The distributed approaches in the control of modern district heating

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Abstract: - This article presents the idea of distributed control method for district heating system. Modern district heating systems integrate the many elements, such as small heat source for example in the form of renewable energy, storage tanks, surpluses form active buildings and many other. The concept of clustering of these disparate elements and their interconnection is referred as Smart Thermal Grid. Effective use of all the elements forming such extensive system also requires new approaches in control. The central approach is already insufficient and the intention is to enforce already mentioned distributed concepts. This article will mainly focus on two approaches - multiagent and holonic. These approaches are similar in many aspects, but still there are some differences and these will be discussed.

Key-Words: -District heating, distributed control systems, heat distribution and consumption, holarchy, holon, multiagent system, Smart Thermal Grid.

1 Introduction

The interest in all modern countries in the field of energetics is to behave ecologically and use its resources as effectively as possible. These ideas could be summarized as it aims to reduce primary energy means [1]:

- Modernize and improve the efficiency of technological equipment for heat production (improving the combustion process, development of modern boilers, etc.)
- Use broader engagement of energy from renewable energy sources (RES), which is not be ranked among primary energy.
- Use of secondary heat sources - waste heat from industrial processes, low-potential sources and municipal waste incineration.
- Insulation - reduce losses in the distribution network and heated objects.
- Heat management optimization.

Addressing heat management optimization together with wider use of RES and waste heat is included in the Smart Thermal Grid (STG) concept [9]. In fulfilling this concept is also trying to contribute our proposal distributed district heating control system, which should be built on the idea of holonic structure. The primary idea is however distributed concept itself, which may not necessarily be called holonic, we can understood it as a system of cooperating agents with which is usually a general reader more familiar.

This article will try to show how such a system should be designed - how to divide tasks for individual Holons, how to build a holarchy and what services must be implemented to ensure the optimal performance of the entire system. Because control, or more appropriately management of STG is a huge field and each location can also offer other possibilities, the article will not try to cover the entire field but focus on one sub-area which is CHP sources.

2 District Heating and Cooling

Classical district energy systems produce steam, hot water or chilled water at a central plant [10]. The steam, hot water or chilled water is then piped underground to individual buildings for space heating, domestic hot water heating and air conditioning. As a result, individual buildings served by a district energy system don't need their own boilers or furnaces, chillers or air conditioners. The district energy system does that work for them, providing valuable benefits including:

- Improved energy efficiency
- Enhanced environmental protection
- Fuel flexibility
- Ease of operation and maintenance
- Reliability

- Comfort and convenience for customers
- Decreased life-cycle costs
- Decreased building capital costs
- Improved architectural design flexibility

In addition, district energy systems can use the "reject heat" that results from burning fuel to produce electricity at a power plant, dramatically increasing the overall efficiency with which useful energy is extracted from the fuel.

The reject heat can be used to spin turbines and generate electricity. This arrangement, called "combined heat and power" (CHP). A CHP system may have double the fuel efficiency of an electric generation plant and can also lower the emissions typically associated with conventional fossil-fuel powered electrical production. The less energy used, the less sulfur dioxide and carbon dioxide and other emissions are expelled into the environment [2].

2.1 Smart Thermal Grid

Do not waste energy is the fact that humanity is aware for several decades. Above mentioned concept of CHP is very important, but the effort to optimize the use of energy sources must continue - as also the EU promotes in its project challenges.

Currently it is the concept of Smart Thermal Grid (STG), which efforts to use all the energy produced but also seeks the way to make this use the most optimal. An example might be the use of the sources that are in particular moment the most efficient and also effort to accumulate energy that can be produced profitably and there is no consumer for it at a given moment. This is especially applicable for the energy produced from the sun, wind and other renewable sources.

For STG is also important the role of buildings that should not be considered as simple consumers but as the objects that are able to cooperate with sources for optimum performance of the entire smart system [3].

STG can play an important role in the future Smart Cities by ensuring a reliable and affordable heating and cooling supply to various customers with low-carbon and renewable energy carriers like waste heat, waste-to-energy, solar thermal, biomass and geothermal energy.

Technical elements of smart thermal grids cover thermal generation like small-scale low-carbon heating and cooling systems, CHP and new approaches for producing domestic hot water, thermal storage technologies and innovative network improvements such as new piping materials new piping layouts and non-invasive construction and maintenance of thermal networks. Network-integrated sensors and smart heat meters allow for more effective and efficient use of the separate components, supported by overarching energy management [4].

Possible components of STG are shown in fig. 1.

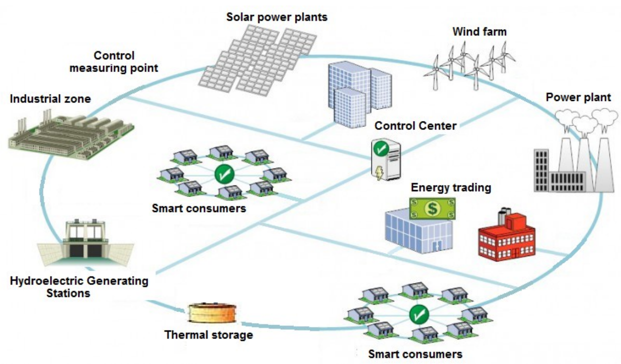

Fig. 1. Components of the STG [5]

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3 Multiagent and Holonic Approach

From the above description of STG is obvious, that it is very appropriate to treat STG as distributed dynamic and stochastic system. For the investigation of the behavior and properties of the STG it is therefore necessary to create a distributed model of the same character, in terms of control for STG need to be addressed methods of control of distributed systems.

Distributed systems currently utilize (are based on) several concepts - bionic, holonic, fractal, multiagent etcFor application in production systems are often used holonic and multiagent concepts. It turns out that these concepts are useful for district heating systems designed as STG as well.

In the next parts of this paper, these two concepts and their use in the STG will be analyzed in detail.

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3.1 Agents

A MAS is made up of two or more related agents. An agent is an autonomous and flexible computational system, which is able to act in an environment [17]. Flexible means, that the agent is:

- Reactive: It reacts to the environment it is in.
- Pro-active: It is able to try to fulfil its own plan or goals.
- Social: It is able to communicate with other agents by means of some language

Some properties which are usually attributed to agents to a greater or lesser degree for solving particular problems are [15]:

- Autonomy: Agents can operate without the direct intervention of humans or other agents.
- Social ability: Agents are able to interact with other agents (human or not) through an agent communication language.
- Rationality: An agent can reason about perceived data in order to compute an optimal solution.

Lange [16] provides a more pragmatic definition that is oriented towards industrial demands: He defines an agent as a software object that has the following properties: situatedness, reactivity, autonomy with respect to its actions, and proactivity. Furthermore: an agent should be continuously executing. Option ally: an agent can be communicative, mobile, believable or able to learn.

3.2 Holons

The term "holon" and “holonic system” appeared more than 40 years ago, it was introduced by Herbert Simon and Arthur Koestler [6]. In recent years the concept of holonic systems expanded, elaborated and applied inter alia in the field of production systems, especially in discrete manufacturing. It is one of the concepts applicable to distributed systems and their management, but it has also potential for use in other industrial areas.

The term holarchy refer to a set of holons including their mutual relations. Holarchy is a system of holons that can co-operate to achieve a goal or objective. The holarchy defines the basic rules for co-operation of the holons and thereby limits their autonomy [7]. The concept of holarchy is illustrated in the following fig 2.

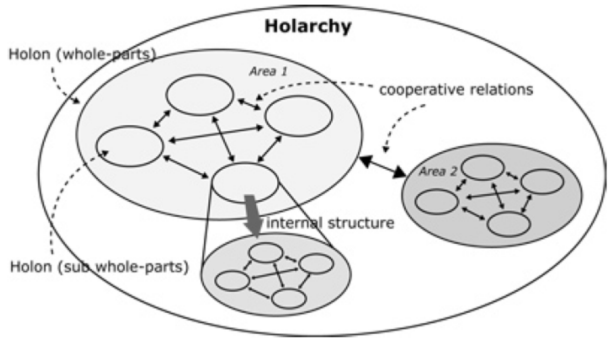

Fig. 2. Holarchy

Holon, in this context, could be defined as an autonomous and co-operative building block of a production system for transforming, transporting, storing and/or validating information and physical objects. The holon consists of an information processing part and often a physical processing part. A holon can be part of another holon. It is also possible to see it as a model of a particular element, i.e. part of the model of the entire system. In this sense is holon used in this article.

The internal structure of holons can be made up of a group of other holons, which can be described as "subholons". Any such subholon is, of course, full holon. This allows a very flexible way to define entire holonic system.

The most important features of holon are autonomy and co-operation. Autonomy is characterized by its ability of self-regulation, i.e. the capability to apply the flexible strategy which allows holon to respond differently to changes in its relevant environment. This ability to respond individually to changing conditions in which holon work, must be connected with a certain degree of intelligence to its reaction to change and adapt to the demands of the environment to be efficient and effective. Cooperation takes place between holons using the corresponding parts "subholons" of each holon - the parts that have the ability to implement relevant cooperation.

Good co-operation requires good communication between holons. Holon exchange information with other holons throughout holarchy. This direct, mutual communication between holons manifests an important distinction between distributed systems management and centralized management systems. In centralized systems, all communication takes place via a central element of the control system.

3.3 Comparison between the agents and the Holon

Suitable explanation for HS is to liken it to multiagent system (MAS). It is therefore assumed

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that term MAS is for readers, at least in general terms known.

Nevertheless, semantically, an agent and a holon have very different meanings and uses. In general, the word “agent” has multiple meanings, but the following meaning from Webster’s Collegiate Dictionary is the most appropriate [12]:

“An agent is one that acts or has the power or authority to act.” In other words an agent is a singular entity with the authority that is empowered to accomplish its purpose.

The term “holon” describes self-contained elements that are capable of functioning as autonomous entities in a cooperative environment. Holon is a fusion of the Greek word “halos” meaning whole and the suffix “on” denoting a particle. In a holonic system, each holon works with all other holons to deliver an overall system objective. The underlying point here is that an “agent” has the right to make decisions for its own purpose, whereas a “holon” can only act with respect to a collective (or holarchy) of holons to which it belongs and thereby provide a collective or system autonomy, as opposed to a collection of individual autonomies. One of the most important properties of Holon is recursion. Holon unlike agents can in their structure contain other Holons with the same or a different architecture. Holons are therefore autonomous, cooperative and partly intelligent modular blocks which are functional within decentralized control. The agent is elemental decision unit that collects and processes the data and knowledge. It is not physically tied to technology.

To design a distributed software system, as with any other solution paradigm, it is useful to follow guidelines. First, let’s summarize the major differences between multiagent and holonic systems:

Scope: agents are focused on local issues while holons are focused on global issues.

Independence: holons are not independent whereas agents can exist functionally independent of other agents.

Relationships: holons cooperate with other holons, whereas agents need not be cooperative; in fact, agents can compete with other agents.

The choice whether the holons or agents are used for the system control will be determined by the point of view that is taken. More specifically, HS can be considered to be a paradigm for distributed intelligent control, whereas MAS is regarded as software technology that can be used to implement HS [11].

In accordance with mentioned approach of the use of holonic or multi-agent concept of distributed systems in the literature also appears concept of holonic-multi-agent system.

Arbitrary structures can be viewed as holons in Koestler's framework, where the sub-structures do not necessarily have to be of the same kind. In contrast all entities can be restrict to agents as defined above, and furthermore, it is required that sub-holons always have the same structure as the super-holon. This requirement may later turn out to be too restrictive when the fild of holonic MAS matures as for the moment this restriction makes it easier to define the merge of agents.

The essential idea is as follows: A holonic agent of a well-defined software architecture may join several other holonic agents to form a super-holon; this group of agents now acts as if it were a single holonic agent with the same software architecture [8].

The representation of a holon as a group of autonomous agents is in a sense just another way of looking at a traditional multi-agent systems. The holon entity itself is not represented explicitly. In this case, holonic structures are only a design aid for structured agent-oriented programming.

4 Conclusion

Building and deploying Smart Thermal Grids into practice requires a number of steps. Besides upgrading hardware and improve communication and measurement is necessary to ensure that elements of the system together and collectively came to the efficient use of resources. The article tried to show that in such a heterogeneous environment, it is advisable to implement a distributed system management. Representative of this approach, are for example holonic or multiagent systems. A brief description of these approaches and explanations of differences focused wanted to show this article.

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