Analysis of the Effect of Interaction on the Large-Scale Systems

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***Abstract*—** This paper consists in an overview of the large-scale systems and methods of decentralized control, which ensures the dynamic properties of the individual subsystems. effect of interaction with some change in parameter.

Keywords: Large-scale systems Decentralized control, Hierarchical system

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I. Introduction

CONTROL of large scale systems is highly discussed problem among professionals. it is the result of quick development of technological and information networks. Mainly this development brought mass implementation of new means of control of such systems. Mass networks or systems with typically high complexity are being created. With growing complexity of these systems, it is necessary to bring new control algorithms so we would be able to handle new states that occur with changes of structure of the large scale system. one of the important elements of large systems are its complex interactions that can act as a media for disturbances transfer or media of state changes of the system. the professionals in the area state that changes of state of any subsystem are in common life the most frequent cause of malfunctioning of the whole system. it often happens in regulation that due to erroneous state of one part of a large system, another part of the same system operates in erroneous state although it is completely healthy by itself. the transfer of disturbances (erroneous states) is the result of interactions between individual subsystems. a change of subsystem's state can be caused by operational error or total malfunction of one or more parts of the subsystem. in general, there occurs a change of dynamics matrix of the particular subsystem. these changes appear randomly and in a discrete way. the result of such state change does not have to lie in occurrence of operational error of one or more parts of the subsystem. it can be also caused by input of expected or unexpected error that can be understood in common system as a change in load of the system, change of working environment or change of demands laid upon the system, thus changing the structure of the system..because we talk about randomness of changes of parameters of the system and about attempt of control, we have to take in account this randomness and implement it into the control algorithm. in common operations such random (stochastic) events can be observed in long term and that allows creating statistics with its possible implementation into control algorithms and in this way we can control such system more efficiently. for modeling of a sequence of stochastic states a mathematical process that allows to copy random processes that occur in nature. this process is the so called markov process (for continuous states systems) and markov chain (for discrete systems). With the ability to observe, create and implement statistic models into algorithms of control of complex systems we come to real increase of reliability of the controlled system. "by reliability we will define a set of features that include fulfillment of demands laid on operation of a system during given operational conditions [7]." we perceive reliability as a highly important and therefore not negligible economic marker. often reliability gets in front of new modern methods. the theory of reliability is much bound with the theory of maintenance and repairs and by their integration it is possible to come closer to satisfactory operation of the system. the focus of mankind is always more oriented on the so called optimal solution of problems. by optimization of any system we focus on selection of solution of the problem that will be the best among all others (according to our preset criteria). these criteria are in practice often mainly financial savings. as most of the dynamic systems are presented as large scale system, it is not possible to control it just by classical approach to control. here, decentralization combined with optimization of individual subsystems results in optimization of the whole system. control by decentralized approach can be understood as multi-agent control of a large scale system, where individual controllers act as agents that have to control the designated subsystem

II. HIERARCHICAL CONTROL OF LARGE-SCALE SYSTEMS

the notion of large-scale system, as it was briefly discussed, may be described as a complex system composed of a number of constituents or smaller subsystems serving particular functions and shared resources and governed by interrelated goals and constraints (mahmoud, 1977). although interaction among subsystems can take on many

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forms, one of the most common one is hierarchical, which appears somewhat natural in economic, management, organizational, and complex industrial systems such as steel, oil, and paper. within this hierarchical structure, the subsystems are positioned on levels with different degrees of hierarchy. a subsystem at a given level controls or 'coordinates' the units on the level below it and is in turn, controlled or coordinated by the unit on the level immediately above it figure (2).shows a typical hierarchical ("multilevel") system [4]. The highest-level coordinator, sometimes called the *supremal coordinator*, can be thought of as the board of directors of a corporation, while another level's coordinators may be the president, vice-presidents, directors, etc. the lower level can be occupied by plant managers, shop managers, etc, while the large-scale system is the corporation itself. in spite of this seemingly natural representation of a hierarchical structure, its exact behavior has not been well understood mainly due to the fact that very little quantitative work has been done on these large-scale systems (march and simon, 1958) mesarovic et al.(1970) presented one of the earliest formal quantitative treatments of hierarchical (multilevel) system. since then, a great deal of work has been done in the field (schoffler, and lasdon, 1966; beneveniste et al, 1976; smith and sage,1973; geoffrion,1970; schoffler, 1971; pearson, 1971; cohen and jolland, 1976; sandell et al, 1978; singh, 1980).

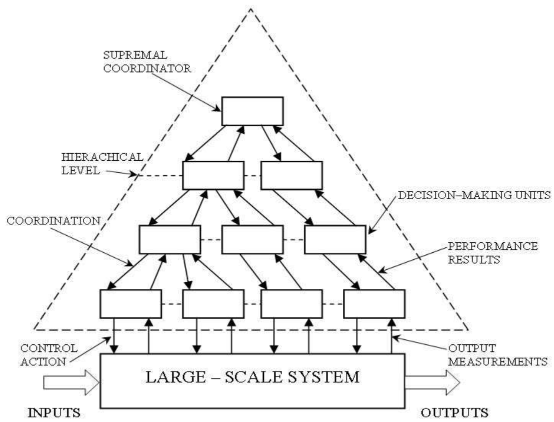

Fig.2 A hierarchical (multilevel) control strategy for A large-scale system

for a relatively exhaustive survey on the multilevel systems control and applications, the interested reader may see the work of mahmoud (1977). in this section, a further interpretation and insight of the notion of hierarchy, the properties and types of hierarchical processes, and some reasons, for their existence are given. there is no uniquely or universally accepted set of properties associated with the hierarchical system however, the following are some of the key properties

- a hierarchical system consists of decision-making components structured in a pyramid shape figure. (2).
- the system has an overall goal, which may (or may not) be in harmony with all its individual components.
- the various level of hierarchy in the system exchange information (usually vertically) among themselves iteratively.
- as the level of hierarchy goes up, the time horizon increases; i.e, the lower-level components are faster than the higher-level ones.

III. DECENTRALIZED CONTROL

most large-scale-systems are characterized by a great multiplicity of measured outputs and inputs. for example, an electric power system has several control substations, each being responsible for the operation of portion of the overall system. this situation arising in a control system design is often referred to as *decentralization*. the designer for such systems determines a structure for control, which assigns system inputs to a given set of local controller (station), which observe only local system output. in other words, this approach, called *decentralized control*, attempts to avoid difficulties in data gathering, storage requirements, computer program debugging, and geographical.

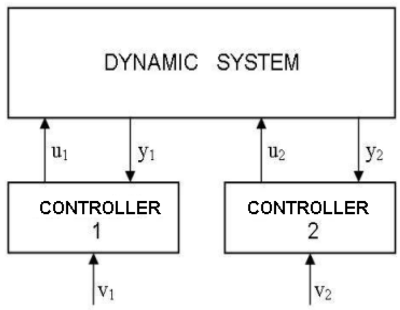

Fig.1 decentralized control structure

The basic characteristic of any decentralized system is that from one group of sensors or transfer of information actuators to others is quite restricted. For example, in the system of figure (1) only the output y_1 and external input v_1 are used to find the control u_1, and likewise the control u_2, is obtained through only the output y_2 and external input v_2. The determination of control signal u_1 and u_2 based on the output signals y_1 and y_2, respectively, is nothing but two independent output feedback problems, which can be used for stabilization or pole placement purposes. It is therefore clear that the decentralized control scheme is of feedback from, indicating that this method is very useful for large-scale linear systems This is a clear distinction from the hierarchical control scheme, which was mainly intended to be an open –loop structure.

V. DECENTRALIZED CONTROL WITH DISCRETE EVENT

It will be assumed that the large-scale system to be controlled is described by the linear vector differential equations:

$$\dot{x}_i = A_i[r(t)]x_i + B[r(t)]u_i + \sum_{\substack{j=1 \\ j\neq i}}^{N} A_{ij}[r(t)]x_j \qquad (1)$$

where $x_1(t) \in r^n$ is the system state, $x_1(t) \in r^m$ is the control and a_i, b_i, a_{ij} are matrices of dimensions n x n, n x m, n x n, respectively. the stochastic behavior comes from the dependence of a_i, b_i, a_{ij} on r(t). denote the event $[a_i(t), b_i(t), a_{ij}(t)] = [a_{i,k}, b_{i,k}, a_{ij,k}]$ when r(t) = k and denote the set s =

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{1,2,..., s}. the stochastic variation of the process parameter will be described by the markov process r(t):

$$\Pr\{(t+\Delta)=l \mid r(t)=k\}=\begin{Bmatrix} p_{kl}\Delta+o(\Delta), k\neq 1 \\ 1+p_{kk}\Delta+o(\Delta), k=1 \end{Bmatrix} \qquad (2)$$

$$p[r(t_0)=k]=p_k; \qquad k-1,2,\ldots\ldots, s; \quad k,l\in S$$

here p = $[p_{kl}]$ is (s x s) matrix with $p_{kl} \geq 0$, k ≠1,

$$p_{kk} = -\sum_{\substack{l=1 \\ l\neq k}}^{s} p_{kl}$$

denoting the state probability vector as;

$$p(t)=[p_1(t),\ldots\ldots\ldots, p_s(t)]^T$$

and the transition matrix as p we can consider modes of the system as states of the markov process with a finite number of states e_k, k = 1,2,..., s and continuous time

$$\dot{p}(t)=P\, p(t); \qquad p(t_0)=p_0 \qquad (3)$$

it is assumed that the following sequence of events occurs at time "t":

1. x_i and x_j are observed exactly,

2. then $a_{i,k}$, $b_{i,k}$, $a_{ij,k}$ switches to $a_{i,l}$, $b_{i,l}$, $a_{ij,l}$,

3. then $u_{i,k}$ is applied in the sense of some averaged quadratic performance index

$$J=\sum_{i=1}^{N} J_i=\sum_{i=1}^{N} E\left\{\frac{1}{2}\int_0^T (x_i^T Q_i x_i + u_i^T R_i u_i)dt\right\} \quad (4)$$

the optimal solution in the sense of (4) can be expressed

$$u_{i,k}=-R_i^{-1}B_{i,k}^T K_{i,k} x_{i,k}+R_i^{-1}B_{i,k}^T h_{i,k} \qquad (5)$$

where r(t) = k ; i = 1,2,..., n; k = 1,2,.. .,s. the matrices $k_{i,k}$ and the vectors $h_{i,k}$ can be computed from a set of coupled stochastic differential equations

$$\begin{aligned}\dot{K}_{i,k} &= -A_{i,k}^T K_{i,k} - K_{i,k} A_{i,k} + \\ &+ K_{i,k} B_{i,k} R_i^{-1} B_{i,k}^T K_{i,k} - Q_i - \sum_{l=1}^{s} p_{k,l} K_{i,l}\end{aligned} \qquad (6)$$

$$K_{i,k}(T)=0$$

$$\begin{aligned}\dot{h}_{i,k} &= -\left[A_{i,k}-B_{i,k}R_i^{-1}B_{i,k}^T K_{i,k}\right]^T h_{i,k} + \\ &+ K_{i,k}\sum_{\substack{j=1\\ j\neq i}}^{N} A_{i,k}x_j + \sum_{\substack{j=1\\ j\neq i}}^{N} A_{ji,k}^T (K_{j,k}x_j - h_{j,k}) - \\ &- \sum_{l=1}^{s} p_{k,l} h_{i,l}\end{aligned}$$

$H_{I,K}$ (T) = 0; I, J = 1,2,...,N; K,L = L,2,...,S

The equation (6) is generally known from [8], [9] the equation (7) is obtained from the equations for deterministic problem where is necessary to compute m $\{h_{i,k}(t)\}$ = m $\{h_{i,k}(t) \mid r(t) = k\}$ the proof of the relation (7) is described in [6]..

IV. SIMULATION RESULTS FOR FIfTEEN AREA SYSTEMS (with & without Interaction)

At the end of simulation is shown some interpretations of simulation, which are acquired from the simulation program *Matlab:*

Step Input Pd (HZ):	***Starrt of error time Td (S):***
(Pd01) = 0.01	(Td01) =10
(Pd02) = 0.01.	(Td02) =10
(Pd03) = 0.01	(Td03) =10
(Pd04) = 0.01	(Td04) =10
(Pd05) = 0.01	(Td05) =10
(Pd06) = 0.01	(Td06) =10
(Pd07) = 0.01	(Td07) =10
(Pd08) = 0.01	(Td08) =10
(Pd09) = 0.01	(Td09) =10
(Pd10) = 0.01	(Td10) =10
(Pd11) = 0.02	(Td11) =20
(Pd12) = 0.02	(Td12) =20
(Pd13) = 0.02	(Td13) =20
(Pd14) = 0.02	(Td14) =20
(Pd15) = 0.02	(Td15) =20

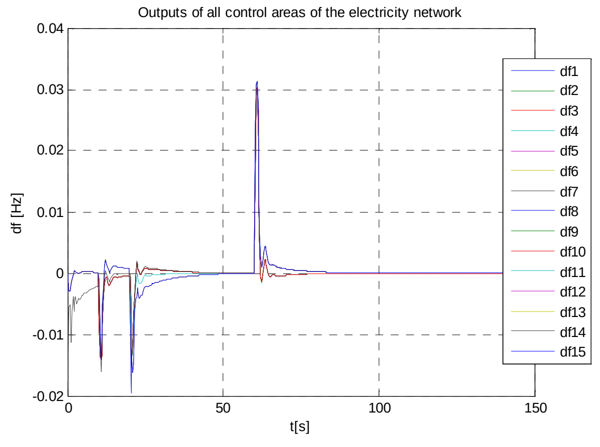

Fig.3 with interaction.

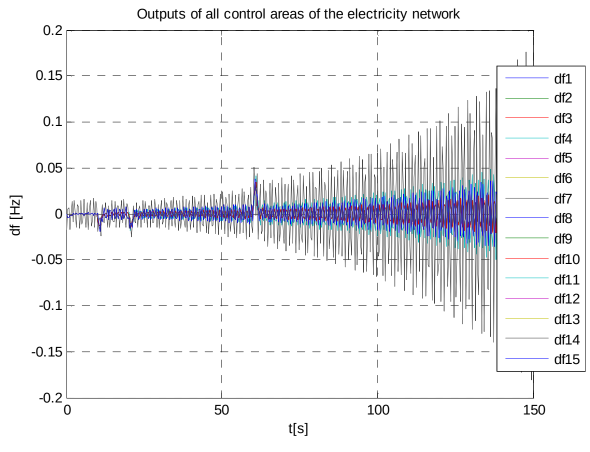

Fig.4 without Interaction.

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VI. CONCLUSION

Large-scale systems are often controlled by more than one controller or decision maker involving “decentralized” computations. Large-scale systems can also be controlled by local controllers at one level whose control actions are being coordinated at another level in a “hierarchical” (multilevel) structure. Large-scale systems are usually represented by imprecise “aggregate” models. Controllers may operate in a group as a “team” or in a “conflicting” manner with single- or multiple-objective or even conflicting-objective functions. Large-scale systems can also be controlled by local controllers at one level whose control actions are being coordinated at another level in a “hierarchical” (multilevel) structure. Large-scale systems are usually represented by imprecise “aggregate” models. We observe that, from all results of five area systems the values of outputs decays till zero value and that when the control area systems is connected with the Interaction functions. Large-scale systems can also be controlled by local controllers at one level whose control actions are being coordinated at another level in a “hierarchical” (multilevel) structure. Large-scale systems are usually

We observe that, from all results of *fifteen area systems* the values of outputs decays till zero value and that when the control area system is connected with the Interaction.

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