HIERARCHICAL SYSTEM FOR POWER MANAGEMENT OF A BUSINESS BUILDING TYPE MALL

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In this publication are formed the main technical and economic requirements for system management of a commercial office building, consistent with the basic criteria for comfort and easy maintenance. Consider the formation of the organization and the functionality of the hierarchy system management of the power system by specifying the functions and allocation of tasks to solve all subsystems. Proposed is a structure and technical implementation. It is provided development of the system vertically, as a subsystem of a larger system. Resolved tasks are monitoring and management of the power system, automatic changeover and control and dialog with operator for emergency situations. The proposed subsystem implements manual and automatic control mode, local and central control.

Keywords
hierarchical system, power management, monitoring, automatic control, SCADA, PLC

1. Introduction

One of the main requirements for a commercial office building is the comfort for employees and visitors. To achieve this, a number of factors are needed to be met, such as quality microclimate in the common parts – temperature, humidity and pollution, fire safety, good lighting, and many others. Otherwise, for the local areas is good the microclimate to be adjusted locally. All this achievements increase the productivity of their employees. An important factor is ensuring effectiveness on monitoring and management of energy consumption in the building in order to lower costs.

Providing these basic requirements improves working conditions and reliability in economic terms, which in turn provides additional benefits to building owners. These include the possibility for higher rent, flexibility in changing the status of use of a room, individual cost accounting of each tenant, and many others.

With the creation of a central system to manage all processes in the building, owners will have the opportunity for both – central and remote management. This increases reliability and saves time.

The construction of such a system improves the opportunities for maintains and support – better information, easier diagnosis of problems and the possibility of establishing a schedule for the maintenance staff and the equipment in the building as well, which improves the efficiency of both. This system provides early detection of problems and the ability to eliminate them quickly.

In fulfilment of these conditions, lies a sense of comfort to all visitors, employees, tenants and building owners.

2. Characteristics of the hierarchical structure of the systems

One of the most important systems in each building is the system that supplies the energy needed for all other systems. In modern buildings this is the system for power management. Depending on the volume of the building, such a system can have complex configuration.

Most often such a system includes:

- Monitoring and control of the main power to the main distribution boards;
- Monitor and control of the position of the load switches;
- Monitoring of power measuring devices and instrumentation;
- Monitoring and control of the Automatic Changeover System and providing redundancy for the specified class (via diesel generator, etc…)
- Monitoring and management of primary, duty and facade lighting (contactors and circuits);
- Monitoring and control of sliding and rolling doors;
- Monitoring and control of warming pipes and ramps mode (anti-frost mode);
- Monitoring and control of hydrophore, sprinkler and sewage pumps;
- Monitoring and control of elevators and other lifting devices;
- Monitoring and control of fire dampers, smoke dampers and skylights (scuttles);
- Information for consumed electricity;
- Other.

As shown, controlled equipment can be wide range and various; it is even possible that the elements of this system could exist as elements of another system (such as fire alarm, fire fighting, water or drainage area, as well as any other for a building).

Then arises the question – can the facilities from one system belong to different systems at the same time? The answer is – it depends on their configuration. A system can always be seen as a subsystem of a larger system. The term "large system" appeared to reflect the increased dimensionality of the complicated form of the models studied objects, systems and processes. It reflects the subjective views and approach of the researcher at the object and is not a result of objectively quantifiable parameters and indicators [Burkov 1977].

Since the same equipment can belong to several different systems, then quite rightly arises the question about the priority of the systems over the equipment. A pattern must be drawn or an approach must be proposed in which the system can recognize its priority for a given situation. Separately, there is the question about the devices in a system that control individual actuators or other devices in a subsystem.

In this type of sites, due to the large amount of information to process, hierarchical structure is required, with the implementation of computer-based communications network management [Stoilov 1996b]. By hierarchy is aimed to reduce activities related to direct calculations centralized mode of operation and management.

Hierarchy as a concept is defined by three essential features:

- Vertical subordination;
- Right of interference of the higher to the lower level;
- Interconnection of actions and states;
- Solving the global mission of the hierarchical system is solved by [Stoilov 1996b]:
- Decomposition [Stoilov 1996a], [Tuzharov 2008];
- Coordination of tasks [Stoilov 1996a], [Stoilov 1996b];

Decomposition is realized by the method TOP-DOWN ("from top to down" or "from the general to the detailed") [Tuzharov 2008]. In this method, the element subject of analysis gradually is divided into several sub-elements, as long as it comes to so-called black boxes – items that can not be divided anymore. When applying this method a tree structure is obtained. Decomposition is probably the easiest technology to understand and also the most difficult to learn. It derives from technological system approach.

The task of the coordinator is to predict the amount of resources that are allocated between its subsystems [Stoilov 1996b].

The attractiveness of the hierarchical approach stems from the fact that at each stage of hierarchical computations problems with low dimensionality are solved.

3. Classical model of two-level hierarchical system

The classic formulation of the theory of hierarchical systems considered hierarchical system with two-levels (Fig. 1) [Stoilov 1996b]. The object is complex and consists of sub objects SO_i, i=1..n, each of which is managed by a local control unit LCU_i, i=1..n. In operation of the subsystem SS_i i=1..n, LCU_i manage SO_i and can not change the impacts coming from the other sub objects connected to it. On the second hierarchical level the coordinator C affects LCU_i i=1..n, in such way that overall two-level hierarchy system operates without contradictions.

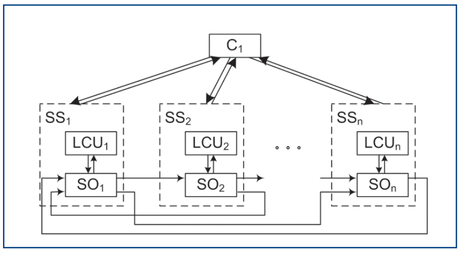

Figure 1. *Classical two-level hierarchy system*

The system is determined by three types of tasks:

- A global task set by the whole system, which reflects the purpose of the system;
- Local problems posed and solved by subsystems SS_i comprising all LCU_i, SO_i and whose co-management solution provides the determination of the global task;
- Task for the coordinator;

The global objective function set and solved by a hierarchical system is in the form:

$$\max F(x)=\sum_{i=1}^{n} F_i(x_i)\ ,\quad g(x)=\sum_{i=1}^{n} g_i(x_i)\ , F_i(x)\in E^n\ ,\ g_i(x)\in E^m \qquad (1)$$

Where $x_i=(x_{1i}, \ldots, x_{ni})$; n_i is the dimension of x_i; g(x) are local limits reflecting the interconnection of the sub objects.

This function is designed to ensure maximum performance of the hierarchy system, all subsystems and objects for management. Further, the report shall examine decomposition and coordination of the tasks of block-diagonal structure of the hierarchical control system in terms of local parameters x_i. Analytical description and algorithms of the displayed structure are seen in another report.

4. Hierarchical structure of power distribution system of business building

In Fig. 2 is shown a structural diagram of a hierarchical system for monitoring and management of electricity management system in a business building which is embedded in real conditions. The main task to solve is providing power to the other systems and equipment in the building and ensuring automatic change over to the reserve power generator in case of failure – Class 1.

This system can be regarded as two-level hierarchy system, considering the classical model.

Several subsystems are formed, whose tasks are to govern at a local level functionality similar processes and objects for management. These are:

- Subsystem for monitoring the power distribution to the main boards;
- Subsystem for monitoring and control of lighting;
- Automatic change over system;
- Etc…

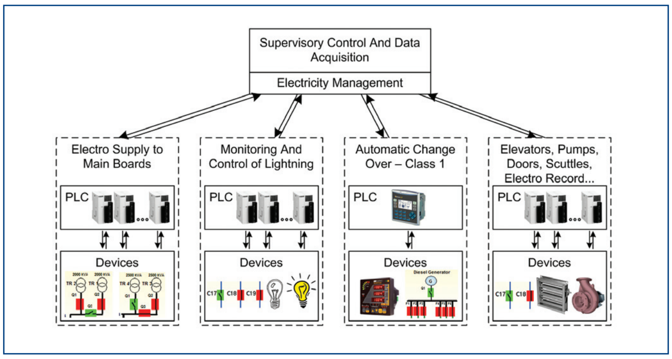

Figure 2. *Two-level hierarchy system – Electricity Management*

The technical implementation of the system is based on programmable logic controllers (PLC). They monitor the input variables and in accordance with the underlying control algorithms form and send a signal to the output values.

The main task of the subsystem for monitoring the power distribution to the main boards is basically to inform for power supply failure from the transformers to the main boards and monitoring the quality of the supply voltage and power consumption. This is achieved by monitoring the status of main circuit breakers and connectors, and accordingly forms of instrumentation data in the database. This subsystem gives the possibility for remote disconnection of a switch. Its joining, however, can be made only locally, for reasons of safety.

The subsystem for monitor and control of lighting is designed to provide adequate lighting in common areas during different intervals of the day. Inclusion and exclusion of individual circuits is done manually or automatically – using a weekly schedule. In automatic mode is achieved greater efficiency of consumed electricity, as with regard the workload of the maintenance staff. Diagnosis is accomplished by individual contactors circuits in the state of the contactor (incl. / excl.) in relation to its functionality. This simplifies the maintenance.

The subsystem for redundancy of the power (automatic change over) can also be viewed as a hierarchical control system with two levels (Figure 3).

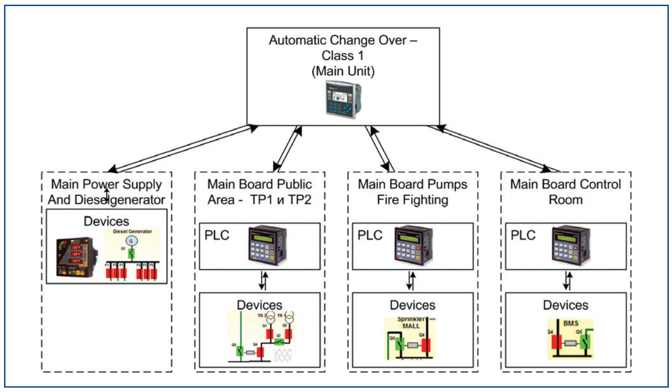

Figure 3. *Two-level hierarchy system – Automatic Change Over*

The system aims to ensure the availability of quality supply, both locally and globally, and in case of failure of voltage to ensure quality one. And in case of fire, it should ensure power supply to certain main distribution boards [Raychev 2011].

The system has a Master – Slave communication infrastructure. The central control unit and local ones of each subsystem are all PLC. They monitor whether there is quality power supply on the main power bus through relays for phase sequence.

If there is no quality power the control devices at a local level disconnects their switches from the main bus and send a request to the central device for joining the reserved bus. Central unit decides in which cases to launches the procedure for backup power.

After establishing the existence of such a situation, it transmits a signal to switch the diesel generator on and through instrumentation evidences for quality backup power. Then it gives priority permission to the subsystems for joining the reserved buses.

The central unit monitors the power quality of the main bus also using relay of phases sequence and the signal for fire in the building receives on a corresponding digital input.

In case of loss of central main power or fire situation, the same actions are performed, but permission for inclusion to the reserved bus is made within a specified algorithm.

In case of fire, for example, with the highest priority are the main distribution boards, providing power to the fire fighting equipment. Making a decision about managing the emergency is made by the central device. It may indicate that the system works in manual or automatic mode, when operating in automatic mode, the system performs predefined algorithms, while operating in manual mode – the operator must act on processes to emergencies or in case of just a maintenance.

So viewed, the system operates fully autonomously. But in practice it is part of the previously examined system as it uses its data structures, and also it dependents on the highest level of that hierarchical system.

From the highest level in the hierarchy can be also specified whether the system for redundancy should work in automatic or manual mode, and on the main level manager has more information about the events, as he has access to other subsystems of the system for power distribution. In this way the power distribution system and the subsystem for redundancy of the power could be considered as three-level hierarchy system (Figure 4).

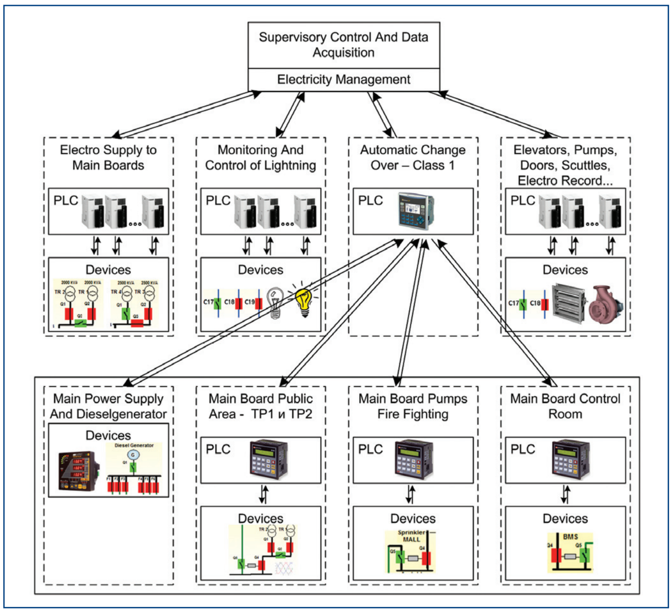

Figure 4. *Three-level hierarchy system – Electricity Management*

The proposed hierarchical control system realizes an automatic and a manual mode, a local and a central management. It Implements real-time diagnosis of the power distribution management, storing data in a database, allowing momentary reference for power consumption and a reference for a past period. It also ensures early detection of the problems and quick management with emergency situations.

Hierarchical system described has been implemented in real conditions – Grand Mall Varna. Summarized version of organisational structure of the three-level hierarchy system is shown in Figure 5.

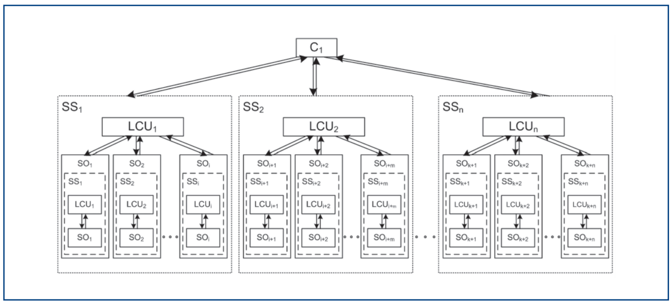

Figure 5. *Organisational structure of three-level hierarchy system*

5. Conclusions

Based on classical two-level hierarchical structure of complex control system is proposed realization of a block-diagonal structure of two-level power distribution system of business building.

The proposed two-level hierarchical structure is developed in three-level hierarchical system for management:

- First Level – subsystems for power management at a local level;
- Second level – subsystems for monitoring the power supply to the main distribution levels, lighting, power redundancy, lifts, pumps, etc.;
- Level – Coordinator.

After decomposition of the system structure are formed the tasks of the individual subsystems and objectives are distributed for decision making about managing with the emergency.

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