Factory Configuration Analysis and Optimization Using InFrame Synapse Simulation Suite

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Introduction

Detailed resource planning, analysis and optimization are mandatory to ensure good return in investments of any new factory. Highly sophisticated mathematical models and computer simulation methods are used to analyze several factory layout concepts in order to find feasible solutions that achieve the proposed production throughput within acceptable building and ownership costs. Usually, the proposed concepts are designed manually by highly qualified engineers involving hundreds or thousands of work hours, and many crucial decisions are founded entirely on the work experience of the designers. The high number of possible Fab configuration, and the amount of work necessary to define and analyze each of them, limits the number of concepts analyzed and therefore reduces the probability of finding the optimal solution. Automated concept analysis and optimization tools are necessary to reduce the amount of work and time needed, to increase the fab planning phase reliability and to find optimal solutions which are beyond the designer's intuition.

acp-IT's InFrame Synapse Simulation Suite offers complete and automated solutions to define, analyze and optimize factory concepts. Using XJTec's Anylogic discreet event simulation platform, OptQuest non-smooth problems solver engine and our specialized simulation component libraries, we are able to model and automatically optimize factory various factory layout structures. In the following we will present a case study about the application of our optimization techniques for determining the amount and position of necessary buffers in a production line.

Problem definition

Consider a thin-film photovoltaic production line with a designed throughput of 100MW / year. According to the static analysis, the throughputs of the equipments are 20% higher (in average) then the designed throughput of the factory, excepting the bottleneck equipments which throughput is exactly 100MW / year. Although the static analysis considers down times and scrapping probabilities of the equipment, after building a detailed simulation model of the production line, it is shown that the actual production throughput of the factory is almost 10% lower than the designed one. It is also shown that by adding storage buffers at the front of each production equipment the throughput is improved and it reaches the maximum possible throughput of 100MW/year. Due to the fact that the cost of the buffers are too high to be feasible to add buffers to each equipment it is necessary to determine the most important buffers that maximizes the factory throughput and minimizes the additional building costs.

Approach

OptQuest non-smooth problem solver engine, is consist of a heuristic search algorithm that repeatedly generates set of input parameters for a given optimization problem in order to minimize or maximize a certain output parameter or function. Combined with Anylogic simulation models it is possible to search for simulation parameters that optimizes the behavior/output of a given simulation model.

Using XJTec's Anylogic, and our specific simulation component libraries, we built a detailed simulation of the production line, modeling all the important peculiarities of the equipments and transportation systems, including down times, batching and material routing logics. The model includes FIFO buffers placed between consecutive production equipments, and a simulation parameter to each buffer to enable or disable it. An objective function is also defined to evaluate the goodness of the production line considering the production throughput and the number of enabled buffers. According to the acquisition price of the buffers and the selling price of the products we have considered that one buffer is equivalent to 0.3% of the annual production, so each buffer utilized adds a penalty of 0.3% to the production. Considering these data we built an optimization experiment, using OptQuest problem solver engine where the parameters to optimize are the simulation parameters to enable/disable buffers, and the function to maximize is the production of the line considering the buffer penalties.

Results

Using OptQuest problem solver engine, we have executed 223 simulation runs for 3 month of production. Fig. 1. Show the results of the experiments.

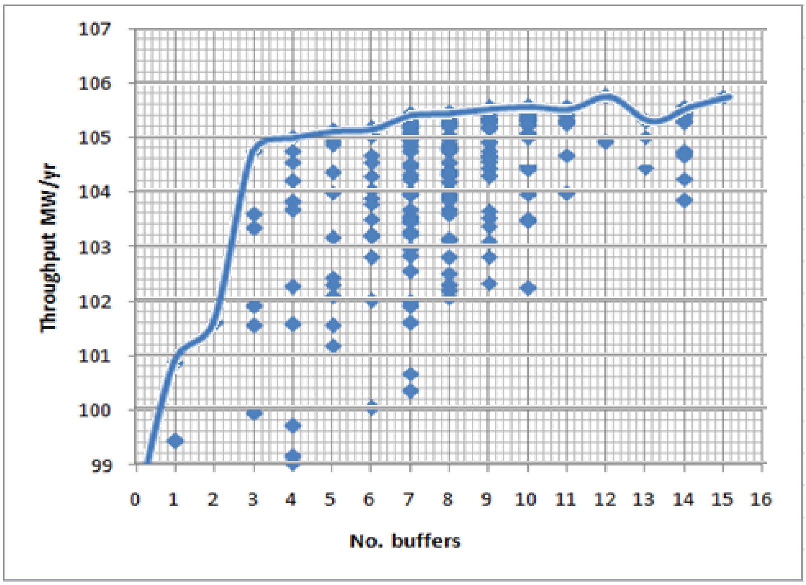

Fig. 1. Experimental results for 3 month of production, 223 simulation run

Fig.1. shows much higher production throughput due to the fact, that the first 3 month of production does not includes all down events so the estimated annual production is higher than the actual annual production. Nevertheless the impact of the buffers is well represented even for the first 3 month of production. Using the experimental results, we have computed a statistical impact factor of each individual buffers using the following formula:

$$Buffer\_Impact\_Factor_{buff} = \frac{AverageThrougput_{WhereBuffIsEbabled} - AverageThroughput_{WhereBuffIsDisabled}}{MaximumThrougput}$$

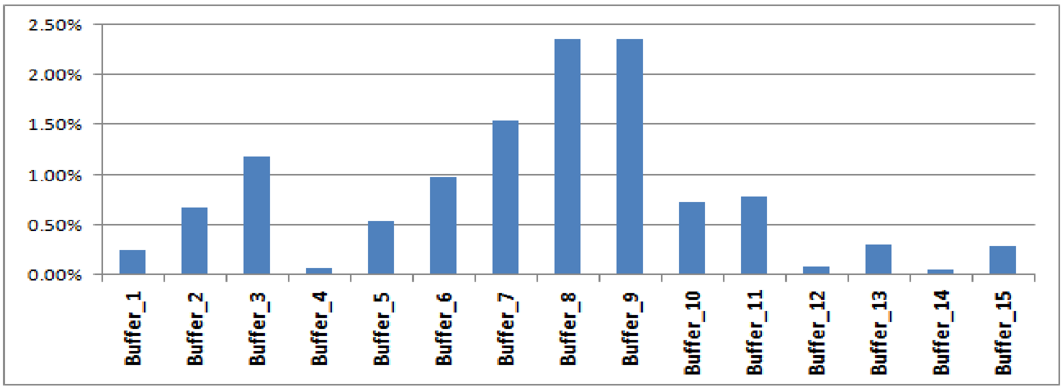

Fig.2. Impact factors of individual buffers.

Impact factors are utilized to sort by importance the buffers and determine one optimal buffer configuration for each number of buffers utilized. Fig. 3. shows the experimental results for running complete 1 year simulations with optimal configurations for 0,1,2,3,4 and 16 buffers.

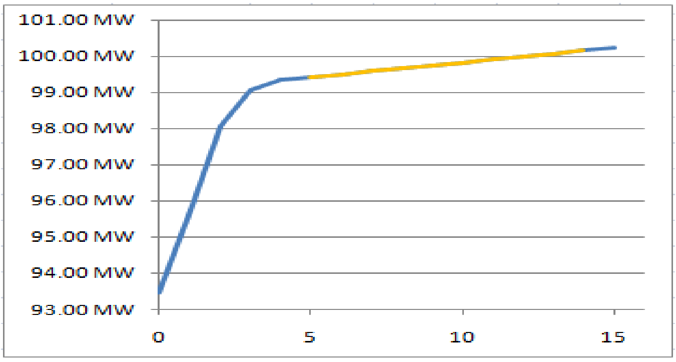

Fig. 3. Experimental results for 1 year of production 6 simulation runs

It can be concluded that the number of necessary buffers is 4 and the required buffers are Buffer_8, Buffer_9, Buffer_7 and Buffer_3.

Alternative Approaches

An alternative approach to determine the importance of individual buffers is to run a simulation experiment where each buffer is enabled and monitor the average utilization of the buffers.

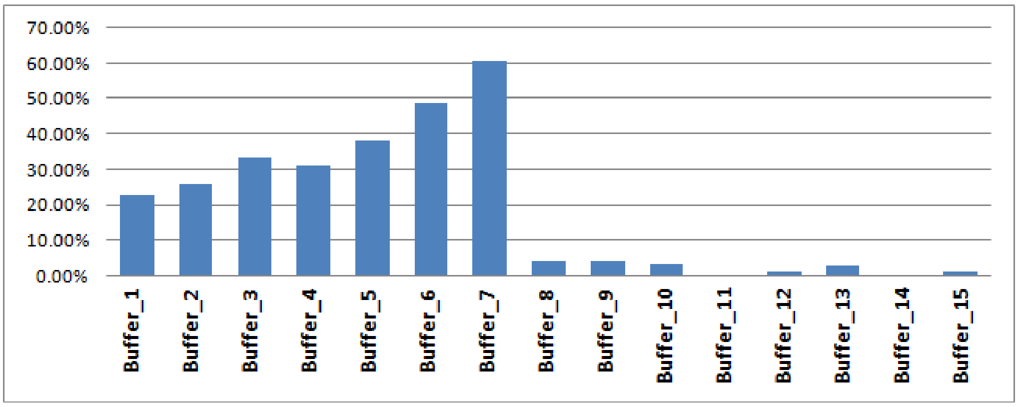

Fig. 4. Average buffer utilization.

In Fig. 4. we can observe that the buffer utilization is not relevant in determining the importance of the buffers. This is because buffers which are mostly full or mostly empty have no effect on the throughput of the production line.

However if we monitor the amount of changing in the buffers loading we can obtain much more relevant results. To compute the amount of changing in the buffer load, we introduce the following formula:

$$Dynamics_{buff}(n) = \begin{cases} \text{abs}(WIP^{buff}_{n} - WIP^{buff}_{n-1}) & \textit{If} \quad signum(WIP^{buff}_{n} - WIP^{buff}_{n-1}) = signum(WIP^{buff}_{n-1} - WIP^{buff}_{n-2}) \\ 0 & \textit{Otherwise} \end{cases}$$

$$Dynamics_{buff} = \sum \boldsymbol{Dynamics_{buff}(i)}$$

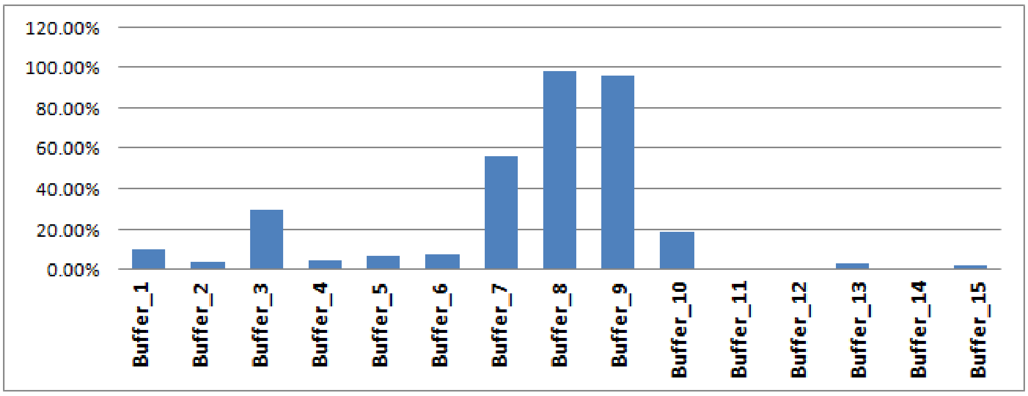

Fig. 5. Buffer dynamics.

Buffer dynamics analysis give more accurate result than buffer utilization analysis but there are still some deviations from the buffer impact factors obtained using optimization algorithms.

Conclusions

Using acp-IT's InFrame Synapse Simulation Suite it is possible to improve factory throughput with minimal costs. We have shown that advanced heuristics search algorithms with repeated simulation experiments, are superior to static analysis of single simulation runs, however static analysis can be used to reduce the set of possible solutions improving the performance of the search algorithms. Also, we have introduced a new method for analyzing buffer usage by single runs, method that gives close results to the advanced optimization runs.