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Multilevel models of power systems based on network technologies

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ABSTRACT:In this article, the authors have shown that the use of smart grids in the electric power industry significantly transforms the process of solving the assigned tasks. This will allow you to apply methods of distributed computing and speed up finding a solution. As a result, this strategy will also inevitably entail the transformation of the communication system in the power system, since for the correct operation of a multi-agent system, secure high-speed communication channels are required, and not only processor power.
The authors have shown that the property of self-organization is implemented using virtual clusters of agents that are dynamically created and changed as needed for joint planning and actions on tasks. The authors present a layered architecture for an autonomous agent.

KEY WORDS: multi-agent system, single-agent,smart grids, simulation, electrical grids.

I. INTRODUCTION

The advantage of a decentralized structure over distributed multi-agent single-tier control structures is the lack of communication between controllers, which leads to lower computational requirements and faster management. However, this benefit is usually achieved at the expense of overall performance. Thus, the advantage of a distributed multi-tier single-agent management structure is that improved performance can be obtained, albeit at the cost of increased computational time due to interaction, communication, and possibly coordination between management agents. However, even though improved performance can be achieved, productivity will still be lower than an ideal single-agent management structure.

The layered control structure provides the ability to achieve a trade-off between system performance and computational complexity. The higher layer looks at most of the system and therefore can direct the lower layer of government to gain coordination.

Such a tiered management structure can combine the benefits of a single-agent management structure with a single-tier multi-agent management structure, that is, overall system performance with traceability. However, it should be noted that data exchange in a multi-agent multi-level control structure is usually more complex than in a single-agent control structure and a multi-agent single-level control structure.

II. SIGNIFICANCE OF THE SYSTEM

The paper mainly focuses on how intelligent technologies can be used to build mathematical models of electrical networks. The main attention is paid to the agents of the electric power complex. The study of literature survey is presented in section III, Methodology is explained in section IV, and section Vdiscusses the future study and Conclusion.

III. LITERATURE SURVEY

To find the actions that are most consistent with the control objectives, management agents need to find a compromise between the various actions available. To make the best decision and therefore find the best action, all relevant information about the consequences of the choice of action should be considered. For power grids, the typical information that is available consists of forecasts of energy consumption and exchanges [1], capacity constraints for transmission lines, dynamics of components such as generators, capacitor banks, transformers and loads [2]. In addition, it is usually possible to measure the amplitude of the voltage and the angles in the network throughout the area to ensure an up-to-date state of the network situation. A particularly useful form of power grid management, which in principle can use all available information, is the predictive control model [3].

Electric networks [4] are large networks with a large number of components. The dynamics of the power network as a whole is the result of the interaction between the individual components. Generators generate energy that is fed into the grid on one side, while loads draw energy from the grid on the other side. The distribution of power in the network is dictated by Kirchhoff's laws and depends on the settings of generators, loads, transformers and possibly also capacitor banks and FACTS devices. This system of components participates jointly in the continuous movement of active and reactive power as well as voltage magnitudes and angles. Power grids exhibit not only continuous dynamics, but also discrete dynamics. Discrete dynamics in electrical networks occurs due to discrete events caused by turning generators and loads on and off, breaking transmission lines, discrete switching logic inside transformers, saturation effects in generators, and so on. Consequently, electrical grids are large-scale hybrid systems with complex dynamics.

IV. METHODOLOGY

Electricity networks are developing towards a new structure. Typically, in electrical networks, electricity was generated by several large generators. This energy was then transported through the transmission and distribution network to the place where it was consumed, such as households and industry. Electricity flows were relatively predictable and the number of control agents was relatively low. In the near future, the number of origins of the distribution network will increase even more as large industrial suppliers and small individual households begin to supply electricity to the grid.

As a consequence, the structure of the electricity distribution network is evolving from a hierarchical top-down structure to a much more decentralized system with multiple generating sources and distribution agencies. This multi-user structure thus results in a system with many interactions and interdependencies. In addition, the following events are or will take place in the near future:

- on a nationwide scale, power no longer only flows from the transmission network towards the distribution network and on to industrial sites and cities, but can also flow into the transmission network [2]. Network flows will change more and therefore it will be necessary to improve the coordination of decentralized local controllers;
- on a local scale, loads at consumption nodes become manageable, and it becomes possible to store energy using batteries [5]. In addition, groups of households can become independent from large electricity suppliers by organizing energy exchanges among themselves.

Therefore, in order to continue to guarantee the basic requirements and service levels such as voltage levels, frequency, tolerance limits, stability, elimination of transients, etc., as well as to meet the requirements and customers, it is necessary to develop and implement new control methods. These control methods need to be adaptive and responsive as the input and output requirements can change over time.

Consider an example of multilevel control, consider electrical networks. Power grids in general are managed using multi-level management, in which the management of the physical network is the result of the joint efforts of several levels of government at the local, regional, national and sometimes international levels [6].

The physical electrical network consists of several interconnected subsystems such as generators, loads, transmission lines, etc. This network is managed by several layers. The lowest level of control consists of agents who locally control the actuators on the physical network. The higher levels of management are made up of management agents (dispatchers) who define the actions and settings for the lower levels of management. Set points can be used to obtain coordination between management agents of lower management levels. Higher levels of government usually consist of regional or national network operators, for example. These human operators make decisions about the action to be taken based on online research, experience, heuristics, knowledge bases, and actual system states from telemetry or other sensors. The set points should be determined in such a way that the objectives defined for the higher level of

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control are achieved. In this case, the higher level of control usually takes into account the non-linear behaviour of the system, the behaviour of which can be ignored by lower levels of control.

Figure 1 shows a multilevel power grid management system. The higher level provides the set points for the lower level. The lower level controls the actuators in the power system (dotted lines). Figure 2 shows the structural components of a multilevel management system. This architecture of an intelligent control system consists of three levels: conceptual, informational and operational (Figure 2). A system based on such an architecture controls the behaviour of complex technical objects in conditions of autonomous and collective interaction. The conceptual level is responsible for the implementation of higher intellectual functions.

Generally, it is not possible to quickly change the set points used by the lower control level in an online and coordinated manner to achieve improved performance [6]. As it becomes more difficult for human operators to adequately predict the consequences of failures and interference in the network (for example, for electric networks, due to deregulation of the energy market, increased demand for electricity [5]), the need for intelligent automatic online control systems is increasing. These automatic control systems can be used to determine which set points should be provided, firstly outside the control loop in the form of a decision support system and later inside the control loop in the form of closed loop control.

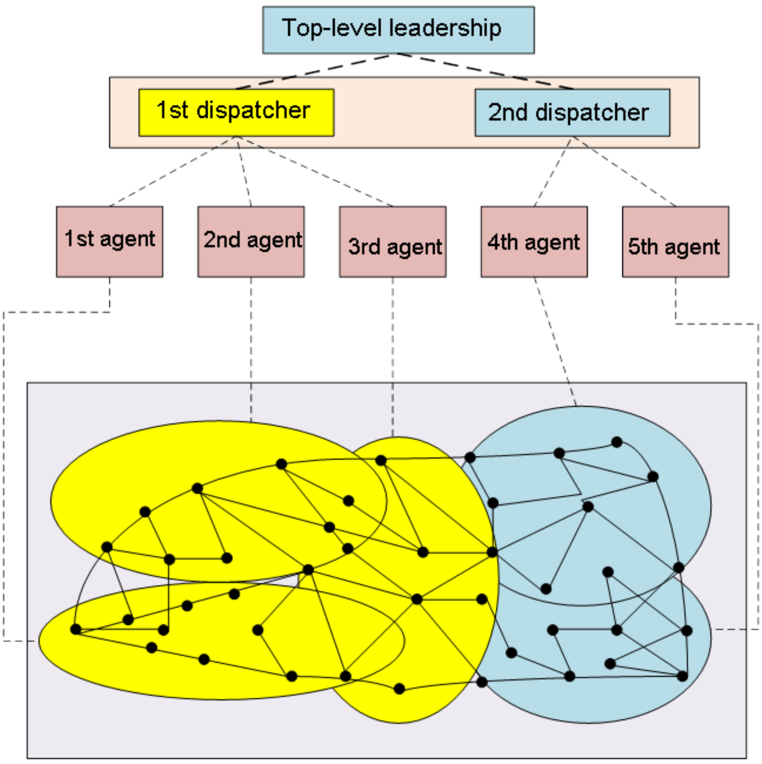

Fig. 1. Multilevel control system for electrical networks

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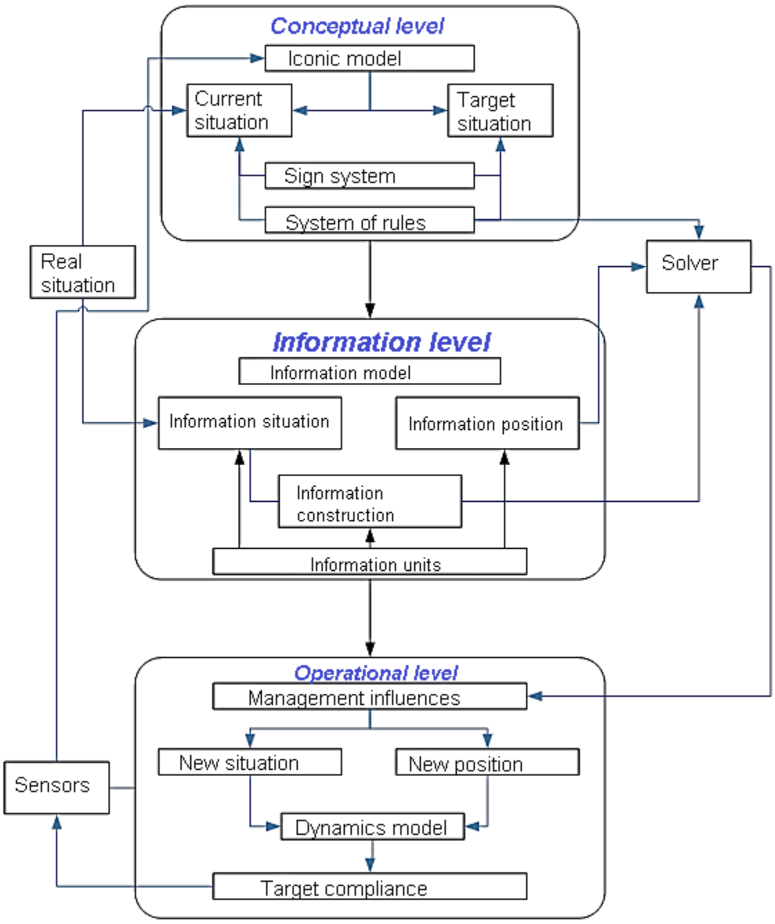

Fig. 2. Structural components of a multi-level management system

Although in general there can be many levels of management, and each level of management can consist of several management agents, hereinafter, two levels of management, middle and lower levels, are considered as an example. The environment management layer consists of one management agent, and the lower management layer consists of several decentralized management agents. To obtain management goals, the management agent at a certain level must monitor the current state of the part of the lower management layer and the underlying physical network of interest. On this basis, the management agent must anticipate when the system's behaviour is moving in an undesirable direction, so that it can provide adequate set points for the part of the low control level that it is considering. We propose a mid-level control agent to determine which target values should be given to the lower control level.

In order for a mid-level managing agent to perform its management tasks, it must be able to predict how changes in the set point will affect the dynamics of the network. The performance of the managing agent is highly dependent on the accuracy of the forecasting model it uses. The prediction model should describe well how the actions of the management agent affect the behaviour of the network and lower-level management agents. Ideally, a management agent should have a model of the overall dynamics of the network, including the behaviour of other management agents. However, such an ideal model can be very complex or impossible to build, which makes the optimization procedure in the management agent slow or impossible. Instead, the management agent should use model approximation.

If this approximation is in a suitable form, relatively efficient optimization techniques can be used to determine the actions to be taken (for example, linear or mixed-integer linear programming). Suppose that the dynamics of the transport network can be represented by a system of ordinary differential equations in the form:

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$$\begin{bmatrix} \dfrac{dx_{\text{very slow}}}{dt}(t) \\ \dfrac{dx_{\text{slow}}}{dt}(t) \\ \dfrac{dx_{\text{fast}}}{dt}(t) \end{bmatrix} = \begin{bmatrix} f_{\text{оч.мед}}\left(x_{\text{very slow}}(t), x_{\text{slow}}(t), x_{\text{fast}}(t)\right) \\ f_{\text{мед}}\left(x_{\text{very slow}}(t), x_{\text{slow}}(t), x_{\text{fast}}(t)\right) \\ f_{\text{быстро}}\left(x_{\text{very slow}}(t), x_{\text{slow}}(t), x_{\text{fast}}(t)\right) \end{bmatrix},$$

where the dynamics were grouped into $x_{\text{very slow}}$ - "very slow", x_{slow} – "slow" and x_{fast} - "fast dynamics". Suppose the middle tier management agent has the goal of controlling only slow dynamics. The question is whether and how this management agent should account for very slow and fast dynamics. Although the managing agent is not directly interested in very slow and fast dynamics, these dynamics can affect the slow dynamics in which the managing agent is interested. Merely ignoring very slow and fast dynamics can result in an unacceptable loss of model accuracy. Rather than completely ignore very slow and fast dynamics, the managing agent can approximate very slow dynamics with constants, and fast dynamics with instantaneous dynamics. The model that the management agent then considers can be described as:

$$\begin{bmatrix} \dfrac{dx_{\text{very slow}}}{dt}(t) \\ \dfrac{dx_{\text{мед}}}{dt}(t) \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ f_{\text{мед}}\left(x_{\text{very slow}}(t), x_{\text{slow}}(t), x_{\text{fast}}(t)\right) \\ f_{\text{быстро}}\left(x_{\text{very slow}}(t), x_{\text{slow}}(t), x_{\text{fast}}(t)\right) \end{bmatrix},$$

which constitutes a system of differential-algebraic equations. Note that very slow dynamics may include changes in set points used by the mid-level management agent. The middle-level manager can receive updates from the higher-level managerial agents regarding very slow dynamics, which he takes constant, including the set points, and he can additionally determine the set points for the lower-level control agents, for example, so that the goals associated with the dynamics of its time scale [7].

Thus, the basic principle of separation of characteristics is as follows: no change in any set of unobservable factors can lead to a violation of the steady state of the electric power industry without changing a certain set of observed characteristics as a consequence of unobservable factors change. Note that the presence of similar correspondences, as well as the ratio of the number of observed characteristics to the number of known unobservable, is one of the main criteria for the adequacy of the model used.

V.CONCLUSION AND FUTURE WORK

It should be noted that the mathematical models for describing and analysing the possibilities of managing the electric power industry can be obtained only if there is an artificially, one way or another, limited set of characteristics of the system, called the observable. The observability of this or that characteristic of the system is determined, first of all, not so much by the objective possibility of its assessment in a particular situation, but by the fundamental necessity and expediency (in the sense of the adequacy of the model). However, the research results do not exclude the fact of the influence of unobservable characteristics on the assessed state of the electric power system. Often, they can remain outside the framework of the model entirely for other reasons, determining the effective degree of its adequacy in each specific case on the basis of expert assessments.

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