Application of The Theorem of ‘About the Unity of the Structural Description of RPA Devices’ for the Simulation of a Power Network Smart-Grid

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***Abstract*—A method is proposed for reducing the computation time while maintaining the stability of the simulation. Examines the joint modelling of objects and devices of relay protection and control. The complexity of the simulation increases when has many sites of a network, especially when real-time algorithms are designed for records in programmable chip devices. Volatility through modelling is associated primarily with the volume of inputs, intermediate and representative accumulated information. Reducing the computation time is necessary due to the exhaustion of a physical resource by clock rate and the effective number of computing processors. The relevance of objectives is maintained in conditions of continuous improvement of the element base of devices, software, technological equipment, and requirements for construction of electric power networks. The method is based on the formation of a semantic signal, which compresses the parametric information on order times. It is shown how the selection of semantic signal in each device will allow known control tasks on the network to be resolved. Shows how to solve problems through simulation of devices taking into account the semantic information flows. For this proposed method of improving the algorithms works on the basis of mutual correspondence of the two equivalent generalized block diagrams of object control and devices for relay protection and control. The obtained quality indicators simulation. Examples of improvement of devices in the task of building high voltage networks for smart-grids with a Petersen’s coil are presented. The results are useful for solving problems of the information ‘throat’, diagnostics ‘not under stress’, and automatic restoration of the sense of emergency files for mobile, stationary and outsourcing jobs.**

***Index Terms*—Smart-Grid; Relay Protection; Automation; Petersen’s Coil; Compensation of Capacitive Currents; Structural-Information Method; Structural-Linguistic Method; Pattern Recognition, Modelling in CAD, Real Time, Transient.**

I. Introduction

With the modern development of industrial technology, requirements for energy efficiency, environmental safety, and low energy cost have been imposed [1, 2]. The network itself is an integral part of the technological cycles of processing and production. So, the qualitative development of networks the traditionally constructed voltage for classes *U* to 1 kV, 6–35 kV, and 110 kV has led to the spread of managed networks of smart algorithms. Structurally, the network is transformed into a regular grid. In the smart-grid, there is automatic support for the balance of a *Generation-Accumulation-Consumption* chain with changing values components of a chain-changing of cost *$*, resources *B* and *G* are supported automatically (Figure 1) [2, 8–10]. Collaboration between a smart-grid of networks and traditionally constructed networks is provided algorithmically [3–5]. Due to the reduction of staff until the implementation of automatic operation of the network is achieved, controlled information will be transmitted to a higher level of automated control or personal computers business entities. Of course, this is true for the technological processes available for this mode of operation [1, 2]. In the result, the development is to implement the concepts of smart-grid, digital substation, outsourcing services.

The conditions of representation of a necessary and sufficient minimum amount of information can be implemented based on the definition of transient processes (TPs) in the network. Handling semantic information streams allows us to offer a way to build networks based on the semantic end result, giving confidence in the efficiency of the network. Confidence can be expressed in terms of a generalized semantic relative criterion: ‘There has been a deterioration of the equipment?’ Therefore, the overall goal of this article is to provide end-to-end design devices for relay protection and automatic equipment (RPA), which allow implementation of this criterion. The problems of the creation of a smart-grid are known: 1. Management of electricity, accumulation, and electricity consumption; 2. Optimization of the network operating modes; 3. Monitoring and self-diagnostics of equipment ‘not under stress’; 4. Systems for data transmission between electrical power objects; and 5. Improvement of RPA devices according to smart-grid principles [1–6, 8]. We will consider galvanic connected elements of a network as an object of control and protection (OCP). Further, will consider the development of algorithms for RPA devices in computer-aided design (CAD) for solving smart-grid tasks.

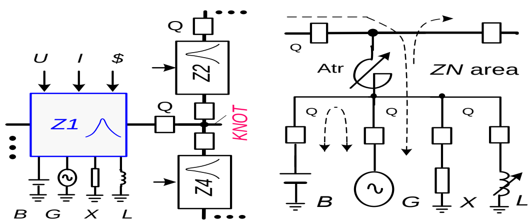

Figure 1: Unified block diagram of smart-grid network in the form of bundles *Driver–EU–OCP*

A. *Setting of Tasks*

Modelling in CAD allows flexibility in addressing these smart-grid problems. Other modelling tasks include reducing costs, elimination of hazardous conditions, equipment, training, and so on [2, 6, 8]. It can be noted that the magnitude of the task to be modelled in CAD has always been limited by time and volatility calculations [7, 8–10]. So, the tasks come to light only in relation to the process of modelling in CAD [7, 8]. The calculation time is proportional to the clock frequency of the computing system. However, the increase of clock frequency has physical limitations and the number of operating cores is limited by Amdahl's law. Suppose that the solution of modelling tasks can be carried out by operating components of the semantic information flows of tasks. The following presents the solution to modelling tasks for the example of a problem-solving smart-grid.

Consider the causes of instability of the algorithms of the RPA devices. It is known that the algorithm consists of a machine with known states and rules *P* of the transitions under certain conditions. Differences in alternative actions result in selectivity and blocking. The effect of instability can be expressed using analogies. Jamming of TPs is comparable to a situation where spikes are constantly hacking the locks of selective machine devices. Breaking locks is not allowed by the machines lock is not allowed by blocking machine guns. Also, the algorithm can be represented by a stencil with the windows located in certain places (transitions). The rules for reading the information of the stencil are predetermined. By overlaying the stencil on a character sequence, an observer may read and determine the meaning of the information. We denote each such stencil semantic situation *SN*, *N*=1, 2, ... , that occurs in the OCP. Example *S1 Normal Mode* (*NM*), *S2 Not Recognized* (*Not*), *SN Accident Mode* (*AM*), *SN One Phase Circuit* (*OPG*), *SN Short Circuit*, and so on.

It follows a number of conclusions. According to the theory of automatic control, semantic information in the OCP is formed dynamically and consistently and is interrelated. According to the theory of information transfer, must be provided with alternativeness of information, formation, and checking of the checksum by transfer and transformation of information. According to the theory of recognition of images, the situation of *S2 Not* is allocated, and training and control of the sample take place. Experience in the improvement of RPA devices showed the need to observe the sequence of actions algorithms: a) The initial lock. The lock is needed to correct recognition errors for the selective portion. b) An additional selective algorithm. This is used to remove the lock from interference and for the continuation of recognition. c) The correct unlock sequence after restoring *S1 NM*. The workplace of the CAD developer will make it possible to test the effectiveness of the changes introduced to provide regular improvements of the algorithms.

To build the model of the OCP highlight the RPA algorithms working in different frequency bands of the TP signals of (Figure 2) [6–10]. In this regard, the concept of separation of movements in frequency was applied. With regard to the conditional separation of frequencies, we will focus on the perception of time by operating personnel. Of the selected ranges, a) high-frequency components (HFCs) are in the band of 2–10 kHz; b) mid-frequency components (MFCs) are in the 0.3–3 kHz band. These ranges are used for selective protection devices (SP); c) low-frequency components (LFCs) are in the 25–50–75 Hz band and are used for RPA devices and automatic normal mode; d) slow envelope components (envel-LFCs) are in interval seconds–watch. Are used for system stabilization; e) infra-slow LFCs (infra-LFCs) for the range of the diurnal cycle (24 hours) are used for systems of self-control that are 'not under stress'; and f) cumulative super-slow information LFCs (super-LFCs) are in the a week, a month, and so on, are used to control the final result of the work of the network. In the end, the task of modelling in CAD is reduced to the tracking of the HFCs at intervals of infra-LFC or super-LFC of TPs signals.

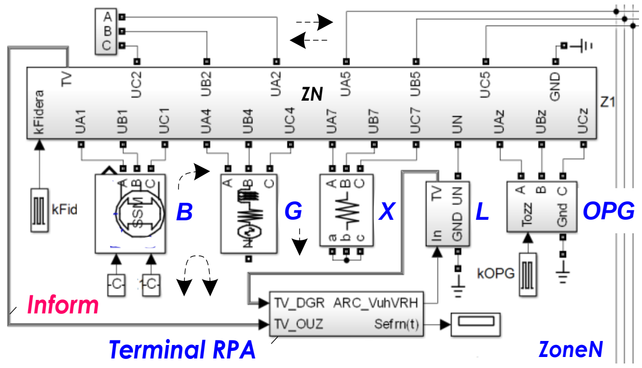

Figure 2: Block diagram of *ZN* area network smart-grid RPA devices real-time in CAD in the form of bundles *Terminal–EU–OCP*. *kOPG* – master time OPG, *kFider* – switching joining network

We call modelling in real-time in CAD the multiple recalculations of elements synchronously with the sampling frequency f_{DISCR} input signals. Later in the article, we offer problem solving methods through modelling in CAD developed to provide stability of the work of RPA devices in severe noise situations *SN*. The article proposes an extension of the scope of these methods for a wider range of objectives of the smart-grid. The results can be applied in each RPA device and in relation to the power consumption of devices.

B. Analysis of the Methods of Solving Problems in CAD

Known ways to simplify models by means of mathematical relationships, of identify the RLC-elements [6, 7]. These methods do not eliminate fragmentation of results and loss of compatibility for HFCs, infra-LFCs and require informal empirical data preparation. The majority of RPA devices have been developed using heuristic, expert methods. Modern requirements become stricter. For example, for conditions of development of different types of complex signals TP, as well as when working in different OCP. The application of the method of pattern recognition removes such restrictions. Common to these methods are the decomposition of information into elementary components, multiplication by a weighting factors, summing of the results, and comparison of the results with multiple threshold values. However, dissemination methods are limited by the specificity of their tasks. In this article the tasks are quite specific, namely the development of the dynamic TP. Interference and selective structurally related situation. Simple filtering is not sufficient. Later in the article, will be guided by graphic structural transformations. The sequence of transformations comprise the algorithm for solving problems. Therefore, article acronyms, figures, are necessary for the conclusiveness of the statement.

II. Description of the Methods Used

A. Description of Structural-information (SI) Method

The method allows one to numerically substantiate the development and improvement of the algorithms of the RPA devices. The method is based on linguistic pattern recognition. The output signals of the OCP present a dynamic flow of terminal symbols (TSs). Further hierarchical levels—morphological (Morph), syntactic (Synt), and semantic (Sem)—are allocated (Figure 3). Each level is recognized by the machine (A). The rules *P* of machines are divided into two alternative flows: *For* (selectivity) and *Against* (lock). The rules *PS* and *PB* are assigned weights *KSN* and *KBM* according to the contribution to the common semantic output $S_{SMART}(t)$. At a certain time, the unit fixing Fix remembers the active rules *PS* and *PB* for accumulating the values of signals $S_{SMART}(t)$. The activating TS is known for each OCP and is set in the settings of the RPA devices. The range of signals, 0% < $S_{SMART}(t)$<100%, is calculated relative to 0% or 100%, depending on the nature of the task.

The system of automatic stabilization of the normal mode (ASNOM) for work with the OCP will be organized (Figure 3). The control system in the sense of ASNOM consists of the following parts: a differential element to a signal *Adjuster SN1*, S-detector *For–Against*, multi-threshold element ρN, the filter result (in the general case, the expert system ExS), and the release of the 'manager' of the system $S_{DISPATCHER}(t)$.

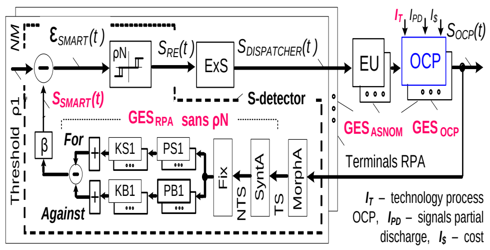

Figure 3: System of automatic stabilization of normal operating mode (ASNOM) working with information components of OCP

It is necessary that the sense is detected from envelope TP signals at the output of the OCP, which are transferred by signals of industrial frequency (Figures 4–6). Figure 6 is obtained from Figure 5 as a result of zeroing feedback signal$S\rho N(t)$=0 by W_{TABL} (Figure 4). In the semantic situation, *SN* is additionally understood to be the occurrence of such a deviation Δ of the external or internal coordinates of the OCP, which leads to semantic deviation Δ*SN* of the signal $\Delta S_{OCP}(t)$ at the output of the OCP relative to the thresholds ρ1 *NM* (Figures 5, 6). In order for the signal of $S_{SMART}(t)$ to exceed each threshold ρN, a certain compliance with volume, structure, and sequence and a lack of mistakes in the information of signals of TPs are necessary. Thus, the threshold value ρN is the checksum for the semantic information received on the input RPA devices.

In an early published article introduced the theorem '*About the unity of the structural description of RPA devices*'1. According to the theorem, all RPA devices can be replaced by a bundle of two elements: a semantic Filter device and a threshold ρN (Figures 5, 6, and 9). This is the same bundle as described in the scheme of formation regarding the TS (Figure 7). In turn, *Filter* is a generic equivalent structural (GES) scheme. The GES scheme is obtained by combining SyntA known RPA devices (Figure 8). RPA devices prove to be the means of recognition of the sense TP. Their algorithms are different views of the authors about the OCP. Association of algorithms makes up the fullness of recognition of the essence of TP in the OCP. Improvement of the algorithms and of the OCP scheme will improve the OCP quality.

n	ρ	ρ1 "NM"	ρ2 "US"	ρ3		ρn "EM"	ρ "Tst"	Weight TS
	S / TSS, TSB	S1	S2	S3	⋮	SN	Stest	kTS, s - step
1	TS S1	1	0	0		0	1	min kTS
2	TS S2	0	1	0		0	1	min+s
	…							
	∑kTS	min ∑kTS					max ∑kTS	-
	kρ=1/∑kTS	min kρ					1	-

Figure 4: Task of the transfer function $W_{TABL}=TSN/SN$

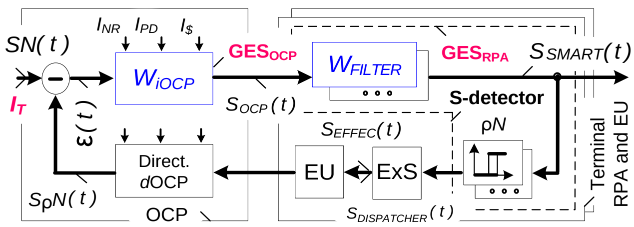

Figure 5: Transformation of the generalized block diagram of ASNOM system of rather semantic situations of *SN(t)*

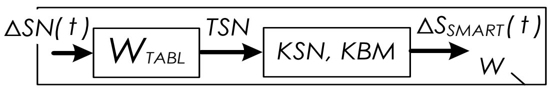

Figure 6: Formation by transfer function $W=S_{SMART}/SN$

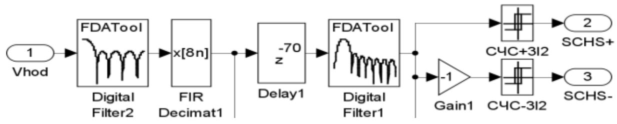

Figure 7: Structural scheme TS in the form of a *Filter* and ρN

B. *Separation of Motions by the Frequencies and by Sense*

To improve device algorithms RPA is sufficient minimal information. For example, it is only the formation of the output signals OCP [7, 8]. The structural-operator method shows that the OCP model can be represented by the relationship of the inertial contours (Figure 9). By the separation of motions by the frequencies, we mean that the number and parameters of the oscillatory circuit in the OCP are determined. Here, an example may be known from the theory of the automatic control method of modelling of management systems by the zero components. From the point of view of the SI-method, a description of the structure of the OCP allows us to improve the algorithms of MorphA, SyntA RPA devices. But improving the semantic SemA is still little grounded in theory and cumbersome in terms of modelling. At the same time, a large number of tasks lead to the limitations of the method of separation of motions by frequency and to the invocation of the method of separation of motions.

By the separation of motions by sense, we understand the dynamic separation of the flow of information into hierarchically subordinate structural parts and the operation of these parts. The method of separation follows from the SI-method. We set the structure and parameters of the machines MorphA to SemA, alternative threads *For–Against*, the list of situations *SN*, and the threshold values ρN (Figures 3–10).

Improvement SemA is a typical task for the method RPA devices gain a number of qualities: a) the formation of a signal *S(t)* that can recognize the modes of the OCP; b) replacing the result (off–on) by a number of interim responses; and c) compression of the parametric information to implement intelligent algorithms and transfer to a higher level of management and control.

The simulation method makes it possible to: a) focus on one hierarchical level, implemented in a separate computing part of the overall project, and thereby minimize the number of elements and the time unit of calculation; b) transfer the minimum information links between the hierarchical levels; and c) model the formation of the image of diagnostic messages for the purposes of supervisory control and automatic restoration of the sense of emergency files.

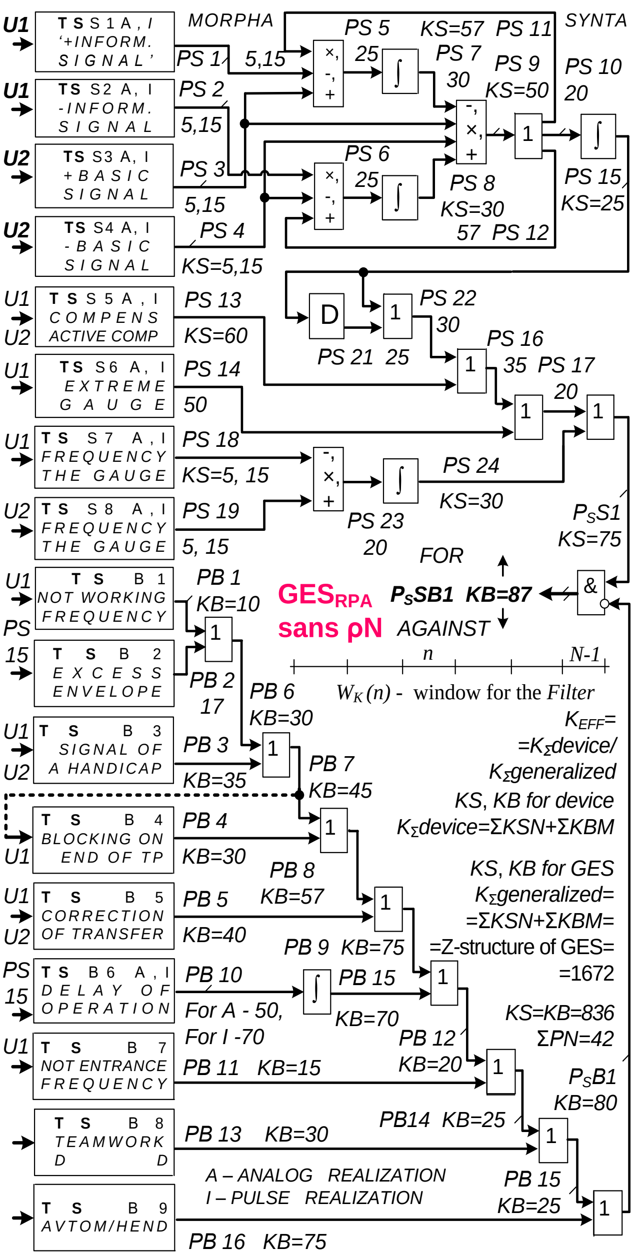

Figure 8: Generalized tree of recognition (GES) of S-detector

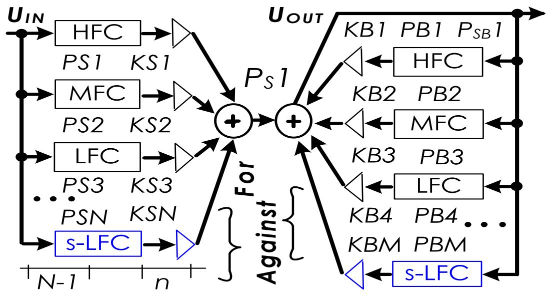

Figure 9: The structural-operational model of the OCP in the form of an IIR filter. Illustration of the division of movements by frequencies

C. The Relationship of Methods of Separation of Motions

Separation of motions by the frequencies determines the structure of the vibrational motion in the OCP (Figure 9). But the meaning of movements is recognized due to the separation of motions in meaning. It is possible to use an analogy. The method of separation of motions by frequency has the relationship of the schema elements within the same plane. LFC processes take up resources of the computing system during the HFC calculation processes. The method of separation of motions in meaning is the relationship in space. Each subsequent hierarchical computational part is less active and does not occupy computational resources.

The method of separation of motions by frequency means that there is a counter-sequential flow of information (Figure 9). The method of separation of motions within the meaning implies the movement of information in one direction: from input to output or from the source to the indicator (Figures 8, 10). We will distinguish the tree formation *SN*→TS for the OCP from a reverse tree recognition TS→*SN* GES$_{RPA}$ scheme RPA devices. Thus, before carrying out the modelling, the algorithm used to prepare the project for calculation is applied, algorithm may be automated. Major general timing parameters of the simulation are the famous pre-installation model in CAD. For example, the time of calculation and the checkpoint information display. From the SI-method, the method of separation of motions by frequency may be an additional preliminary step of establishing the minimum information. The order of application of the above methods can be the following: structural-operator, separation of motions by the frequencies, and SI-method. Then we will apply an SI-method to the solution of problems of modelling and of problems of smart-grids.

III. Theoretical Basis of Solutions

A. Mapping of the GES RPA Devices

The GES$_{RPA}$ scheme is universal for different RPA tasks. A selective part of the GES controls one of the infra-LFC–HFC oscillator circuits. Another circuit is used to provide a blocking function and forms part of the *Against* S-detector. The scheme can be summarized by the list of components. A list is called grammar G_{RPA} (Figure 8)

$$G_{RPA} \to (TS\ SN,\ TS\ BM,\ NTS\ SN,\ NTS\ BM,\ PSN,\ PBM,\ PSSN,\ PSBM,\ PSSBN); \quad (1)$$

Rules of 'For' PSN, 'Against' PBM, $N, M = 1, 2, \ldots$

Record example $PS5 \to f_{\times}(PS1, PS3)$ *or* $PS5 \to f_{+}(PS1, PS11)$;

Record example $PB12 \to f_{1}(PB9, PB15)$;

Root rules PS $PSSN$; $PSBM$; $PSSB1$;

Record example $PSSB1 \to f_{\&}(PSS1, PSB1)$.

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[1] Nikiforov, A. 2015. Unified smart-detector for electrical power smart-grid networks. 13th International Conference on Industrial Informatics (INDIN). Cambridge, UK: 1032-1039. IEEE Catalog: CFP15INI-15, ISBN: 978-1-4799-6648-6/15, DOI: 10.13140/RG.2.1.1812.6487

The central functional element in the GES_{RPA} scheme in Figure 8 is a synchronous detector '–,+,×' (*PS9*) and *Filter* (*PS10*). It compares the information signal U_{OUT} with the reference signal U_{IN} (Figure 9). The element type depends on the implementation of the RPA scheme1. The GES scheme can submit the finite impulse response (FIR) filter. This can be done because the operation of the machine SyntA occurs sequentially from the terminal symbol (TS) to the nonterminal symbol (NTS) and then to the symbol *S* (Figure 10). The TS is assigned a weighting factor *KSN* according to *KS1<KS2<… <KSN*. The appendage δ for $K_{SN}=\delta K_{SN-1}$ can be modified nonlinear, window $W_K(n)$ weight setting function to Filter. The coefficients *KN*, *KM* of the FIR filter defined by $W_{TABL}=TSN/SN$ (Figure 4, 6). Basic coefficient K_{MIN} rebuilding *S(t)* from interference. The window $W_K(n)$ can be 'triangular, growing' $W_K(n)=2n/(N-1)$, $n=0…N-1$ convolution $H(z)=\Sigma h(n)W_K(n)z^{-n}$. Step n determines the interval between the appearances of NTS in the GES scheme (Figure 8). The FIR filter highlights the evolution over time of the situation SN in the OCP and is the semantic S-filter. Based on the concept of controllability of the OCP, it follows that the grammar G_{RPA} reflects the work of the structural scheme of the OCP dynamics. The more control RPA devices perform, the more completely the model of the OCP is restored for $G_{OCP}\approx\Sigma G_{GES}=\Sigma G_{RPA}$.

B. *The Mapping of the GES for OCP*

Structural tree formation *SN*→TS for the OCP uses internal coordinates of the OCP. The RPA devices these coordinates are not observed (Figure 11). The tree will be built on the basis of three pillars:

a) Structural-operational description. A description of the OCP and equipment is prepared on the basis of Figures 2, 5. Information flows are generated by inertia fields and are described by the operators *D=d/dt, 1/D=∫*. The disturbance signal *SN(t)* for the OCP is selected as the input action schema. The elements of the description are divided into alternative streams of *For–Against* in relation to the formation of the exit of the OCP.

b) Separation of motions by the frequencies. The structural-operational description is transformed into the canonical form of a digital filter of an infinite impulse response (IIR) according to the rules of structural transformations (Figure 9). This possibility follows from the theory of filtration, according to which any inertial model can be described by the filter as IIR or FIR. Let us focus on the 'central' elements: '–,+,×' (*PS9–PS10*) of the tree GES_{RPA} in Figure 8. In the *Against* group are the flows that are initiated by the output U_{OUT} and come to an internal adder. Group members *Against* refer to the Filter block as a *Filter* passes only the selective signal.

c) Mutual display $G_{OCP}\approx\Sigma G_{GES}=\Sigma G_{RPA}$. The OCP model is built on the basis of the ligament $W_{iOCP}\rightarrow GES_{RPA}$ in Figures 5 and 10. The OCP model is based on an internal adder. In the scheme of the IIR filter in Figure 11, each rule *P* is assigned a weighting factor of *KN* or *KM*, focusing on G_{RPA} (Figures 8 and 10). In the structure of digital filters inertia is defined discretely. Similarly, the status of TS, NTS in the machine SyntA change discretely. The dynamic behaviour of the filters (their TP) depends on the information received from the input and from the output of the circuit OCP (Figure 11).

From models of the OCP, it follows that in the situation *S1 NM*, the output flow of information 'balances' the input stream. When violation of 'balancing' occurs, a TP takes place. The transition to a new state of the SyntA occurs as the development of the TP and the situation *SN*. Diagram of the IIR filter is preferable to not share the OCP and construction equipment. The G_{OCP} grammar can be represented as a list:

$$G_{OCP}\rightarrow(TS\ SN,\ TS\ BM,\ NTS\ SN,\ NTS\ BM,\ PSN,\ PBM,\ Ps) \qquad (2)$$

The grammar G_{OCP} (2) differs from G_{RPA} (1) because its elements have an oscillatory, often harmonic output, while the elements of G_{RPA} have a threshold exit.

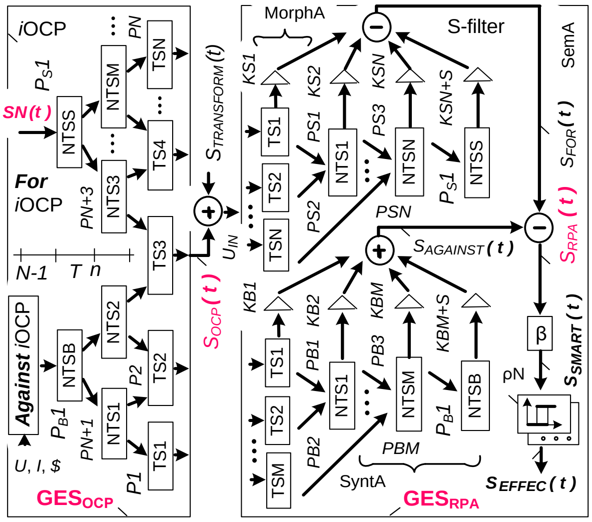

Figure 10: The structural scheme of the GES for the OCP and RPA devices in the form of FIR filters with one-directional flow of information. Illustration of the division of movements by sense. P_S, P_B – root rules

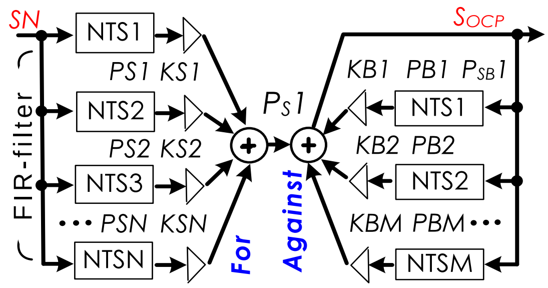

Figure 11: Structural model of the OCP in the form of an IIR filter. Illustration of the division of movements by sense

C. *View of the OCP Semantic Situation SN*

The semantic situation *S1 NM* corresponds to the steady-state values of the internal parameters of the OCP circuit (the outputs of the operators, NTS, rules *P*). Thus, the SI-method under the concept of the semantic situation *SN* is implied by the appearance of the reaction ΔU_{OUT} of the diagram of the OCP to the change Δ in any coordinate of the OCP. This definition of *SN* comes from the description of the OCP.

The compilation of the tree forming GES_{OCP} can be planned by using a table of the transfer function $W_{TABL}=TSN/SN$ (Figures 4, 6). W_{TABL} is populated based on the information in emergency files for training samples, as well as calculating in CAD models of OCP and of GES_{RPA}.

In the model, the OCP is useful to build a machine SyntA grammar G_{OCP} for forming the sense signal $S_{OCP}(t)$. The $S_{OCP}(t)$ summarizes the flow of information in the OCP (Figures 5 and 10). However, the $S_{OCP}(t)$ can be synthesized in the model of the OCP. The real OCP recovers the $S_{RPA}(t)$ with approximation. In the limit of the signal $S_{OCP}(t)$, only the situation *SN* can be specified. This becomes the minimum information required to build the model of the framework that allows us to reduce the time of a single calculation. Knowing the cause and effect of the TP in the OCP, we can construct a semantic tree formation (SyntA) OCP and refine the grammar G_{OCP}. It is possible to classify the situation *SN* for different modes and types of failures of the OCP. This classification and analysis of RPA Ψ-structures was involved in the proof of the theorem[1].

D. Compiling the Combined Scheme GES

From the comparison of Figures 8–11, it follows that the synchronous detector (*PS9–PS10*) is a 'central' element in the GES_{OCP}. So as a filter select feedback U_{OUT} output to the total adder (Figure 11). Replace the transfer function elements involve the feedback. Will be a more general scheme of OCP in the form of a unidirectional tree forming *SN*→TS (Figure 10). The combined diagram in Figure 10 allows to obtain a more qualitative model of the situations recognition of the situation *SN* bearing in mind the mutual reflection $G_{OCP} \approx \Sigma G_{RPA}$ and the possibility of comparing the signals $S_{OCP}(t)$ and $S_{RPA}(t)$. The minimum information required to build the model of the OCP is: a) the two elements of the informational part (*i*OCP) — selective TS or blocking TS (Figure10); b) the combination of the source signal $S_{OCP}(t)$ and the controlled frequency generator. The generator can be the amplitude, frequency, and phase modulation of the output signal from the range of super-LFC–HFC depending on the problem being solved. Such OCP models minimize the time of a single calculation. Thus, the configured models are listed later in the article. The algorithm of restoration of a signal of $S_{OCP}(t)$ from the OCP model can be used for interpretation of the saved emergency files. Doing this involves the expert system model ExS and driver diagnostic messages (Figure 3). Next, shows the methods of restructuring the basic components to solve the problems of modelling and control. First give a description of OCP and how to set the S-detector.

IV. Proposed Solution Objectives

A. An Example of OCP

It is known that the cost of prevention of equipment failure is cheaper than eliminating the consequences. Should be preferred to automatic algorithms, ensuring elimination of damage, search and prevention of faults without switching equipment. The primary cause of damage can be seen as large surface and volume of high-voltage insulation equipment networks. The insulation is physically due to the source of the phenomenon. The desire to perform a long-lasting, ageless isolation is virtually impossible. In this regard, normally in the technical designs a special insulation layer is used that fills the developing damage and ensures continued operation of the insulation (for example, oil-resin layer in the high-voltage cables). This is an area in which the interests of different services on network operation and joint work of devices of automatics and relay protection [1, 6–7].

As an example, the selected task is maintaining the efficiency of operation of a resonant-earthed neutral (EFFEC) networks 6–35 kV with the automatically controlled of Petersen's coil (DGR). Therefore, a further element *L* denotes DGR (Figures 1–2, 4). It is known that of damage to the high voltage isolation network *one-phase grounding* (OPG) is 75% of all injuries in the power industry. In many networks OPG occurs every day. In the case of OPG inductive current I_L is configured *L* and the capacitive current I_C of the network counter directed (Figure 12). Therefore, the current I_0 in place OPG is minimal. The conditions for self-destruct OPG are created. Voltage in the network theoretically does not exceed 2.4 times. Almost high frequency oscillography showed no exceedances of line voltage zones in different networks of traditional construction, and easily reaches 98%. In the high-voltage cables with polyethylene fabric a special layer is not specified and this is a question for the developer's cable. Perhaps a layer in the cable construction is not introduced in view of its marginal cost. But when the conditions created by the DGR are configured, the fluidity of polyethylene (polyethylene that is not charred) can implemented self-healing of the insulation. From any point of view, self-healing insulation is a required property [6–7].

In Figure 12 shows the circuit zero-sequence network (LZSC), consisting of a parallel connection of *RLC*-elements. The LZSC is characterized by small values of the input signals of RPA devices for semantic situations *S1 NM* and *SN AM*. Therefore, the selectivity of RPA devices is ensured by the intelligence of their algorithms [6–8]. LZSC is an example of the OCP with the control criteria of the DGR by eliminating the deviation from the situation *S1 NM*. The DGR operating experience revealed a number of control features such as OCP (Figure 3). In the absence of staff in the network impact features should be kept to a minimum. We list these features:

a) Instability of joint work of many sectors of *ZN*. This is due to the increase in the rate of change *L* when combined DGR;
b) The semantic conflict between the system is self-cancellation of the capacitive currents and selective relay protection. It is known that the task of automation is to ensure the smooth operation of the network, the task of the relay protection is to disconnect the damaged section of the network;
c) The match result signals in situation *S1 NM* and in the situation *SN Failure* in equipment or devices;
d) Lack of remote monitoring of the performance of the network with DGR for long intervals of operation.

B. Proposed Solution Objectives

This article shows how the simulation problems can be solved through the organization of the workplace for through

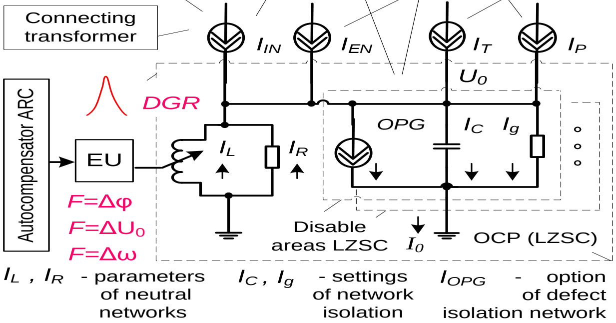

Figure 12: Structural diagram OCP (LZSC), *L* (DGR) and ARC

CAD. In addition, the objectives of the smart-grid are solved due to the mutual determination of parameters grammars $G_{OCP}\approx\Sigma G_{GES}=\Sigma G_{RPA}$. The overall objective is to reduce the time of a single calculation with stability of the simulation. Goal is achieved by using SI-method of pattern recognition and the method of separation of motions. Some received, but not known to the investigation, confirm the correctness of the proposed solutions. Some of the differences between solutions from the known methods of real-time simulation [8–10], you can highlight the possibility of modelling dynamic information problems in the parallelization of computations on different PC.

C. Modelling Information Contours

In tasks of 1–4 of the smart-grid processed at the basic signals of a semantic situation *S1 NM*. For such problems with slow TP, it is possible to propose additional solutions to the problems of modelling in CAD. So, apply a common sync time interval of the sweep simulation, for example, the daily cycle T_{CALCUL}=24 h. In the model of OCP tended to come from real disturbances for the approximation model to the real OCP. The source of the disturbance may be a signal file, for example, the signal of solar panels, node, *KNOT*, etc. (Figure 1). Then the source of the perturbation will modulate the carrier signal with industrial frequency ω. The HFC circuit in the OCP specifies the parameters of the of analog-to-digital converter (ADC) devices RPA. The actual events in TP can follow through considerable intervals of time. The ADC produces an excessive number of samples for tasks with the contours of the infra-super-LFC. It is natural to work of RPA devices in the real OCP. But when modelling in CAD uninformative intervals TP use computing resources. It is possible to compress the time axis of the signal perturbations in the OCP. It is enough to multiply by a coefficient the value of the column time in the emergency file. Interval with minimal signal change in TP is determined from the signals of emergency files. The compression of the time axis is determined on the basis of the total inertia or time of information processing algorithms in the RPA. For example, suppose that each change of signal perturbations will modulate the carrier frequency ω for 5–10 periods ω. The value is selected from the theory of modulation signals. Then the minimum time interval of data compression will be 5×ω=0.1 s. So, for the signal U_{KNOT} the real network, time T_{CALCUL} managed to reduce to 2000 times without loss of information (Figure 1). As a result, the sweep time for the simulation of the diurnal cycle was reduced to T_{CALCUL}=44 s. This principal reduction T_{CALCUL} becomes acceptable for modelling in CAD. Also it allows not to change parameters of algorithms of real time of RPA devices when modelling as it is carried out for reduction of time of single calculation.

D. Method of Separation of Motions in Frequency in CAD

For practical purposes, the parameters of the oscillatory circuit of the shaper signals OCP are determined by the signals files emergency real OCP (Figure 11). Here is an example of the configuration of circuits for one section of the *ZN* is:

a) *Configuring LFC contour (LZSC)* (Figures 12). This is determined by the equality $\omega C=1/\omega L$, where ωC is the capacitive conductance to earth of the three phases of the network to the base part and a switched part of the network, L is the inductance of the DGR, shall be determined from the capacitive current of the network $I_C=I_L$. Experience shows that one should distinguish between three types of network — I_C<10A, I_C=10–100A, I_C>100A based on the parameters of oscillatory circuit. Quality factor of the circuit d=0.05 is determined based on the active current $I_A=dI_C$;
b) *Setting infra-LFC contours.* This range of input signals automation devices. Select the simulation time of the project T_{CALCUL} (Figure 12) based on the time adjustment autocompensator ARC of the control range of the models DGR for 4 sites *ZN* (Figure 2);
c) *Configure MFC-contours.* This is a range of selective devices SP. The frequency is determined by the charge of the healthy phases of the network. Lasts for several half-cycles k after the occurrence of OPG. Based on the experience of emergency reception of files can be generalized for network I_C<10A frequency f_{MFC}=5–10 kHz at k=3–10, for network I_C=10–100A frequency f_{MFC}=1–3 kHz for k=1 to 3 to the network I_C>100A frequency f_{MFC}=0.3–1 kHz with k=1–1.5;
d) *Set up HFC-contours.* HFC signals I_0, U_0 are within the scope of interference signals in the OCP (Figure 12). Bit component of the faulted phase network with OPG in the network f_{HFC}=3–10 kHz. The parameters of the HFC depend on the longitudinal conductivity of the phase network. k=1–3. Visually HFC can be determined by oscillatory changes of the first wave of MFC I_0 (box in Figure 15).

The calculation time of the same hierarchical level can be tens of hours. At joint modelling of several sites of *ZN* with RPA devices time increases many times, and stability of calculation decreases. This limits the application of separation of motions in frequency.

E. Method of Separation of Motions in Sense in CAD

To summarize the summary lists of actions for the method of separation of motions in the sense. For RPA devices:

a) Scheme GES merge block diagrams of RPA devices (Figure 8). With the scheme is written off grammar G_{RPA};
b) Are elements of MorphA, SyntA, SemA in a separate computational parts;
c) Sequentially for modelling parts that are affected by the changes made when the model changes;
d) Formed W_{TABL}, albums of from TS, NTS, *S* to *SN* and the archives of the calculations.

For the OCP scheme:

a) Determined by the number and parameters of oscillatory circuits on mathematical descriptions and files from disaster;
b) A scheme of OCP in the form of a IIR filter (Figure 11);
c) Compiled GES_{OCP} scheme as inverse GES_{RPA} scheme according to $G_{OCP}\approx\Sigma G_{RPA}$ relatively ΔS (Figure 10);
d) Stand out in G_{OCP} and implemented elements MorphA, SyntA, SemA in separate computing units;
e) Filled W_{TABL} for submission to the OCR. Formed training and controlling the sampling of situations *SN*.

For combined schemes of OCP and RPA devices:

a) Divide the project hierarchically subordinate computing part;
b) The recalculated portion of the overall project, involved in the tree formation in the OCP or the tree definition RPA devices according to Figures 8–11. To

do this, the developer pre-specified control point calculation;

c) All signals TS, NTS, *S* are stored in the shared folder of the settlement project in the form of W_{TABL}. Each hierarchical part can consistently use these signals;

d) To automate the process of multiple simulation the algorithm uses a third-party run in sequence CAD of computer parts with a minimal number of elements. The sequence of parts is assembled according to the scheme of combined OCP and RPA devices (Figure 12);

e) Is controlled by a semantic condition on the OCP recovered signal $S_{OCP}(t)$ and is compared with the signal $S_{RPA}(t)$.

F. The Setting of the S-Detector

Solving of tasks the set is based on the work of the S-detector. For the definition of its parameters it is convenient to perform the modelling in CAD in a separate part of the computational adjustment. One of the objectives of modelling is to establish the relationship between parameters in table TSN/*SN* in Figure 8. The parameters include the components of a grammar G_{RPA}, the values of the coefficients *KN*, *KM*, threshold ρ*N*. The number of *SN*, TS is due to objective reasons that are generated in RPA devices and OCP.

Figure 13 shows a scheme of the model S-detector *1–Against* EFFEC. Signal $S_{EFFEC}(t)$ of the subsystems *ARC*, *SP*, *RVC*, *Monitoring* are combined by the adder '+'. The output scaling factor allows you to adjust the amount $S_{EFFEC}(t)$ to the level of '1' or 100% (Figure 14). With the deterioration of equipment OCP signal level $S_{EFFEC}(t)$ can only decrease. In Figure 3 shows the model S-detector *For–Against* RPA devices. The coefficients *KN*, *KM* are activated by the installation of an information sensor TS according to the situation *SN*.

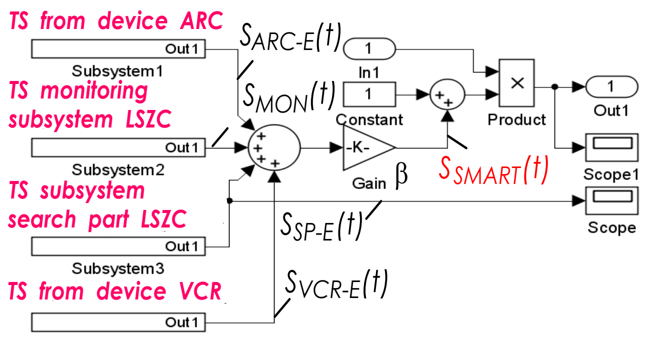

Figure 13: Model iS-detector EFFEC 1-Against, including TS devices and subsystems RPA system ASNOM

The S-detector EFFEC model forms the chart of changes of the size *SN*=ΣKTS for all considered situations of *SN* proceeding from TSN/*SN* table of correspondences. The magnitude of *KN*, *KM* can be adjusted according to the simulation results on the signals training and controlling of the samples TP in the OCP. The chart of changes is stylized under TP in the system ASNOM and OCP (Figure 14). Signal $S_{EFFEC}(t)$ is divided the multithreshold element ρ_{EFFEC} on five semantic results — ρ1 *NM*, ρ2 *Not*, ρ3 *Critical (CM)*, ρ4 *Emergency mode (EM)*, ρ5 *AM*. The threshold value of ρN can be defined as the coefficient of performance of the neutral $K_{EFFEC}=1/S_{EFFEC}(t)$. For example, from the threshold ρ1 *NM* (K_{EFFEC}=0.98) up to ρ5 *AM* (K_{EFFEC}=0.25).

V. Example of Modelling in CAD

Information in circuits (infra-LFC, super-LFC) develops after the completion of the movements at a faster contours. According to SI-method and theorem[1] divide the total project hierarchically subordinate computing part — No. 1 *Calculation of the OCP*, No. 2 *Calculation of MorphA*, No. 3 *Calculation of SyntA*, No. 4 *Calculation of SemA*, No. 5 *Calculation of ASNOM system*.

In *Computational part No. 1. Calculation of the* OCP is a network diagram of the smart-grid (Figures 2–3, 12) — blocks of the OCP, high voltage equipment, *Terminal RPA*, *DGR*. Morphological level of the scheme OCP is modelled. To do this, several problems can be solved — a) *Determining the quantity of SN situations*. Analysis of the accumulated emergency files in real networks shows that the training sample *SN*=30, control — *SN*=15; b) *Determining the quantity of TS*. Fills in the table of correspondence *SN*→TS in Figure 4; c) *The TS simulation in CAD*. In the process of modelling the OCP are formed signals TS are stored in folders named *SN*, for example *SN Burns OPG*. From such folders can be created of a library of *SN* situations; d) *Obtaining additional TS and SN for the model of the OCP*. Their existence and way of realization in algorithms is defined.

A. Performance in CAD of the Example OCP (LZSC)

Solved *Problem No.* 3 *smart-grid. Self-control*. Self-control system EFFEC is realized in the terminal *T-LZSC-ARC* (Figure 2). Figure 10 shows the *S-detector* EFFEC as the recipient of the results of other computational units. It uses information from available RPA devices — autocompensator ARC, selective protection SP for damaged *SPp* and undamaged *SPn* connections network, registrar high-frequency digital (VCR), which supplies additional TS on the state of the OCP.

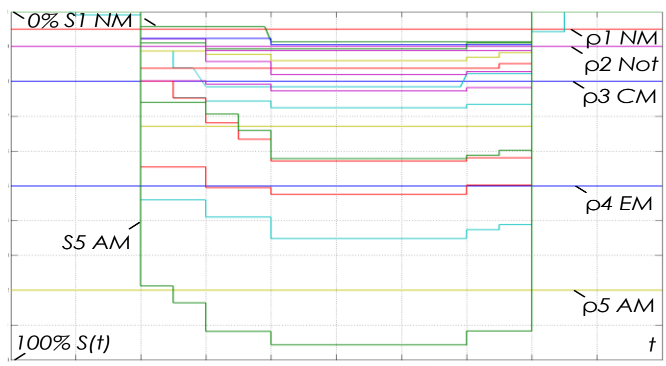

Figure 14: The result of calculation of the diagram changes *S(t)*, taking into account the situation *SN* and ρN from W_{TABL}=TSN/*SN*

B. Modelling MorphA RPA Devices

In *Computational part No. 2. Calculation MorphA*. The MorphA scheme was formed for all RPA devices. Building higher quality MorphA is possible when the minimum number of TS provides a more complete recognition of the situations *SN*. Here are some examples of setting the minimum values of the frequency parameters of the network model smart-grid devices and RPA (real-time sampling rate f_{DISCR} signals):

a) *The output signals TS in the OCP*. The OCP model can present two types of signal sources TP — real emergency files and the OCP model in CAD. The frequency f_{DISCR} signals emergency file may be reduced by decimation (Figure 7). The f_{DISCR} of the output signals of the OCP model is assigned based on the minimum distortion of HFC signals. The f_{DISCR} value is determined by the possibility of designing information sensor TS. For example, at 10–20 points per period of HFC I_0, U_0 is f_{DISCR}=100 kHz;

b) *The input signals of RPA devices.* Based on the problem of modelling real-time, precision signal TS must be supported by the type of chip on which the RPA device is implemented. For example, for the SP device the maximum frequency in the OCP is f_{DISCR}=100 kHz. Its decimation value of 25 times used for autocompensator ARC — f_{DISCR}=50 Hz–4 kHz, then for control systems — f_{DISCR}=300 Hz (Figure 12). May reduce f_{DISCR} for ARC up to 20 points for the period of industrial frequency ω;

c) *The control signals of the executive bodies of the EU.* The frequency f_{DISCR} the calculated control signals can be reduced to units of Hz, focusing on the dynamics of work of EU of the OCP (Figures 4–5). Also refers to the signals *S(t)* selected f_{DISCR}=100 Hz.

C. Modelling SyntA RPA Devices

In *Computational part No. 3. The calculation of the SyntA* are the elements of the *SyntA* RPA devices for all plots *ZN*. Characterized by several features — a) *Reducing calculation time.* It is possible to perform a more thorough separation of the computational part or to count separately the 'composite' block and less 'complex'; b) *Generating synchrosignal*. The values of synhrosignal internal generators machines should be minimized on the basis of the accuracy of repetition of pulse signals; c) *A combination of times.* The combination of time of occurrence of TS in different oscillatory circuit OCP (infra-LFC–HFC) will allow more than just implementing a selective blocking part of the algorithm SyntA (Figure 7).

For example, OCP (LZSC) shows the formation of a signal $S_{EFFEC}(t)$ for the situation *SN Metal OPG*. The *SN* situation is initiated by the *kOZZ* block. OPG is made serially on each of sites of *ZN* (Figures 1–2). In this *SN* when forming a $S_{EFFEC}(t)$ the $S_{SP}(t)$ work selective protection SP with the maximum amount of deviation. For this *SN* when forming a $S_{EFFEC}(t)$ the $S_{SP}(t)$ of work of protection of SP is shown. The correct formation of $S_{EFFEC}(t)$ of SyntA of SP devices is visible. $S_{EFFEC}(t)$ for the damaged *SPp* and not damaged *SPm* of accessions of a network of each *ZN* are presented. The criterion of SP devices is the coincidence of the first half $3i_0$, $3u_0$ or TS $MFC3i_0$, $MFC3U_0$, $LFC3U_015V$, $LFC3U_030V$ and the existence of triggering a selective criterion within a predetermined time (e.g. 1.5 s). In this case, the value of the $S_{SP}(t)$ reaches its maximum value and exceeds the threshold of the relay. In all other cases, the of $S_{SP}(t)$ reaches the threshold ρ_{SP}, selective organ is blocked. For the intact *SPm* with sufficient quantities of signals $3i_0$ lock selective detector is performed using alternative selective detector, which determines the direction for *SPm*.

The proposed solutions give simple solutions to control LZSC. So the way to eliminate the temporary contradictions between automatic and selective protection based on the control signal $S_{SP}(t)$, reflecting the success of self-liquidation OPG (Figures 3–4, 10) is controlled by the magnitude of the signal $S_{SP}(t)$ for monitoring the success of self-liquidation OPG. As a result, the time-delayed shutoff of the damaged section of the *SPp* network becomes a controlled variable. The standards allow her the choice in the range of from 0.1 s to 4 hours. Solution other features related to the change in the speed regulation of the current I_L during the joint operation of the DGR series based on the control signal $S_{ARC}(t)$. In the formation of the $S_{ARC}(t)$ involves smart sensors change the speed control signal EU (DGR).

D. Modelling Semantic Level OCP and RPA Devices

In *Computational part No. 4. The calculation of the SemA* is reduced together with the sources of the signals TS, NTS, *S(t)* of the four network sites of *ZN* obtained in parts of Nos. 1–3 of the project. Figure 13 shows a model S-detector EFFEC of ASNOM system (Figure 3). Outputs of thresholds ρ_{EFRN} move on a indicators level of the $S_{EFFEC}(t)$ as blinkers. The diagnostic message with the colour gradation and the graph-text information is a set of active places (blinkers), which are filled by NTS or *SN*. System ASNOM in the messages can capture instructions to eliminate the cause of the violations *S1 NM*.

E. Combining the Results of the Hierarchical Parts

In *Computational part No. 5. The calculation of ASNOM* combined source signals TP to OCP and signals from RPA devices in the form of sources .mat, .stl. The calculated signals are grouped into blocks according to the ASNOM system (Figure 4). For clarity, the results are displayed in a poster emergency file (Figure 15). The analysis of the modelling process shows that only display the required number of point's results in CAD spent tens of minutes lost the stability of CAD. To preserve the stability of mapping results we apply the method of separation of motions. With this method a number of computer parts are organized to view the groups of signals. You must have previously manually set the f_{DISCR} of the tasks displayed in the *Scope* blocks, corresponding to the signals in the files *.mat*. This is a question for the developers of *MATLAB*. The possibility of displaying graphic information of is very limited in evaluation of the required number of alarm files. In this regard, the features of the program *PSPICE* (*ORCAD*) are preferable. CAD *MATLAB* was chosen because of the availability of the design tool digital filter, functions in programming languages, positioning them to corresponding cores of chips, as well as the availability of SCADA.

The end result of the presentation of semantic information can be a widget of terminal *T-LZSC-ARC*. The widget will allow you to manage and maintain the network with minimal time on repairing in the early stages of their development, the elimination of rare and unrecognized situations *SN*. It provides options to implement a widget for devices such as Google-Glass, tablets and smartphones. The same principles can be implemented in the workplace in organizations that perform outsourcing services RPA or dispatch networks.

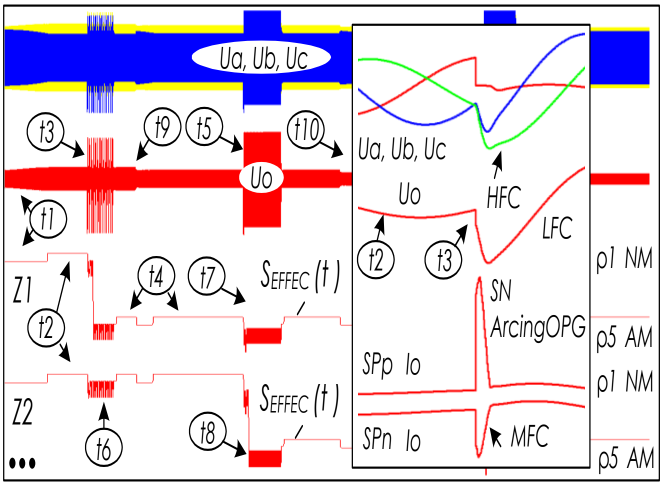

Figure 15: The solution of problems of smart-grid 2, 5. Modelling of work ASNOM system from 4 sites *ZN* at situation *SN One-phase* grounding or OPG. Temporary point's — *t1* – automatic control ARC of a resonance of a network; *t2, t4* – situation *SN NM*; *t3* – *SN ArcingOPG* on a sites of *Z1*, *t5* – *SN MetalOPG* on a sites of *Z2*, *t6* – processes in the OCP; *t7* – correct the deviation of the signal *S(t)* on a sites of *Z1* less than ρ5 *AM*; *t8* – correct the deviation of the signal *S(t)* on a sites of *Z2*; *t9, t10* – disable joining the network and automatic control ARC

VI. Analysis of the Result

Validation of the proposed solutions was implemented in CAD *MATLAB*, *ORCAD and MATHCAD*. The computation time was reduced while maintaining stability. So in CAD *MATLAB* with the following results —

a) *Calculation time of the project.* Modelling of the four areas of network *ZN* was carried out for T_{CALCUL}=44 s. Time of calculation of computing parts made — No. 1–12 h, No. 2–4.2 h, No. 3–3.4 h, No. 4–4.3 h;

b) *The ratio of the signals archiver.* Alarm files characterized by a low occupancy rate. This is due to the large range of possible changes of the amplitudes of the signals, frequency signals, changes HFC at relatively small time intervals, etc. So the memory footprint of a single signal parametric data in the OCP amounted to 68.5 MB. Accordingly, for the six signals U_F, $3U_0$, $3I_0P$, $3I_0N$ took 411 MB. As a result the normal backup volume was reduced to 94.5 MB. The ratio amounted to 411 MB/94.5 MB=4.3. Such a large amount of memory crash file impedes construction of remote monitoring systems and generates the information 'throat' problem networks in the smart-grid;

c) *Compression ratio parametric semantic information signal S(t).* Memory resulting signal amounted to $S_{EFFEC}(t)$=192 KB. The compression of the parametric information amounted to 411 MB/192 KB=2140. Such a large compression ratio is achieved due to the slow change of the semantic information in time, hence, less sampling of the *S(t)* during storage. Further compression of the $S_{EFFEC}(t)$ the normal archiver resulted in a reduction of up to 8 KB. The compression reached 192 KB/8 KB=24. This is a high compression archiver. As a result, the ratio of *S(t)* in packaged form reached 94.5 MB/8 KB=11812. The change of meaning occurs relatively rarely. On the basis of such a considerable compression of information it is possible to realize the ASNOM system.

VII. Conclusion

A method of division of movements by sense is offered. The method makes it possible to reduce the time of a single calculation while preserving the stability of modelling. The method of describing the internal structure of the OCP on the basis of the generalized scheme GES_{RPA} and parameter grammars $G_{OCP}\approx\Sigma G_{GES}=\Sigma G_{RPA}$. GES schemes to control elementary elements of TS, NTS, *P*, their combination in the RPA device, of *ZN* and the network. Shows the organization of the workplace in CAD for regular improvement of RPA devices based on the SI-method. Two types of problems were solved: modelling of real-time systems and networking for smart-grids. Task modelling was solved by a separation project on a hierarchically subordinate computing part with mixed results in the executive summary. For the solution of smart-grid problems, an ASNOM system for recognizing the dynamic signals is organized. The performance of the model was determined with regard to the computation time, the ratio of meaningful signal *S(t)* to the original signal of the OCP.

Improvements were made to the terminal-auto-compensator *T-LZSC-ARC*, selective protection with a high-frequency digital recorder *U-VCR-SP*, and the widget of the terminal *W-LZSC* to their joint operation in smart-grid networks of a 6–35 kV smart-grid with an automatically controlled Petersen's coil. Examples of simulation results in the project were shown.

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