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Model of interaction in Smart Grid on the basis of multi-agent system

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Abstract. This paper presents model of interaction in Smart Grid on the basis of multi-agent system. The use of travelling waves in the multi-agent system describes the behavior of the Smart Grid from the local point, which is being the complement of the conventional approach. The simulation results show that the absorption of the wave in the distributed multi-agent systems is effectively simulated the interaction in Smart Grid.

Introduction

At the present time, multi-agent systems among others intelligent methods [1-7] fulfilled intelligent energy control and management systems in Smart Grid. Traditional power systems used Supervisory Control and Data Acquisition (SCADA) systems. SCADA systems provide communication architecture capable of controlling and maintaining power system hardware using certain signaling protocols. Many off-the-shelf SCADA are installed with vendor specific control protocols software which limits communication with different DER devices. This results in increased deployment costs. The use of the multi-agent systems in Smart Grid has recently been provided to overcome this disadvantage. Multi-agent systems offer various advantages over the SCADA system for the implementation of Smart Grid. Reactive agents are associated with the subsumption model of intelligence. The core property of reactive agents is that they do not perform reasoning through symbolic manipulation; instead they react to inputs from their environment and signals from other agents [8]. Ease of implementation is an advantage of this approach. It is urgent to consider the influence and time delay when agents issue control signals to control physical devices in Smart Grid during the commands execution. Agents must be able to rejoin to the signals sensed from the external environment quickly enough to control the Smart Grid in an appropriate time. These issues are considered during modeling the interaction in Smart Grid on the basis of the travelling waves in the distributed multi-agent system.

1. Model of the distributed multi-agent system based on wave's notation

The distributed multi-agent system consists of four agents, namely control agent (1), DER agent (2), user agent (3), central agent (4) and database agent (5). In this research we consider absorption of the wave in the distributed multi-agent system where the agents are not identical. The behavior of *n*th agent in a multi-agent system is described as

$$X_n(s) = W^d_{n,n+1}(s) + W^a_{n,n+1}(s) = W^d_{n,n-1}(s) + W^a_{n-1,n}(s),$$

where agents denoted *(n−1)* and *(n+1)* are neighbours of *n*th agent; $W^a_{n,n+1}(s) = G(s)W^d_{n,n+1}(s)$. The first lower index indicates the agent where the wave departs, while the second lower index indicates the agent where the wave arrives. The upper index denotes if the wave belongs to the departing ('*d*') or arriving ('*a*') agent. A complex boundary is assumed to be in the multi-agent system. Fig.1 presents the Simulink model of the distributed multi-agent system.

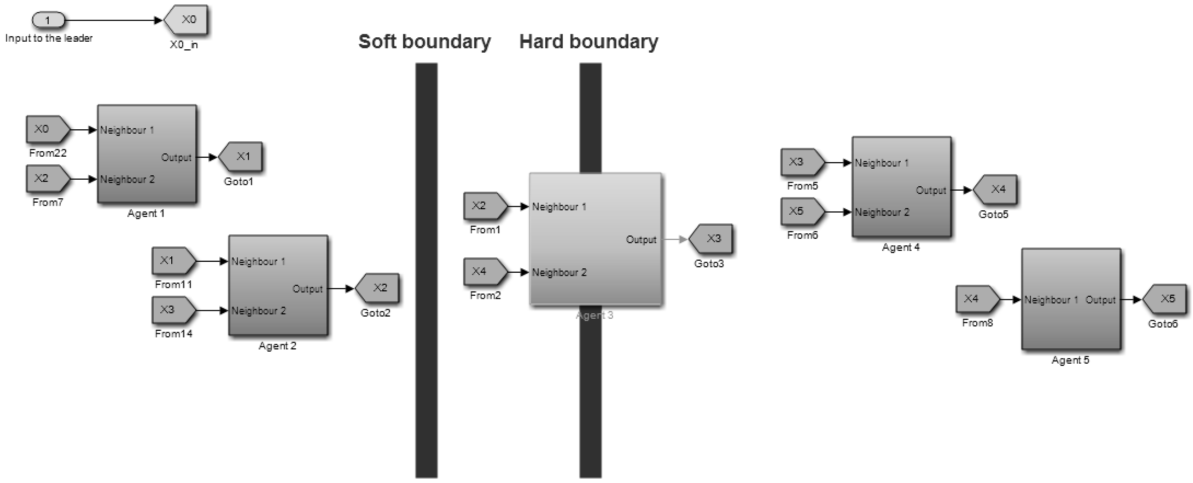

Figure 1. The Simulink model of the distributed multi-agent system

Time step for simulations is 0.005. The terminal simulation time is 50 s. Open loop transfer functions of the individual agents are specified in the symbolic form. We consider the simple model of interaction in Smart Grid on the basis of the travelling waves in the multi-agent system The front and rear node transfer functions of multi-agent system (1) respectively are defined as follows:

ol_tf_front = (5*s+5)/(s^2*(s+5)) and ol_tf_rear = (s+1)/(s^2*(s+3)). (1)

The front and rear node transfer functions of multi-agent system (2) respectively are defined as follows:

ol_tf_front = (5*s+7)/(s^2*(s+5)) and ol_tf_rear = (4*s+5)/(s^2*(s+4)). (2)

2. Simulation and results

All the simulations for this study are implemented in MATLAB, Simulink. The absorption of the wave in the distributed multi-agent systems is demonstrated through a simulation study of the Simulink model (Fig. 1). Figures 2 and 3 show an animation of the travelling waves from above-mentioned multi-agent systems (1) and (2).

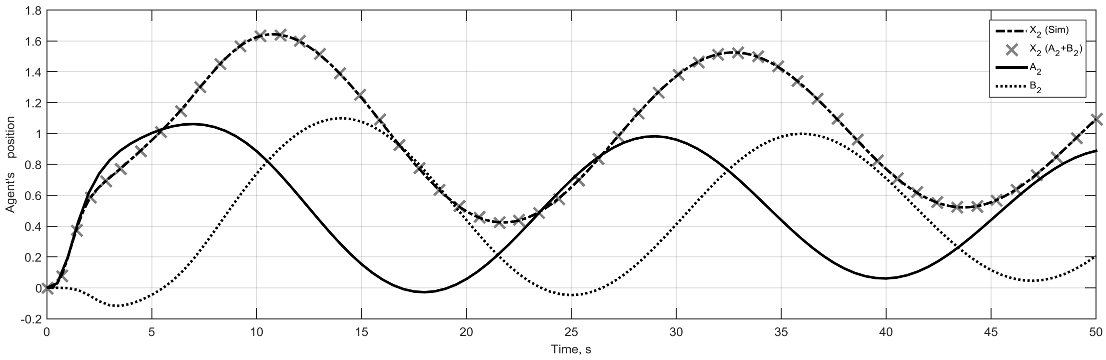

Figure 2. Plot of individual contributions of waves arriving from the neighboring agents of the distributed multi-agent system (1)

The wave travelling from the first agent to the rear-end agent is indicated by 'A'. The wave travelling in the opposite direction is indicated by 'B'. The derivation of the closed form formula for the agent's output necessitates taking into concern all the rejoins in the system, which is, in this case, troublesome.

The output of the multi-agent systems is computed by the following equations:

$$X_2 = A_2 + B_2; \tag{3}$$

$$A_2 = G^2 * X_{ref} - B_2 * G^4; \tag{4}$$

$$B_2 = T_{ab} * A_2 + T_{bb} * B_{3,L}; \tag{5}$$

$$B_{3,L} = \text{bar\_TAB} * A_{3,L} + \text{bar\_TBB} * B_{3,R}; \tag{6}$$

$$B_{3,R} = G^5 * A_{3,R}; \tag{7}$$

$$A_{3,R} = \text{bar\_TAA} * A_{3,L} + \text{bar\_TBA} * B_{3,R}; \tag{8}$$

$$A_{3,L} = Taa * A_2 + T_{ba} * B_{3,L}; \tag{9}$$

In this study, the absorption of the wave in the distributed multi-agent systems (1) and (2) is compared under the same conditions. Figures 2 to 3 illustrate the simulation's results.

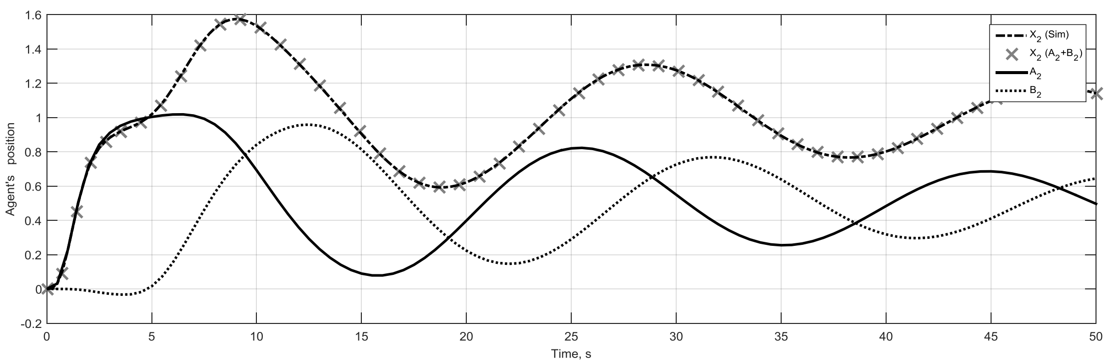

Figure 3. Plot of individual contributions of waves arriving from the neighboring agents of the distributed multi-agent system (2)

Extensive simulation studies on Simulink model have been carried out on different initial conditions, different disturbance profiles. It shows the wave similar behaviour, which is specifically plausible in a large scale Smart Grid.

3. Conclusions

Extensive simulation studies show that the absorption of the wave in the distributed multi-agent systems is effectively simulated the interaction in Smart Grid. Unlike traditional state space description of the multi agent system the important benefit of the Simulink model with travelling wave is that it explicates the comportment of particular agents. By the analysis of the travelling wave and its absorption on the agents, we can measure, how the output of one agent transmits in the multi-agent system.

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