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Resource leveling in the project design process by Petri net using

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Abstract. Petri net using for dynamic design of projects is reviewed, the resource leveling algorithm is offered.

Introduction

Increase in amount of work in the design companies of oil and gas industry (OGI) in Russia requires the use of corporate information management systems. In this case detailed project features description for the design organizations, both in focus of project management, and in focus of project design is recommended [1]. Majority of OGI design companies have introduced quality management systems (ISO 9001) for the improvement of design work quality [2] and for the strengthening of their competitiveness. It requires the use of various notations for the modelling description of processes. Such description usually is represented in the form of static models, for example, classes EPC and IDEF [3-5]. However it is not enough for resource constraint project management and process monitoring. In practice everywhere [6,7] there are situations when the need for design work resources exceeds available possibilities for a specific period of time. Indeed, the topology of project network model is a common reason of the several works parallel execution (unscheduled projects) using the same resources. It leads to a corresponding increase in the total requirement for them at certain points of time. As a result there is a conflict situation when at a given moment of time the requirement for resources exceeds their capabilities. Thus, it is impossible to perform some works according to a current plan. Such situation, as a rule, becomes the subject of an efficient analysis [8,9] because it should be rapidly solved. Conflict should be resolved by means of project rescheduling. Purpose of such rescheduling is either a maximum reduction of the resources over-expenditure without the increase in total duration of the project schedule, or reduction of requirement for resources in conformity with the established limits (even at the expense of some project terms lengthening), or a combination of these two objectives. In these cases mechanisms and algorithms of resource leveling are used. This stage appears to be one of the most important works in project management. The aim of this work is the Petri net using for resource leveling during OGI projects realization.

Description of design works dynamic

In this work the workflow management system of the design company, based on the EPC-notation and Petri net (PN) is considered. Such formalism is becoming more popular [10,11,12] because the use of these notations gives a number of advantages for project management.

Indeed , the development of static models in notations (ER, EPC, etc.) are limited to the following purposes:

(1) General organization of business processes and interactive approach to the actual implementation of design works in the enterprise.

(2) Formation of conceptual database model.

(3) Specifications and attributes definition of design processes.

(4) Determination of logical branching of processes.

(5) Official and administrative regulating documents improvement and correct formation of responsibility in project managerial process.

(6) Improving the efficiency of accounting and administrative dataflow. Control the availability of unused documents.

(7) The formation of accounting documentation and flow of records improvement.

(8) Compilation of the required resources list.

On the other hand dynamic model design by the PN allows to:

(1) Establish and describe initiating events.

(2) Check the absence of ruptures in the course of project performance.

(3) Define necessary resource volumes and the cost process parameters for performance of the project separate stages.

(4) Establish a degree of workers and divisions loading.

(5) Make decisions on changing the established course of the works depending on external and internal conditions.

Also algorithms on the PN basis allow to:

(1) Supervise necessary rhythm of works performance.

(2) Synchronize and co-ordinate separate works performance in time.

(3) Efficiently manage the unstructured information at dispatching control level.

According to Russian standard requirements, integrated design process of oil and gas industry objects consists of the stages separated in time and involves executors of various trades, and also interaction with the Customer and a set of foreign organizations, including government agencies. Project life cycle consists of basic obligatory stages: formations and coordination with the Customer of the design assignment (DA), inspections of object and carrying out of engineering researches (ER), the development of the general design decisions (GDD), maintenance of the design documentation (DD) and receiving a positive conclusion from the state agencies and expert review (SER), maintenance of the working documentation (WD) and conducting the object building architectural supervision (AS). Each stage is divided into a set of procedures and considers the inherent restrictions in the form of Customer requirements, the standards, the geological and geotechnical information, as well as the environment. Each stage of the project (GDD, DD, WD) is thoroughly tested by the Customer various divisions.

Accounting, regulating and administrative documents flow includes binding of official duties, information about the list of project sections, an order of the works which are carried out by the worker, who is allocated with such duties, data on the timing of work, in particular, in a format of the Gantt chart, resources data and the results of project performance etc.

Let the tree of designing processes represents a structure is shown in Fig. 1. Direct creation stages of the project are represented by the shaded figures.

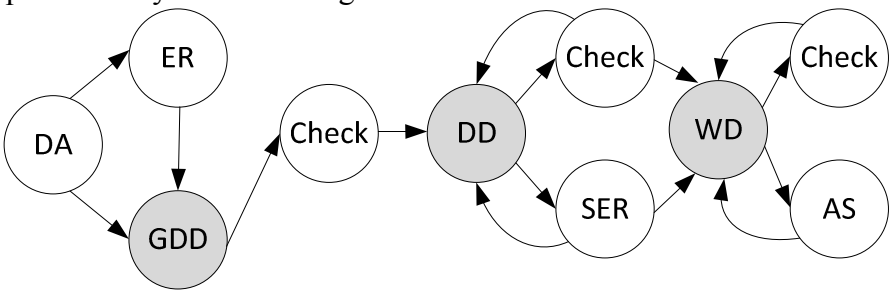

Fig. 1 A designing process tree

At the bottom levels of hierarchy the presented designing process tree is detailed by PN topology and represents the designing production movement through industrial elements (designers workplaces) from input to output and the movement of providing objects caused by it - documents, drawings, files, etc. For management automation of these objects the engineering document

circulation system (EDCS), in particular, on the basis of Microsoft Office SharePoint Server (MOSS) is commonly used. EDCS structure implements the basic functional modules: the management organization of the project, transfer of tasks for project parts working out (TPPW), performance control, management of the design estimate documentation (DED).

Project organization module assumes to deliver the data for other modules and to be a link in a design work's management chain. Fig. 2 illustrates the modules interrelation within the limits of EDCS. Such interrelation allows synchronizing divisions' activity, to optimize the availability and adequacy of the project data and to support the date system information at any moment of time for effective maintenance of management processes.

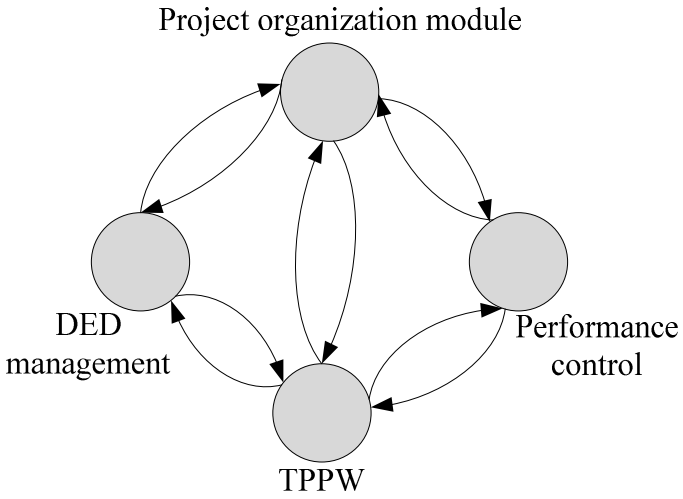

Fig. 2 Interrelation of EDCS modules

Description of resource leveling algorithm

In work [13] the resource leveling algorithm for the PN is provided. It can be modified according to the priorities of the tasks. Task priorities are selected in accordance with the decisions of company's senior management. In the conditions of acute resources shortage, the revealing of priorities is a necessary condition for planning. The main resources of designing processes in the analysis are the personnel. While the PN model is worked out for business processes duration planning and TPPW performance, it is offered to take into account the time which is defined in PM for each operation of design works. If there was a deviation of current runtime of the TPPW or project, than it is possible to easily define the reason of terms failure by using the PN models or to make adjustments to standard time. Discrete conditions set of TPPW and project performance processes are displayed by various PN positions. Implementation of the color PN (CPN) considerably reduces process model dimension. CPN uses various types of tokens. Each type of tokens is presented by abstract data type (code number of projected object according to the internal classifier of the design organization, posts of executors etc.).

The offered sequence of resource leveling algorithm is detailed below.

Step 1. Define a start point of the analyzed project works schedule. Find the general time requirements to resources in each period of the work schedule by adding requirements to resources for each resolved transition during this period. Calculate (refer with: Eq. 1) the measure of effectiveness (MOE):

$$MOE = \sum_{t=1}^{m} R_t^2; \qquad R_t = \sum_{i=1}^{n} r_{it} \times k_{pi} \tag{1}$$

Where m - number of time periods in the schedule of works, n - number of enabled transitions; r_{it} - requirement for the time of performance by the i-th enabled transition during t-th period (actually it

can be more than the norm of time for operation taking into account an expectation or idle time mode); k_{pi} - factor considering a priority of p-th problem which concerns i-th operation performance (ith transition). The higher the priority of p-th problem, the more value factor k_{pi} has.

Step 2. Define the period with peak resource requirement in the current schedule.

Step 3. Rank the enabled transitions (activity) in this period in decreasing order of their general reserve of time. Choose the least loaded enabled transition (from standpoint of the maximum reserve) for possibility of its shift.

Step 4. Consider moving of the chosen activity by one period later. Calculate MOE of the new schedule. If MOE value has decreased, confirm the new schedule with the executed moving of activity performance for later term. Go to step 2.

Step 5. If there is no improvement in the MOE, check the chosen activity. If it can be shifted further by one more period of time, go to step 4, in case the total reserve of time is not zero.

Step 6. Choose the following activity in the ranked list, go to step 4. If no further activity is available for shifting, go to step 7.

Step 7. Repeat the procedure with enabled transitions in the following lower peak, having gone to step 2, assuming that shifting of an activity from a lower peak to a higher peak is not allowed. If all periods are examined, then go to step 8.

Step 8. Stop.

Management of design works by EDCS using

Introduced resource leveling algorithm allows to administer a project at any time interval of performance by the detection and analysis of a critical way. Fig. 3, Fig. 4 illustrate suggested algorithms of commission formation and document creation by EDCS.

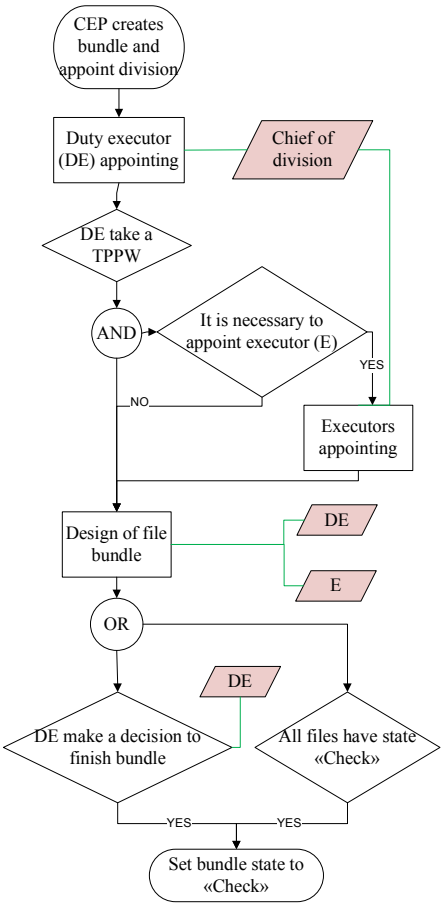

Fig.3 Algorithm of commission formation

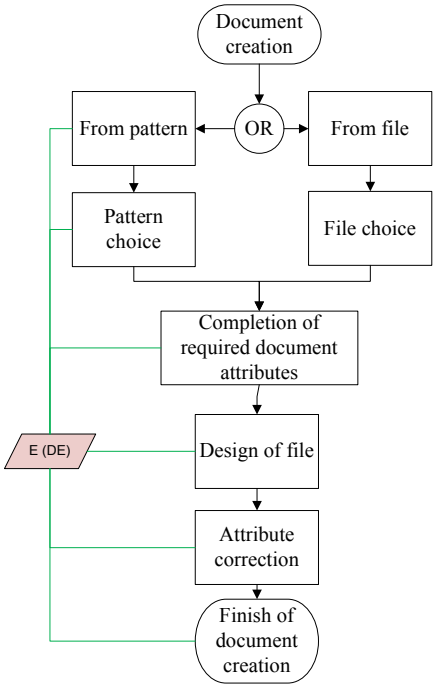

Fig.4 Algorithm of document creation

Algorithm performance and the analysis of designing process modelling by PN optimizes an order and terms of TPPW delivery, and also DED execution. TPPW module realized in EDCS allows to automatically prepare and examine materials necessary for TPPW in division, to co-ordinate tasks with the chief engineer of the project (CEP) and to accept tasks from corresponding adjacent design division. On the basis of the DED management module data, chief engineer of the project can supervise more fully a progress of project performance. Heads of design divisions will receive the tool for displaying statistics of work-in-progress and staff workload. Consequently, managers will have the possibility to trace in details a course of complete TPPW sets developing, operatively correct terms of development and resources redistribution.

Summary

The proposed algorithm based on PN reduces labour input in resource leveling procedure, provides ranked project performance with data necessary for correct choice and at the same time allows to examine the design work semantic. Resource leveling results in better planning of the organization's limited resources. Thus, using engineering document circulation system jointly with Petri net models provides supervisor mechanisms for design workflow management.

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