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Agent-Based Modelling in the Operation of a Farm Equipped with Renewable Energy Sources and Electric Motors

Abstract: Presently, agent-based modelling is becoming increasingly widely used in various areas of science. The study contains an overview of various types of agent-based modelling applications and provides a modelling solution for a farm provided with renewable (electric) energy sources (RES) and electric motors. The final part of the study contains conclusions drawn during the performance of the research work discussed in the article.

Key words: operation of an RES farm, agent-based modelling (ABM), photovoltaic farm (PV farm), electric motors, inspections

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1. Introduction

The operation of large RES farms is accompanied by problems related to the proper securing of the operation of the devices located in such farms and usually scattered over a large area.

It is necessary to take into account possible failures, work stoppages and the necessity of quickly responding to various events.

The service personnel should be on site and have access to the appropriate means of communication in order to quickly and efficiently restore the operation of the power generation system. Simulation (e.g. Agent-Based Modelling) programmes capable of tracking the strategy and methodology of operating such power plants can appear very helpful.

The RES systems may be troubled by various types of events (e.g. fires, lightning discharges or short circuits), potentially disrupting the normal operation of the entire system.

The aforesaid events can take place individually or jointly. Repairing failures is related to the logistics involving the transport of specialists and the removal of obstacles posing threats to the normal functioning of the entire system.

2. Division of renewable energy farms

Currently, RES farms can be divided into three main groups, i.e.:

1. wind farms with generators and wind-powered turbines,
2. photovoltaic farms containing photovoltaic panels (above 100 kWp peak power),
3. mixed renewable energy farms, containing both generators with wind turbines and photovoltaic panels.

The article focuses primarily on photovoltaic farms.

3. Operation-related activities at renewable energy farms

In general, the operation of the RES equipment involves the following activities:

- acceptance of devices for operation,
- start-up of devices,
- maintenance of equipment operation,
- inspections,
- control and measurement works.

All the above-presented activities must comply with applicable requirements contained in related legal acts [10–17].

4. Requirements concerning sites for photovoltaic farms

An area of at least 2 ha should be provided for farms expected to generate a minimum of 1 MW of power. In addition, the width of such an area must amount to not less than 50 m.

Because of the possibility of panel darkening, it is necessary to maintain a minimum distance of 100 m from residential buildings.

5. Acceptance of devices for operation

In accordance with EN/PN/IEC standards, the start-up should be preceded by measurements of curves I-V (in relation to each group (”strain”) of photovoltaic panels connected in series [16, 17].

It is also necessary to measure the temperature of panels and radiation intensity values as well as convert actual results to standard conditions declared by the module manufacturer under the conditions specified in the Standard Test Conditions (STC).

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6. Start-up of devices

The technological start-up is accompanied by tests and measurements performed before the final acceptance of the installation. This requirement applying to renewable energy producers is imposed by the Energy Law [11].

Related activities include tests and assembly checks of individual components of the system.

7. Equipment maintenance

The operation of a photovoltaic (PV) farm must be monitored on an ongoing basis. The farm should be maintained in order to ensure its long-lasting operation with the highest possible efficiency.

Application of the SCADA (Supervisory Control And Data Acquisition) software system in the monitoring of areas and parameters of equipment operation.

The system enables the detection of irregularities and alerts the service personnel in the event of any irregularity in the operation of equipment, thus preventing or minimising potential damage. The SCADA system also makes it possible to remotely control the generation of energy and its flow as well as adjust the parameters of generated energy to weather conditions.

8. Inspections performed at RES farms

Inspections at RES farms can be divided as follows [10]:

- mandatory periodic inspections of photovoltaics (once every 5 years),
- emergency and interventional inspections (due to low efficiency or inverter shutdown),
- inspections performed in order to maintain guarantee rights for equipment/devices,
- preventive service, including random inspections (drone flights, infrared camera) and regular technical inspections performed on a monthly, semi-annual and monthly basis.

9. Control and measurement activities performed at photovoltaic farms

Control and measurement activities performed at photovoltaic (PV) farms include measurements of, among others, the following parameters:

- voltage of the open circuit of the PV system,
- short-circuit current of strings of panels connected in parallel,
- intensity of solar radiation (i.e. irradiance),
- temperature of the panel and ambient temperature,
- resistance of the insulation of AC and DC circuits,
- earthing resistance.

10. Electric motors at RES farms

It is assumed that buildings located at RES farms are heated by heat pumps. Renewable energy farms are also characterised by the presence and use of electric motors. Electric motors are usually applied for the positioning of PV panels (the so-called PV trackers); the aforesaid motors are usually brushless direct-current motors (BLDC) or electronically commutated motors. The operation of heat pumps entails the performance of related technical inspections.

Electric motors are also installed in vehicles intended for service operations.

Heat pumps are usually equipped with asynchronous water-cooled squirrel-cage motors.

Manufacturers usually provide a 5-year guarantee for heat pumps.

In order to maintain the guarantee rights, the inspection of the heat pump must be performed one year after its installation.

Inspections involve, among other things, tightness checks, exchanger condition, the condition of filters, fuses, sensors and safety valves.

Because of the increased numbers of electric vehicles and heat pumps, the consumption of electric power by motors is expected to increase from 9 % to approximately 30 % of the total consumption.

11. Agent-based modelling (ABM)

Computer simulation has long been a tool for analysis in management [5], e.g. when designing automotive electric motors [6], in transformer operation modes [7] or the operation of combat aircraft [8].

The above-named simulations are the so-called lower--level simulations. Agent-based modelling takes into account the interaction between individual agents.

The agent-based modelling (ABM) technique has been developed for a long time [2]. At the early stages of its development, the technique covered primarily finance, medicine, election methodology, military, management and power engineering [3, 4].

Presently, the application areas of the ABM technique have expanded to include logistics (production, supply chains), trade, aviation, military defence systems and photovoltaic systems on green roofs [1].

Today's wide range of modelling programmes includes both free-of-charge (i.e. open-source) and payable programmes or programmes which can be used on a free-of--charge basis in education, yet within a limited scope.

Table 1 presents various types of ABM programmes along with their features.

Table 1. Agent-based modelling programmes and their features

Name	Features	Operating mode
Mason	Free (open-source)	2D and 3D
Repast	Free (open-source)	2D and 3D
Anylogic	Payable, for free-of-charge use in education, within a limited scope	2D and 3D
Gama	Free (open-source)	2D and 3D
Framsticks	Freeware	2D and 3D
Net-logo	Free (open-source)	2D and 3D

Particular attention should be paid to two ABM programmes, i.e. AnyLogic and Net-logo. AnyLogic is a very advanced and software-developer-friendly programme based on the Java language. The software is characterised by numerous functionalities and can be used for various purposes, i.e. market simulation, healthcare sector, logistics (e.g. supply chains), defence systems, traffic, aviation and trade.

The Net-logo programme (based on the Logo language) has gained significant popularity because of its wide availability and "open-source" nature.

12. Examples of ABM applications

Table 2 contains examples of certain applications of agent-based modelling in electrical engineering.

Table 2. Examples of agent-based modelling applications

No.	Applications	Source
1.	Wind turbine maintenance model	File Help in AnyLogic
2.	AnyLogic-based modelling of smart energy systems for regions and cities/towns	AnyLogic Conference 2015, Philadelphia, USA
3.	Simulation model of the parking and battery charging of electric vehicles	AnyLogic Cloud
4.	Energy transactions between energy community members – ABM method	2018 International Conference on Smart Energy Systems and Technologies (SEST), Seville, Spain
5.	Agent-based modelling of the behaviour of motion and charging of electric vehicles	2015, 23rd Mediterranean Conference on Control and Automation (MED), Torremolinos, Spain

13. Agent-based modelling in AnyLogic

The AnyLogic language was chosen for modelling because of its versatility and ease of use [9]. AnyLogic has a graphic user interface (GUI) and enables graphic modelling. Figure 1 presents a schematic diagram concerning an approach to the creation of a general modelling process.

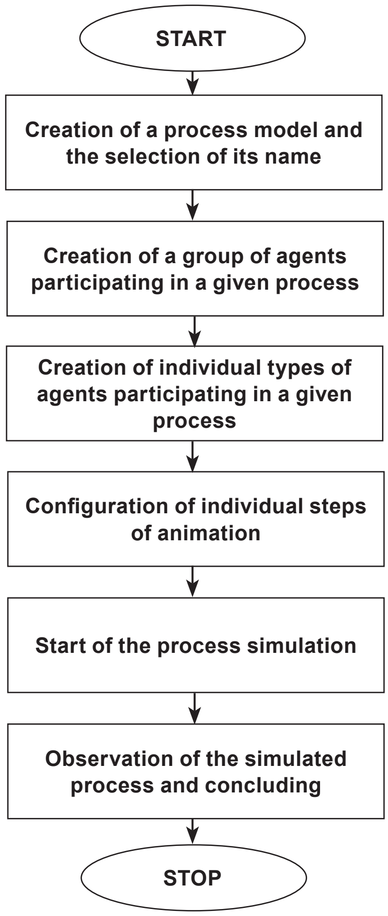

Fig. 1. Schematic diagram of activities performed during the modelling of an RES farm

14. Implementation of the agent-based modelling of a PV farm

The project was implemented using the AnyLogic programme. The project involved the agent-based modelling of a PV farm having an area of 2500 m^2.

Periodic inspections:
- farm has 30 photovoltaic (PV) panels,
- weekly inspections,
- getting to the panels involves the use of electric vehicles,
- service time: 8 h.

Emergency repairs:
- average intervals between failures: 20 days.

Repair time:
- repair time characterised by uniform distribution: 8–16 h.

The farm had a hangar, a building for the service personnel, two drones and two trucks.

Table 3 presents successive steps of the agent-based modelling of a photovoltaic (PV) farm.

Some stages of the agent-based model development are presented in the figures below. Figure 2 presents the creation of the centre of the MC service and photovoltaic panel.

Figure 3 presents individual agents of the photovoltaic farm model.

Figure 4 presents a simulated object with evenly distributed elements for 30 photovoltaic panels, two drones, two electric cars and the control centre.

Figure 5 presents the definition of the transport base and the simulation of the initial state of the constructed transport agents.

15. Summary and conclusions

Many various mandatory and preventive requirements as well as their implementation necessitate the modelling of the operation and service of small RES power plants. The model of a photovoltaic farm in AnyLogic fulfilled its functions.

The AnyLogic programme for creating agent-based simulation models is based on the Java object-oriented programming language.

The AnyLogic programme has found numerous applications – it has proved to be a good and constantly improved tool. However, even in terms of the simplest models, it is necessary to use (to a large extent) instructions written in the Java programming language.

Table 3. Sequence of ABM modelling of a PV farm on the AnyLogic programme

No.	Step of modelling	Name and type of the model agent and action	Function
1.	Creation of a maintenance process model	Maintenance, time units for the model: hours	Initial actions
2.	Construction of a new type of maintenance centre agent	Name: Centrum; Type: MC	Agent type and name
3.	Selection of 3D "Hangar" animation from the "Building" section	Connections per agent: 2	Centre type: hangar
4.	Creation of a new object scale of 5 pixels/m Specified explicitly. Additional scale: 75 %	Setting the scale so that the object can be visible during the animation	Scaling
5.	Creation of the agents of photovoltaic panels	Setting the scale so that the object can be visible during the animation; 10 pixels/m. Specified explicitly	Population of agents
6.	Creation of transport	Agent animation None Empty population	Empty population – Transport)
7.	Addition of trucks and drones (helicopters) to the transport model	Trucks, Drones	Centre equipment
8.	Creation of the truck agent	Speed:10 km/h	Addition of a parameter
9.	Creation of the drone agent	10 pixels/m	Scaling
10.	Creation of the drone agent	Setting of agent parameters	Agent type selection
11.	Performance of the initial simulation after the construction of system elements	Initial model animation	Service animation
	Stage 2		
12.	Transport base definition	Development of the service algorithm in the Java language	Means of transport placed in the hangar
	Stage 3		
13.	Definition of transport logic	Addition of transport variables, Creation of the diagram of states	Actions and routes of drones and trucks
	Stage 4		
14.	Definition of transport management	Creation of transport management logic	Function algorithm in the Java code
	Stage 5		
15.	Completion of transport logic	Sending of a service request signal by the panel	Creation of a function with transport request
	Stage 6		
16.	Final phase of model development	Creation of diagrams of states concerning scheduled maintenance and emergency repair	Service request Starting the model

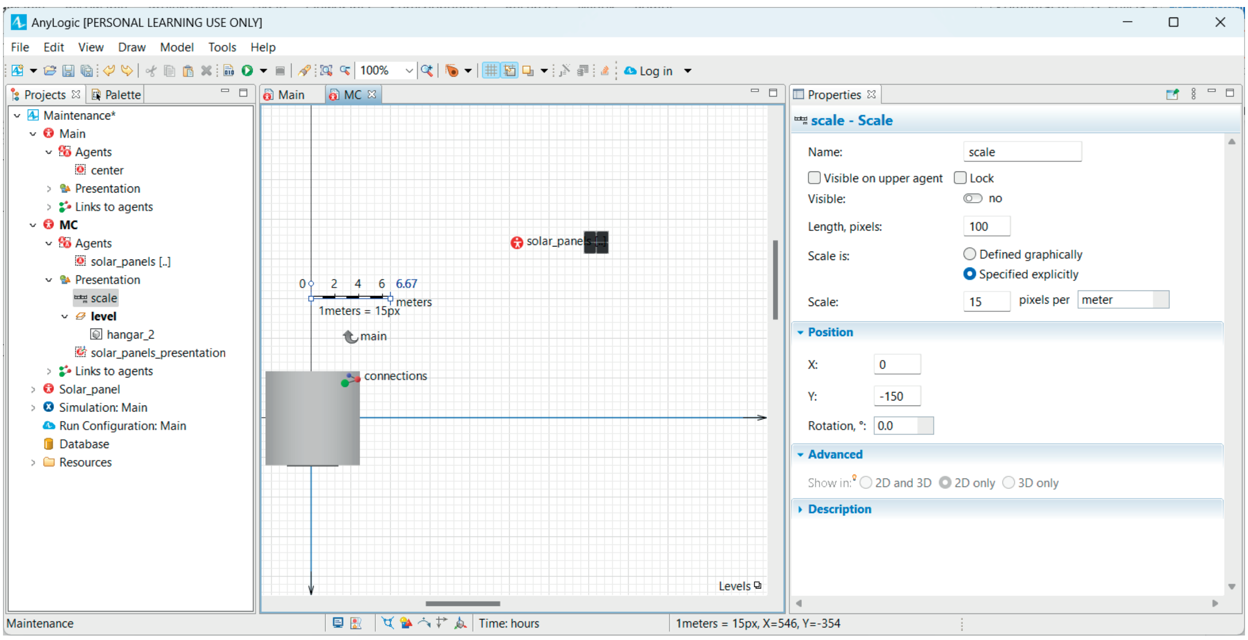

Fig. 2. Creation of the centre of MC service and photovoltaic panel

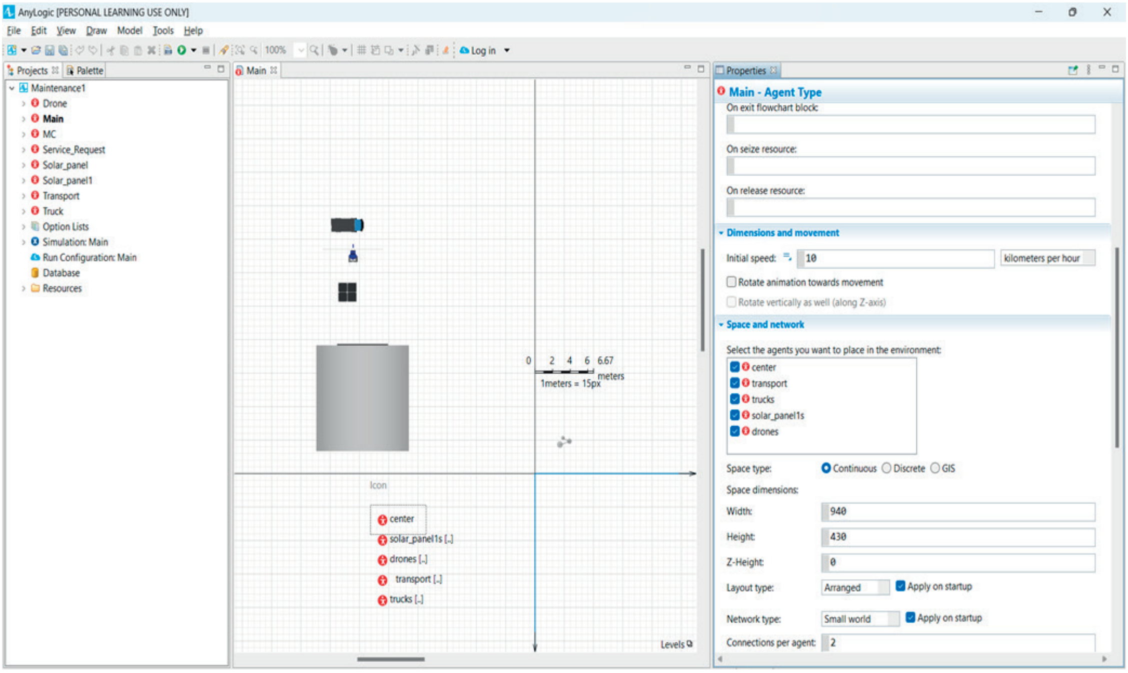

Fig. 3. Individual agents of the photovoltaic farm model

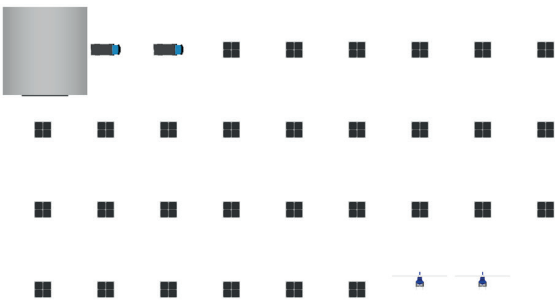

Fig. 4. Simulated object with evenly distributed elements for 30 photovoltaic panels, two drones, two electric cars and the control centre

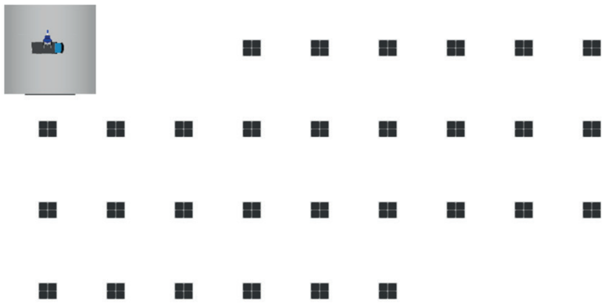

Fig. 5. Definition of the transport base and the simulation of the initial state of the constructed transport agents

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