Applied knowledge management for complex and dynamic factory planning

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ABSTRACT

This paper describes the functionality, applicability, and the development of dependency maps which are the basis for standardized information exchange between responsible parties during the fab design process. Examples and experiences are related to the solar industry; however this generic approach may be applied to a wide range of different industry sectors with similar challenges. The aim is to provide a guideline for realizing a fab design of dynamic and complex production systems. Its main benefit is a higher degree of transparency regarding dependencies within the production system, which results in a reduction of risk for incorrect planning. In addition, it enables the factory designer to execute the fab planning process and further continuous improvements for achieving respective targets.

Introduction

A production system typically comprises objects such as production equipment, buffers, operators, infrastructure or production control software. These objects, which play a major role in the fab design process, are referred to as 'Fab Planning Objects' (FPOs) in this document.

Due to the dependencies that exist within production systems, changing attributes or requirements of single FPOs directly affect other FPOs. This is especially true in the planning phase where changes resulting in additional complexity are a frequent occurrence.

Suppliers of end-to-end factories are faced with this complexity in particular, as they are involved in planning multiple lines simultaneously. Moreover, the variation in planning and implementation phases as well as the different releases of single equipment increases the complexity of the whole planning process.

In addition to that, great effort is required to coordinate the high number of responsible parties arising from the large number of objects existing in complex production systems. If there is no structured and standardized process for information exchange between the affected persons in charge, the organization can barely keep pace with the changes that so frequently occur. The result could be a high risk of information loss and a wasted use of human resources. The opportunity to react rapidly and reliably to changing conditions becomes limited.

Generic planning processes are described in guidelines such as VDI 5200 for "Factory planning – Planning procedure" [1]. More than this, however, an information management system is necessary to identify changes in production systems and to find suitable solutions quickly. Such a solution enables persons who are responsible for FPOs to (re-)act efficiently in changing conditions. The FPOs are structured in a hierarchical way, such that one FPO may consist of several underlying FPOs up to the topmost entity that represents the whole fab. Depending on the vertical level in the FPO structure, the basis for decision-making may differ.

Functionality of the dependency map

Fab planning objects

To assess the functionality of a production system it is necessary to divide it into its integral parts [2], hereafter referred to as FPOs. These include all those units that have to be considered during the fab design process and which are the responsibility of the Fab Planning Department, such as:

- Production equipment
- Operators
- Transport routes
- Handling equipment
- Production control software
- Facilities, like power supply
- Environment, health and safety.

There also exist a range of objects that are not the liability of the Fab Planning Department. However, they also have to be integrated into the planning procedure. Among these, the product design, production process, and process-related requirements shall be mentioned.

Elements of the fab planning objects' interface

Every FPO is engineered, designed, or at least represented according to its quantity in the fab. The actual configuration is based on the properties of the preceding objects. Based on the configuration, each FPO owns special properties that are fundamental to the planning of subsequent objects.

Therefore, almost all objects have requirements regarding previous FPOs. In addition, FPOs have their own properties which reflect the required set of information as well as the obligation of forwarding the information in the case of change. These two aspects, 'requirements' and 'properties' respectively, compose the two interfaces of each single FPO.

"Such a solution enables persons who are responsible for FPOs to (re-)act efficiently in changing conditions."

1. Requirements interface of the Fab Planning Objects

The most important part of this interface is the list of the requirements for preceding FPOs. The person responsible defines requirements for its FPO and places a request to the person in charge of the previous FPO to be aware of relevant changes. In cases where the properties of the previous object are changed, the person that placed the request will be informed. 'Relevant' changes are basically those that require confirmation or lead to re-evaluations or further actions.

It is in the nature of things that successive FPOs will have to decide on changes and for others to assume such changes. Therefore, it is enough to inform the person in charge. In some cases, the changes may be considered as being of minor importance and for this reason the responsible person doesn't have to be informed at all. The decision to contact the relevant party lies with the person responsible for the FPO that places the request. It is up to him/her to establish the criteria and the bandwidth for defining

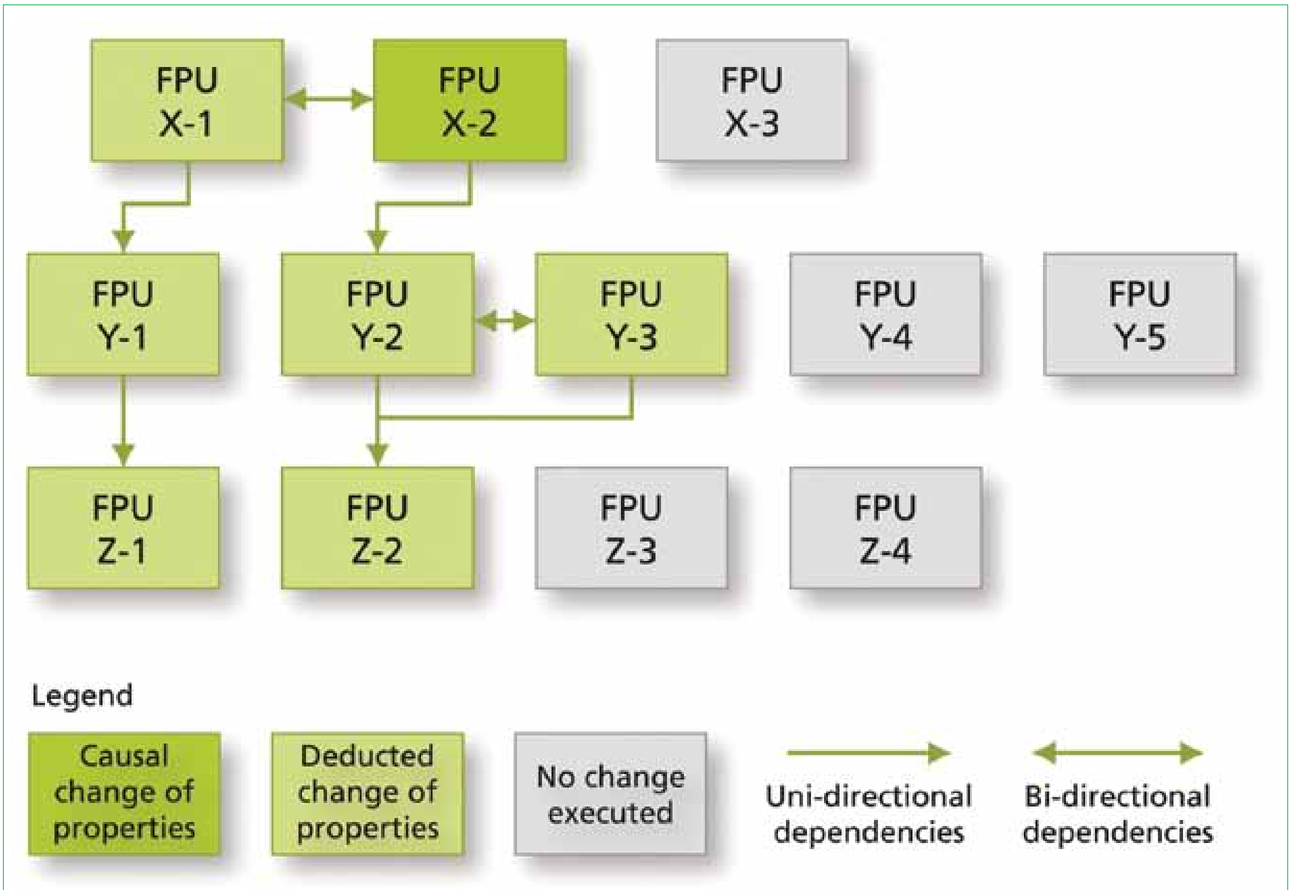

Figure 1. Generic dependency diagram of Fab Planning Objects.

the following categories that classify the changes to the previous object:

"*To-be-confirmed (FPO/TBC)*": Confirmation of the person in charge required. (In the case of measurements which demand the adaption, the confirmation is no longer needed and will be replaced by the highlighting of its relevance if the change meets the criteria of this category.)

"*Information (FPO/I)*": The person responsible for the precedent object may assume that the adjustment will be confirmed. The person in charge of the downstream object will be informed about the corresponding change.

"*No-action (FPO/NA)*": No information will be communicated.

A representative requirement could look like the following:

Process capacity exceeds 20 pieces per minute → category: *To-be-confirmed*

Process capacity ranges from 15 to 20 pieces per minute → category: *Information*

Process capacity is beneath 15 pieces per minute → category: *No-action.*

The requirements and the corresponding categories and bandwidths should not only reflect the normal case but also special lots such as worst case-/ breakdown-/ rescue-/ and other scenarios which generally require exceptional handling.

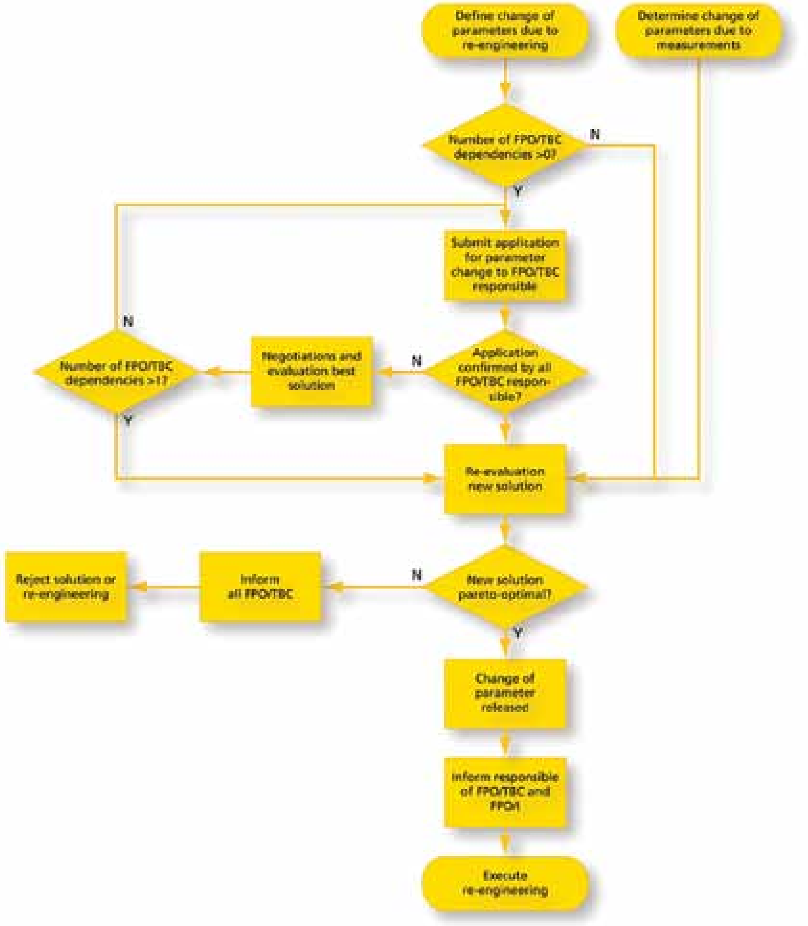

Figure 2. Simplified process flow diagram for uni-directional dependencies of Fab Planning Objects.

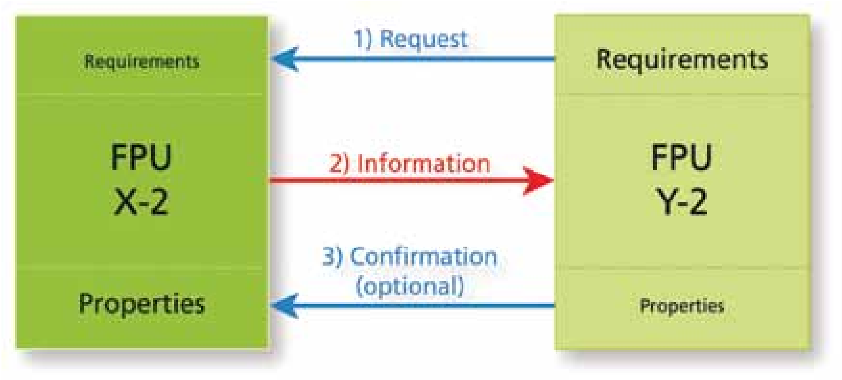

Figure 3. Interfaces of Fab Planning Objects.

The 'requirements' interface should also contain information about the respective person in charge and should provide a possibility to add further comments to the change request.

2. Properties of the Fab Planning Objects

In accordance with the requirements of a FPO, the overview of single properties is a core part of this interface. Such information, for example, can refer to the properties of mechanical handling, the process time, the temperature of the material after finishing the process, the process flow to produce the product or the maintenance rate. In general, the interface describes the FPO and all properties that are of importance to the succeeding object.

It is therefore mandatory to have links to successive objects. These links, controlled by the categorization of the related change, highlights the obligation to forward the information to the person responsible for the objects according to the dependency map. The necessity of stating the particular person in charge and the flexibility of attaching comments remain the same.

Specification of the dependency map

Caused by the dependencies of the FPOs there is a steady need to re-evaluate and adjust all succeeding FPOs which meet the corresponding criteria.

By using the functionalities of the dependency map it is possible to quickly communicate these changes to the person in charge and to enable him to adapt himself to the new situation. In exceptional cases there might also exist regressions and interdependencies among objects at various levels. However, most of the dependencies have been proven to be hierarchical.

Depending on which object is changed, the result could have a significant influence on multiple succeeding objects. A change in a solar module design, for example, could have an influence on process recipes. This might affect the amount of required production equipment, handling devices or ID-readers, which, in turn, cause alterations in the fab infrastructure. The requisite supply of electricity is one such example.

In other cases, changes to an FPO might have little or no influence on dependent FPOs. Altering the setup of an ID-reader, for example, does not change the overall required power supply of the fab. The question therefore is how to decide whether the implementation of additional grippers of a handling machine needs to be communicated to the power supply planning team or not? And, with that, is the initial re-engineering still profitable or will the expected benefits of the optimization be overcompensated by the required investments in equipment, automation, ID-reader and electricity-infrastructure, so that the original solution (without the change of the module design) is more viable?

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When deciding whether to go for an optimization action, a holistic analysis incorporating all resulting impacts is needed. The person in charge for the whole fab manages the planning process, merges and concentrates the information for all FPOs. Taking into consideration output, cost, qualitative facts and risks he finally decides if planned changes will lead to a Pareto optimal solution.

For this purpose, a comprehensive mapping of all FPOs and their relationships needs to be accomplished. This is the primary aim of the dependency map. Additionally, it helps persons in charge of the FPO to identify other parties that need to be informed, if necessary.

Another use case for the dependency map occurs when finding new constraints, attributes or requirements that are caused, for example, by measurements. In this case, the change is enforced and no decision process is needed.

Regarding the preceding object and its modification of properties, the dissemination of the corresponding information is generally used for releases or for announcements in advance to all participants (if new facts have been determined).

The final release of the original and subsequent adaptation of the configuration will not occur until:

- All FPOs associated with critical paths are confirmed by a person in charge (in this case a critical path corresponds to FPOs of the category "*To-be-confirmed*").
- The person responsible for a substantive section of the entire fab has confirmed the complete package. It is possible that different evaluation criteria will be used depending on their position within the hierarchy (responsible for one FPO, for several FPOs, or for the overall fab).

Provision of information

The specification of the demand for information is stated by the person responsible for the succeeding FPO, who requests the person in charge of the previous object to submit the changes in a kind of obligation to perform. Fig. 3 depicts the interface of a FPO and the corresponding paths of communication.

In the case of interdependencies, an optimal solution will be found among the affected objects before any uni-directional dependent, subsequent object is informed. The dependency map supports the project manager by making the fab design more transparent while ensuring that the whole project adheres to the given timeframe.

The implementation of IT assistance should be based on standardized communication interfaces. A central database comprising all information should be accessible to responsible persons via remote access, such as a web browser. It is imperative that users are provided only with information which is relevant to him to enable efficient information update.

Development of the dependency map

Building up the dependency map is certainly the most difficult and most critical part of the process. However, even before the map has been developed, one can profit significantly from this tool. The following description shows how to proceed in creating the map and how to benefit from it during the development phase:

Step 1: Listing of Fab Planning Objects:

Having a complete overview of all FPOs results in a kind of checklist to be used by the planner. Based on this, any change within the production system can be verified, whether it has an impact on a certain FPO or not. Even if the involvement of the person responsible for the downstream object will not be triggered automatically, there is a reasonable probability that this person will be requested to comment on the modification.

Step 2: Listing of requirements and properties: A significant number of FPOs, such as production equipment, handling devices, controlling software, etc., have to be specified and documented. By doing so, a list of requirements and properties provides a considerable amount of information to be integrated into these documents.

Step 3: Create (inter)dependencies: The dependency map links several FPOs by establishing connections between their requirement and property interfaces. As such, it ensures a standardized and automated way of communication.

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The earlier the dependency map is set up during the planning phase of the fab, the more effective it is. However, even if the process has progressed considerably or the fab is already erected, it is worth building up a dependency map or enlarging its battery limits with new attributes (thereby increasing its degree of detail) as long as it can be expected that flexibility is needed to react to future challenges.

Summary

The complexity of an existing production system generates a high demand for communication and exchange of information. Particularly during the planning phase, the available pool of information is very large due to the results gathered by constant engineering. Suppliers of end-to-end solutions are faced with the challenge of handling such a large amount of information as they have to deal with several production lines being planned and implemented simultaneously.

The dependency map aims to capture, structure, and standardize the exchange of all relevant information, requests and confirmations in the case of modifying integral parts of the production system. This capability has to be transparent to ensure that all persons in charge of certain FPOs – which might be affected by any modifications – can raise their hands. A process that not only considers output and cost but also qualitative aspects and possible risks has also to be evaluated by the one responsible for the fab or a segment of it. Such a procedure ensures or at least comes close to a Pareto optimal solution and avoids single-sided, political or individually-motivated optimizations.

Establishing a comprehensive and accurate dependency map will require process-discipline, commitment of the management and well-defined responsibilities for FPOs. Continuous content validation and updates will keep the quality of the dependency map at a high level.

The benefits will compensate all efforts as the advantages are manifold:

- As information is tailored for the corresponding target group, the cost of communication (mainly time) can be lowered and the supply of information made more reliable.
- Higher transparency of dependencies and reduction of tacit information [3] results in the reduced risk of incorrect planning.
- The flexibility in fab design enables the fab planner to execute continuous improvements in order to achieve a Pareto optimal result.

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