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CRITICAL STUDY ON ELECTRICAL ENERGY SYSTEM MODELLING

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ABSTRACT :

The electrical energy system is traditionally an interconnected, large scale system with dynamic behaviour over time; it is composed of networks at different levels spread over vast geographical areas. Different participants from these areas, each with their own range of local interests and objectives, all interact with the energy system. These factors indicate that the energy system can be approached as a complex system. Complexity science is an emerging interdisciplinary field of research that has been mainly studied in the social sciences, biology and physics. However, complexity, as such, is not restricted to these areas as a subject of research. It aims to better understand and analyse the processes of both natural and man-made systems which are composed of many interacting entities at different scales One of the ways of studying complex systems is through modelling and simulation, which are used as tools to represent these systems in a virtual environment. Models that have been created as individual agents to represent specific components can be combined and integrated to represent the energy system. Putting the models together allows the system to be represented by aggregating these models like building blocks in a modular way. This paper reflects critical study on Electrical Energy system Modelling.

Keywords : modelling , components , energy , dynamic , phenomena , approach

I. INTRODUCTION :

In order to represent an energy system as a complex system through an agent-based approach, it is necessary to individually model the components. Therefore, a special focus is put on modelling the components, or entities of the system, as they behave rather than taking a macro-system approach of using statistical models or averaged, high level representations.

Entities of the electrical system need to be modelled by taking into account their individual states and modes of operation. This can also be called micro-modelling, as for example, the objective is not to model a consumer by statistical means, representing an aggregated, averaged and typical behaviour. Rather, each individual household should be modelled, parameterized by information which can be taken from statistical datasets, and then recreating each household as an individual entity generating a power curve.

II. MODELLING APPROACH :

Agent-based modelling tools are able to capture complex system behaviour such as wanted and unwanted emergent behaviour in these systems, internal and external events, communications within the system, etc. In particular, local effects of the single units comprising the system can be modelled and their effects can be analysed at the system level. On the other hand, technical models of the single agents are necessary. Therefore, dynamic systems have to be represented in the form of the physical and mathematical models of the devices.

Furthermore, the large amounts of interactions and feedback appearing in distributed energy systems make linear simulation models inappropriate for systemic simulations. Therefore, an agent-based approach has been chosen. This approach is combined with other complex-system-relevant tools, such as system dynamics and discrete event simulation. The agent-based approach allows the inclusion of other modelling methods, for example modelling the reasoning of an agent. They can also be coupled either at a parallel level or embedded in a hierarchical structure. The agent-based approach was chosen because it is able to represent autonomous entities, which interact with their environment. While retaining a broad definition of what an agent can be, we can imagine representing even very simple entities of the energy system through agents. So, for example, an electrical heater has a constant operating power, which can be switched on and off. It interacts with the environment through heat dissipation and power consumption. Its behaviour is defined simply by a constant consumption. Modelling the entities of the system in this way, also allows an encapsulated and hierarchically structured representation, as we suppose that an agent (as an extension of objects in object oriented programming, and inheriting their properties) can have one or more other agents nested inside itself. What is important to remark is that, even if the agents are modelled in a simple way, the modular structure of an agent based model allows for the

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improvement of the behaviour of the entities at any stage. This enables the addition of extra features, such as an intelligent control, to the previously mentioned heating system. The degree of intelligence is not limited, so an agent can include any kind of decision algorithm, from the most simple to the most complex. The advantage is that the modelling system provides the potential for this from the beginning. This is because it has been conceived with these features in mind, and to overcome issues of non-modular or difficultly extensible approaches.

III. MULTI-SCALE SYSTEM MODELLING

Multi-scale modelling is an emerging subject of research and development, in which systems are represented in different structural, spatial and temporal scales.

These systems show important features that are the objects of the modelling and should therefore be represented on these different scales. Multi-scale phenomena can involve complex processes, such as feedback loops between different scales.

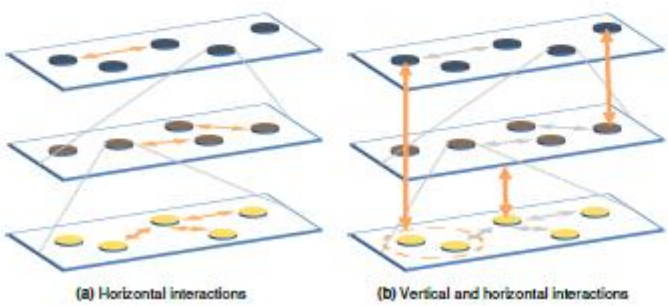

Figure 1 : (a) Horizontal interactions (b) Vertical and horizontal interactions

The topology and structure of the energy system has different scales itself, which are not directly linked to spatial or temporal scales. The low voltage grid, the distribution grid and the transmission grid can all be seen as different structural scales within a complex system. They must be taken into consideration in this systemic representation.

Multi-scale simulation systems offer several advantages over classical models. The ability to run simulations on different scales using the same model is a relevant topic for the future modelling of energy systems. The need for this kind of simulation emerges from:

• Distributed generation that has to be integrated at almost all scales (and not only in the high voltage grid as was previously the case).

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• Demand which is no longer considered as a static and uncontrollable mean. At lower levels of the system, local demand side management can be performed which can have an effect at higher scales.

• Monitoring that is implemented at lower scales of the electrical system (local measurements) will allow the analysis and optimisation of its operation at these lower scale levels.

Furthermore, simulating several scales in the same model has the advantage that there are fewer models and no need to port data between platforms. This leads to a more efficient simulation run and decision-making support. The challenges of these kinds of simulations are that a multi-scale model, at present, is not as accurate as a purpose-built model. So, the modelling method, the parameters, etc. included must be carefully chosen to ensure both flexibility and accuracy. Further attention has to be put on the inter-scale interactions. This is a complex issue, as multi-scale systems require both horizontal and vertical interactions. Horizontal interactions should be easily managed, as they take place within the same scale. Vertical, cross-scale interactions enable the representation of complex system phenomena. These cross-scale interactions must be modelled carefully to a design that that enables them. This is not an easy task. parameters, etc. included must be carefully chosen to ensure both flexibility and accuracy. Further attention has to be put on the inter-scale interactions. This is a complex issue, as multi-scale systems require both horizontal and vertical interactions. Horizontal interactions should be easily managed, as they take place within the same scale. Vertical, cross-scale interactions enable the representation of complex system phenomena. These cross-scale interactions must be modelled carefully to a design that that enables them. This is not an easy task.

Figure 1 shows these interactions in a multi-scale system. Current agent-based models usually take place only at a fixed scale and in general do not encompass different scales or layers. Adding multiple scales to the representation of the system increases the degree of complexity. However, only in this way can complex interactions at different levels of the system be represented.

Multi-scale models usually also have to deal with different spatial and time resolutions, which should be adapted to each scale. When modelling cross-scale interactions, different representations have to be considered. Geographical information systems (GIS) can be used to represent different spatial resolutions and the location of the entities.

IV. SOCIO-TECHNICAL SYSTEM MODELS :

Social sciences use simulation modelling as a tool in order to analyse and understand phenomena related to human behaviour. Behavioural models include a large degree of uncertainty, as their aim is to represent difficulty predictable, or only statistically characterisable, actions. These models have therefore to be non-deterministic in order to capture the heterogeneity of the actors. Behavioural models can only be validated with difficulty, due to their complex decision making processes. On the other hand, technical models aim to represent the operation of technical systems. These systems (in the real world) are usually intended to be deterministic, or at least, their mode of operation is completely known as these systems are, in fact, man-made. Models representing those systems are directly aimed to recreate the system's mode of operation, for example based on its physical laws or discrete states. Their operation can be usually modelled in an unequivocal, predictable way and is deterministic. Socio-technical systems are present in the real world everywhere in which a technical system interacts with human behaviour. This is the case for almost all technical systems. In order to model the "whole" behaviour, human behaviour has to be added to technical models. Coupling social with technical models is therefore a requirement for modelling large, complex systems. Agents are well suited to this approach, as by definition, they include behaviour which can be interpreted as a social or also technical behaviour. Both systems have interactions with the environment, and they interact with each other, either directly or through the environment. However, it can be said that technical models are rather deterministic, and that the agent definition includes a proactive behaviour which is not always the case for technical systems. In any case, a simple technical behaviour can also be seen as a behaviour in itself. More important is its autonomy concerning its behaviour and the fact that a technical system always has the objective for which it was designed and operates with the intention of fulfilling this objective.

V. SIMULATION AND MODELLING TOOLS USED :

Matlab is probably the most widely used simulation program for control systems at the academic level, although there are many other programs like Maple, Mathematica, Octave,

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Scilab, etc. that are also very common. With Matlab, simulations are possible in a mathematical sense, i.e. to apply numerical methods to solve differential equations representing the system. However, as it is designed using technologies from the 1950's-60's, it lacks the advantages of more modern object-oriented software. These advantages are evident if the system to model is of discrete event type and even more so if it is a hybrid or an agent-based system. Taking this approach, we will look at the problem from a new perspective, trying to offer new solutions with an innovative approach based on multi-method modelling.

VI. ENVIRONMENTAL AND PRODUCTION MODELS :

Production of electricity can be mainly classified as conventional or renewable, from the point of view of the primary energy source used. In the following section, we will address renewable energy sources (RES), as they are especially relevant for modern grids. Some of the RES are strongly correlated to environmental conditions. This is particularly the case with wind and solar power; although other RES might also be affected by meteorological effects. In the following example, the production models shown are used, making a special focus on RES. This has allowed greater focus on the fluctuating RES, which introduce stochastic and unpredictable magnitudes into the energy system.

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