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Methodical Approach to Developing a Decision Support System for Well Interventions Planning

V A Silich[1], A O Savelev[2], A N Isaev[3]

[1] Professor at Tomsk Polytechnic University, Information system department
[2] Assistant at Control system optimization department of Tomsk Polytechnic University
[3] Head of Quality management Center of Tomsk Polytechnic University

e-mail: sava@tpu.ru

Abstract. The paper contains aspects of developing a decision support systems aimed for well interventions planning within the process of oil production engineering. The specific approach described by authors is based on system analysis methods and object model for system design. Declared number of problem-decision principles as follows: the principle of consolidated information area, the principle of integrated control, the principle of development process transparency. Also observed a set of models (class model, object model, attribute interdependence model, component model, coordination model) specified for designing decision support system for well intervention planning.

1. Introduction

The development of control systems for information support of decision-making process in the field of oil production engineering is a complex and actual task. The complexity of oil production engineering process is caused by incompleteness and ambiguity of the data about the exploration field [1].

A stabilization of crude oil output volume and equalization oil extraction ratio belong to most important and complicated tasks in the oil engineering area. One of the ways to solve these tasks is to optimize the process and methods of well interventions selection (a proper combination of geological, technological and technical measures) [2-7].

2. Methodical approach to developing a Decision Support System (DSS) for well interventions planning

The process of well interventions planning is a complex, multicriterion task. It is also characterized by poor formalizability of processed data and atypicality of system components. All these specific aspects induce to develop a special methodical approach to developing a DSS that provide and effective well interventions planning process [8].

The following requirements to the methodical approach were determined according to aspects referred above:

– versatility and high level of approach generality;
– operational flexibility and simplicity of customization (according to specific tasks);
– clearness of models;
– openness and high integrity level of development tools;

– availability of development tools integration with applications that use other approaches.

According to requirements determined a new Methodical approach to developing DSS for well interventions was discovered. The Methodical approach possesses:

– methodical principles of system design (based on determined requirements list of well interventions planning actor), that improves an efficiency of well interventions DSS development;
– a system-based well interventions planning sequence;
– a set of interrelated well interventions planning DSS (WIP DSS) object-oriented models, that decreases total time of WIP DSS development and increases economical efficiency of well interventions planning decision-making process.

3. A system-based well interventions planning sequence

To build a system-based well interventions planning sequence the problem domain was analyzed including following basic aspects: methodical and regulatory documents, documentary standards of oil industry and procedural regulations of single oil companies. As a result following stages of well interventions planning sequence were determined (fig. 1) [9]:

1. A detection of oil producing well with underused capacity.
2. Prediction of well capacity after providing technological process optimization and well interventions.
3. Decision-making of well interventions.
4. Well interventions providing.
5. An efficiency analysis of well interventions provided.

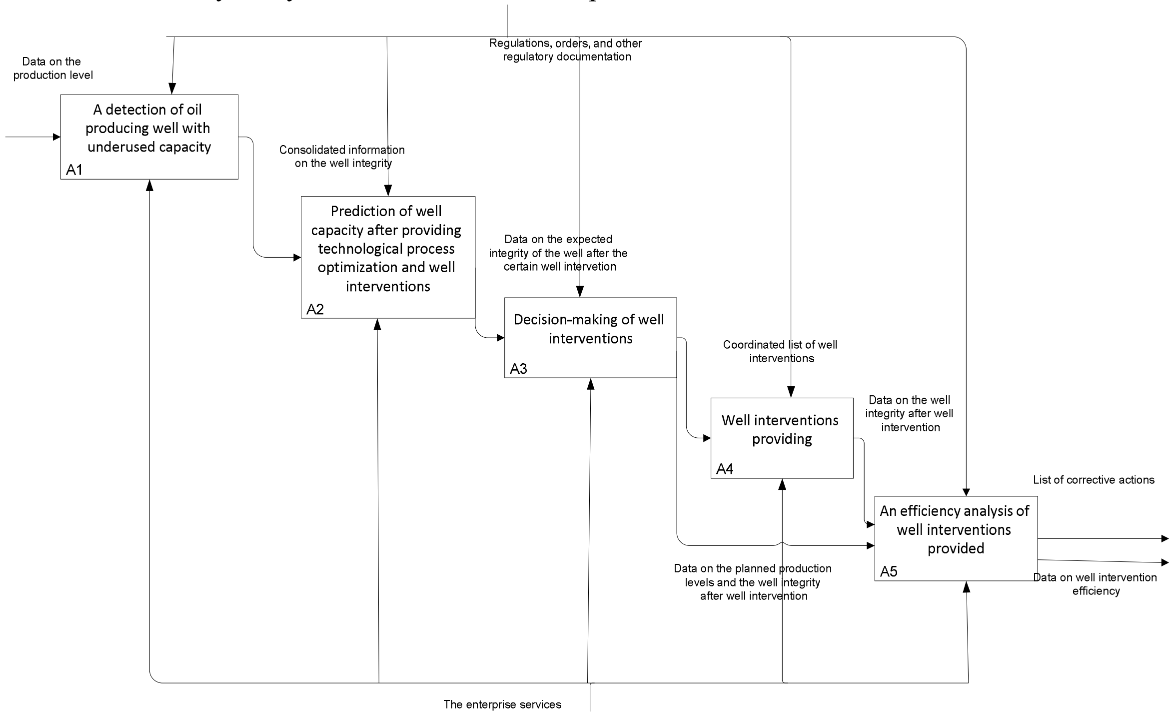

Figure 1. Well interventions decision-making process

4. Principles of well interventions planning DSS design

4.1 The principle of consolidated information area

It is supposed to implement a consolidated information area to increase the efficiency of information exchange among organizational units within an oil company and to integrate up-to-date data about current state of field production. The consolidated information area should be considered as a unity of data bases (DB) and data repository (including procedures of their usage, management and support), telecommunication systems and tools that perform according to common rules and procedures.

The implementation of the consolidated information area comes to solve following tasks:

1. To ensure the unity of data storage structure.
2. To ensure the standardization of data exchange processes among different informational infrastructure elements of oil-field.

The first task could be solved by usage of datamarts that can be considered as a local subject-oriented repository. Datamarts are connected to global data repository and provide services to definite groups of well interventions planning actors.

To solve the second task a set of common rules, procedures and integrated technologies of data transmission should be developed and implemented within IT-infrastructure of oil-field. In this case a unified standard of data transmission (from data-source to global data repository and backwards) can be considered as a main instrument for problem solving. To determine a unified standard of data transmission a WITSML standard is proposed to be used within the new methodical approach to developing a WIP DSS described in the paper.

4.2 The principle of integrated control

Assume that WIP DSS and its global data repository are represented by unity of separate software components that are located on different geographically distributed servers we have to specify monitor system for net infrastructure and information system monitoring. The specified monitor system assure availability and operability of elements of the DSS designed.

The WIP DSS' net infrastructure monitoring subsystem should exhibit following set of properties:

- the subsystem should provide monitoring of all net infrastructure objects;
- all indications read by basic collecting systems should be transmitted through the global data repository that unites net infrastructure representation;
- monitoring should be provided in a real-time mode (24 hours a day, 7 days per week);
- process of collecting current net infrastructure state indications should not have any sufficient implications for the net operating.

4.3 The principle of development process transparency

The structure of DSS should be represented by set of components (modules). The formal specification of modules should include definitions of attributes and functions used by the module. When possible "responsibility" of every component (functions operated by the module) should cover decision of very specific tasks, in order to minimize possible changes.

An OMSD technology (Object Model for System Design) is proposed to be used as a main instrument of the principle implementation. The technology is supposed to form and use process-models of designing systems that contain problems and resolve them.

5. A set of WIP DSS models

A set of WIP DSS model, developed on the basis of OMSD-technology, is represented by unity of models, that belong to one of five determined model types:

$$M = \langle M^C, \{M^O\}, \{M^A\}, M^S, \{M^K\} \rangle, \qquad (1)$$

wherein M^C – class model, M^O – object model, M^A – attribute interdependence model, M^S – systems' components model, M^K – coordination model.

5.1 Class model

Class model includes variety of classes (e.g. fig. 2) that are used for system's components specification and for description of relation among classes. A class includes variety of class attributes and class methods. An attribute is specified by triplet "name-type-set of values". A variety of methods comprises an imperative subset of access methods to value of attributes. Different classes can be related to each other through sub-classing, that allows specifying a new class on the bases of already existing class. A sub-classes' variety of methods and attributes includes appropriate varieties of parent class. In this case overlaping attributes of sub-class narrow the range of definition of overlaping attributes of parent class. And at the same time overlaping sub-class methods redeclare overlaped parent-class methods.

Hydraulic fracturing
Well test : object; Well: object; Proppant: object; Fluid volume: real; Projected production rate: real;
Set_value (Well test, object) Set_value (Well, object) Set_value (Proppant, object) Set_value (Fluid volume, %)

Figure 2. Representation of class "Hydraulic fracturing"

5.2 Object model

An object model is formed by the class model. An object is specified in the following way:

$$o_k=<n(o_k),\ c(o_k),\ \{d_k(a_m)/cf(d_k(a_m))\}>, \qquad (2)$$

wherein $n(o_k)$ – name of the object; $c(o_k)$ – indicator of the class, that was taken as a base for object implementation;

$d_k(a_m)\in D(a_m)|a_m\in A(c(o_k))$ – value of attribute; $cf(d_k(a_m))\in[0,1]$ – factor of attribute value warranty (from 0 – total uncertainty to 1 – absolute reliability).

A variety of one class implementation variants is represented as a Multiobject (e.g. table 1). A Multiobject is a set of objects of one class that are specified according to a particular characteristic. A Multiobject is used to present a plenty of system states in different moments in time. The type of characteristic that drive the multiobject to be created can be of three kinds: time-divisional, three-dimensional or group.

An object model is used to solve tasks of pattern detection that is based on: comparison of objects that form a multiobject; selection of an optimal variant of system's component implementation. The last can be done by forming alternative variants of the component, evaluation of alternatives and optimal variant choice.

Table 1. A fragment of the Multiobject «Well interventions economic efficiency»

Economic efficiency	Well 7058, Date: 22.01.01	Well 3451, Date: 07.02.01	Well 3277, Date: 10.02.01	Well 3263, Date: 12.02.01
Production rate before Hydraulic fracturing, ton\day	10	26	18	7
Production rate after Hydraulic fracturing, ton\day	75	83	96	62
……….				

5.3 Attribute interdependence model

An attribute interdependence model is used for representation of complex attributes dependencies with alternative output paths. It allows combining different methods of attribute dependencies formation and implementing various strategies of decision-making.

A network of attributes' functional dependences is represented by variety of class attributes that are linked by functional dependence relation and specify any component of a system:

$$T^A(c)=<A(c),R^{fd}> \qquad (3)$$

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The network is a nonstrict hierarchy that can possess some roots (network sink). Basic attributes are considered as a network source.

For evident representation of complex attributes dependencies with alternative output paths was developed a different model. The model allows combining various methods of attribute dependencies formation and implementing various strategies of decision-making.

The specified attributes dependence model helps to solve following tasks:

1. Problem of interpretation. In this case values of basic attributes are initially stated and calculation is provided to find target attributes values that correspond to initial data.
2. Admissible decision search. The task is used to define alternatives (well candidate selection). In this case the target attribute is a planned pay-back period of an intervention. The calculation of a planned pay-back period is driven by Pressure Transient Test data and physical characteristics of geological horizon.

5.4 Components model

A components model (e.g. fig. 3) is used to compose a hierarchy of subsystems. A set of subsystems S = $\{s_i\}$ integrates following components: global system, considered as a top level “Black Box” model; subsystems of a designed system and environment.

A subsystem can be represented as a tuple:

$$s_i=<n(s_i),c(s_i),M^O(c(s_i)),M^A(c(s_i)),\{M^L(c(s_i))\}>, \quad (4)$$

wherein $n(s_i)$ – name of a subsystem; $c(s_i)$ – class, that is referred by subsystem (it is sub-classed from basic class “Subsystem”); $M^O(c(s_i))$ – objects model, associated with the subsystem; $M^A(c(s_i))$ – attribute interdependence model, that specifies the subsystem; $M^L(c(s_i))$ – coordination model associated with the subsystem.

A subsystem tree represents the structure of the system designed. The subsystem tree is formed by sequential subsystems decomposition. The tree poses a stratified hierarchy, where one system is considered on different levels of the tree through various abstraction scales. A higher-level system can be considered as a root of the subsystem tree. As well it includes environment systems relevant to system designed.

Elements can be also considered as components besides subsystems. In this case elements are considered as entities that take part in subsystems functioning (for example, final products, performers, subjects of activity, mechanisms), or integrated properties, that are specified by set of characteristics (for example, technological parameters, economical results, technical specification, etc.).

The element $e_i \in E$, as far as subsystem, is associated with the name, class and also can be associated with object model and attribute interdependence model:

$$e_i=<n(e_i), c(e_i), M^O(c(e_i)),M^A(c(e_i))>, \quad (5)$$

wherein n(ei) – name of the element; c(ei) – class of the element (inherited from basic class “Element”; $M^O(c(e_i))$ – object’s model, associated with the element; $M^A(c(e_i))$ – attribute interdependence model, that specify the element.

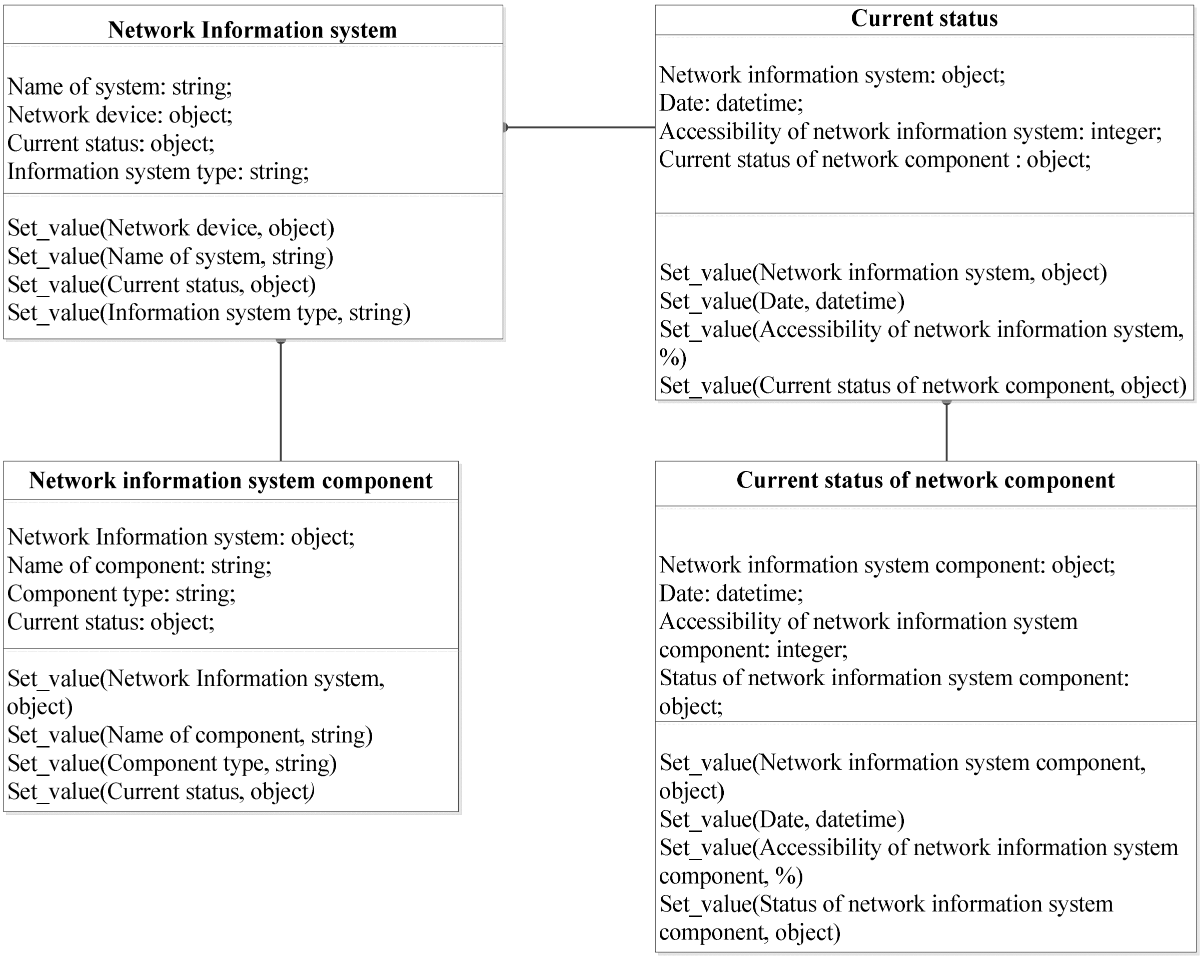

Figure 3. A fragment of the components model of network infrastructure monitoring system

5.5 Coordination model

A coordination model is built to explore interdependences among attributes of subsystems of the same tree-level. It is also used to solve tasks of integration (when it is necessary to specify attribute values of the parent system through interlevel dependences description) and coordination tasks (in this case parent system attribute values are considered as restrictions of descendant attributes admissible values). A coordination model associated with any subsystem s_0 of a complex system includes an interdependences network of subsystems attributes, its descendant components and methods to work with the coordination model:

$$M^K(s_0)=<N^K(s_0),P^K> \tag{6}$$

A set of methods P^K includes following groups: methods of model formation (knowledge elicitation); methods of problem-solving (among them integration methods and coordination methods).

6. Conclusion

The presented methodical approach to developing a DSS for well interventions planning makes it possible to:

- increase the efficiency of DSS for well interventions planning development process;
- decrease the total time of DSS for well interventions planning development process;
- increase the economic efficiency of the planning process through the increasing of decision-making operational efficiency.

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