are very obvious: The user is now choosing a market strategy that reflects the uncertainty in the market and which is optimized to exploit possibilities of spikes as well as to minimize expected imbalance costs. The question is whether this type of system is simple to create. The consensus is that more work has to be

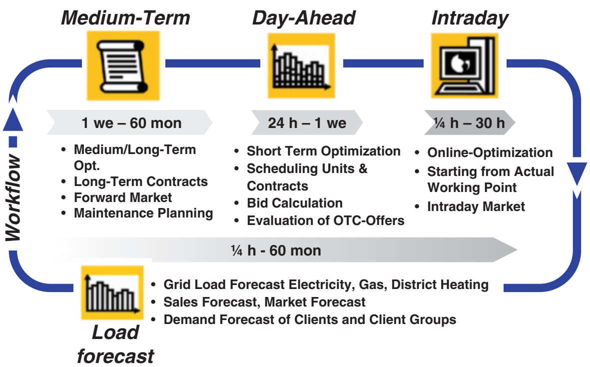

Fig. 1.9. Decision horizons and results in production planning

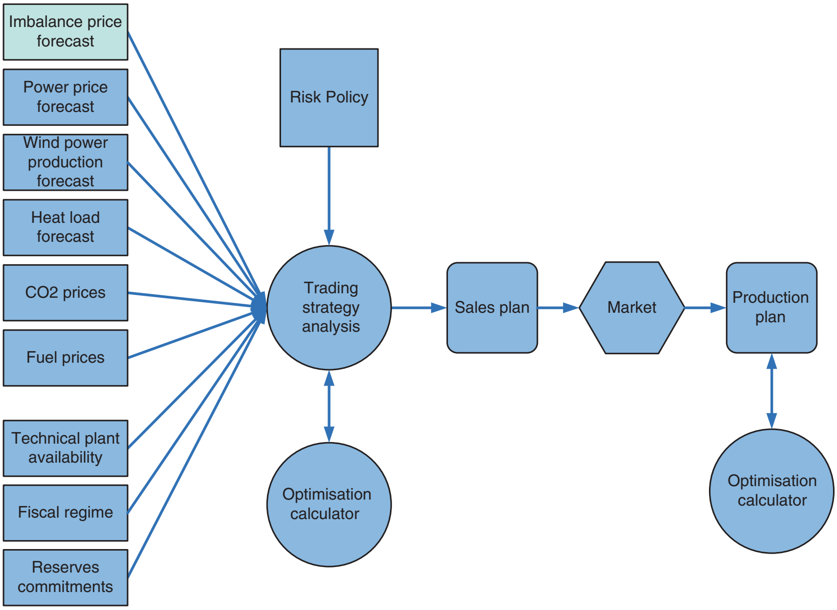

Fig. 1.10. Production planning system of tomorrow

done and this will involve stronger cooperation between research institutions and solution providers, e.g. see [2, 4].

Handling uncertainty implies a need to include stochasticity. Evaluation of different strategies leads to handling a multitude of calculations and scenarios, which ultimately requires an automation environment and extensive data management system to support the users efficiently.

From an IT perspective, integration aspects call for the application of a modern service-oriented architecture, the principles of which are exemplified in Fig. 1.11. It facilitates the different phases in the life cycle of a production planning solution, being process configuration, process execution, and process control. Major benefits of the SOA are its flexibility in deployment and its readiness to add new services e.g. stochastic optimization kernels or Monte Carlo simulations.

The SOA facilitates the definition and automatic execution of workflows. This is shown in Fig. 1.12. Following the detailed analysis of the business processes these are orchestrated in a graphical user interface. Once approved, the workflows are executed automatically at certain times or manually. They are controlled by showing the actual parts of the workflow being successfully or unsuccessfully executed. The services and the data inputs are combined and executed in the order of this workflow. The results are stored in a time series management system and can be visualized in user-defined reports.

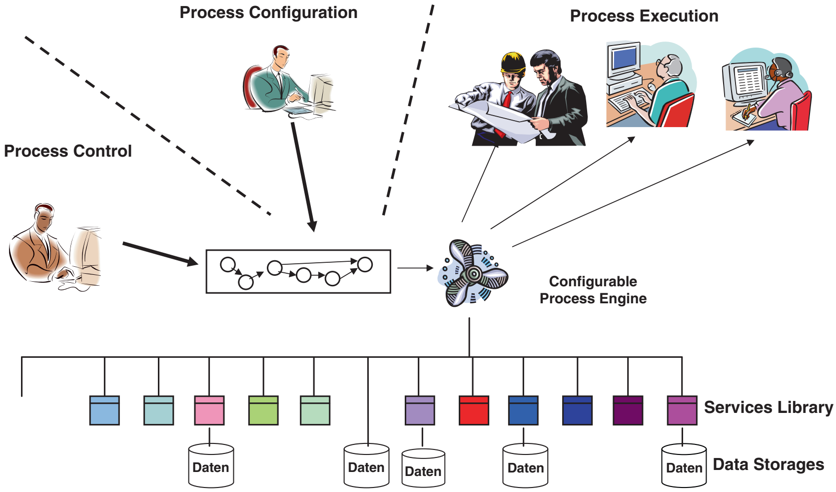

Fig. 1.11. Principle of a Service Oriented Architecture (SOA)

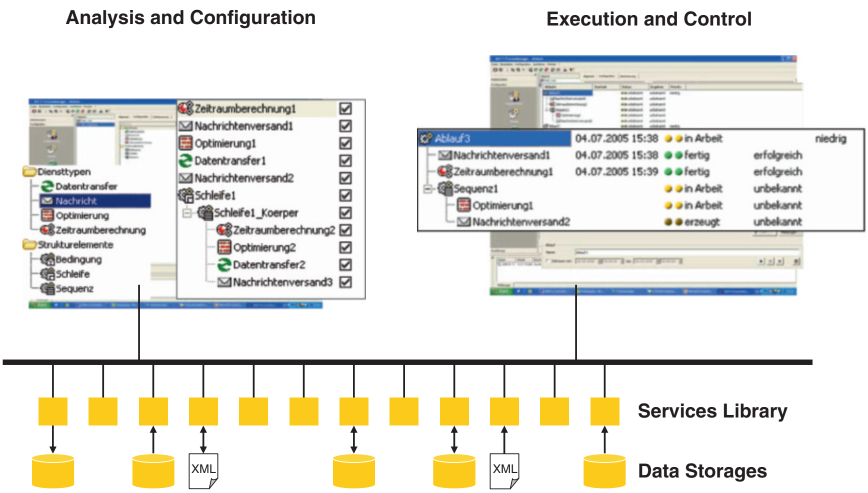

Fig. 1.12. Configuration and automatic execution of workflows

While the requirements from business and IT are fairly clear today, there is still a good deal of research to be done on the core issue of handling uncertainty. It is of pre-eminent importance to find a meaningful way how to describe and represent uncertain input. Unless a very simple and systematic way to estimate uncertain input parameters can be found for production planners, there is little chance that such a system with stochastic optimization tasks will be used by the clients in multi-commodity production planning.

Furthermore, the need for quick response times in real planning and bidding situations has to be fulfilled. However, there is a growing need to enhance energy management systems to deal with uncertain (stochastic) input because of the requirements of the planning process as shown above.

Today's planning systems for co-generation of thermal and electrical production are in general not equipped to deal with uncertain input. Nevertheless, the data models used must not be so different from stochastic models because the fundamental efficiency curves of power plants or the maximum or minimum power production capacity of the plants are not stochastic. Therefore, there is a possibility to migrate existing deterministic models by using stochastic input distributions and scenario tree techniques. The future will have to prove the benefits of those approaches in real production planning processes.

Apart from the technical challenges, there are also educational and organisational issues which need to be addressed rather sooner than later. It is necessary to educate production planners to deal with uncertainty. On top of that it is necessary to educate planners and traders in each other's 'languages'. On one hand, production planners will have to become more familiar with the complicated language of financial traders who juggle terms like delta-hedging or spread options and many more. On the other hand, traders need to become more familiar with the technical characteristics and physical limitations of power plants and co-generation units respectively. The fact that the economic implications of production planning decisions are coming more into the focal point of planning, leads to the question, whether production planning should be executed by the trading companies or the power plant owners. There is good reason for both choices and a lot of internal struggles upon the right answer to the question is currently ongoing in many European utilities. Depending on the final decision, it will be necessary to check and afterwards adjust the business processes around production planning.

1.5 Conclusion

Production planning has come a long way over the past 10 years. A number of methods and tools have been developed which make it possible to operate in new markets and new environments. So far, major focus has been placed on developing tools that can support production planning in a situation where uncertainty is ignored. Nevertheless, risk management and handling uncertainty is an area that still needs to be improved. As the future is most likely to bring more volatility, the next step forward is to start finding a way to efficiently manage risk and uncertainties and especially to be ready to exploit the opportunities this brings. Finally, this integration should be linked with process and workflow automation systems. This enables the automation of those very complex calculations which are going to integrate a number of different tools and methods to achieve certain goals under tight time schedules.

All technical improvements need to be accompanied by corresponding organisational and educational measures to ensure an outmost exploitation of the business improving potential which the improved planning systems offer. This is the challenge energy companies have to master!

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