

Agent based energy management system for microgrid

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Abstract

This paper presents the concept to develop energy management system of the 120 kWp microgrid system by using computer software agent technology called agent base technology. The microgrid energy management system is used to present all information in the system and to inform the system administrator for any status of the microgrid system. The system administrator can use data and simulation result from energy management system to estimate system performance and to set the production plan for matching the load demand with renewable energy resources.

Keywords: *Agent based simulation, energy management system*

1. Introduction

Microgrid system can be defined as a group of distributed energy resources (DER) and loads functioning as a single controllable system that reacts to central control command signals and supplies both power and heat to its regional area [1]. Moreover, it is also defined as an independent low-voltage distribution system that has a group of distributed energy resources with energy storage system and various energy sources such as solar power, wind power, biomass, hydro power, CHP, fuel cell, etc.[2].

The microgrid system was installed at SERT (School of Renewable Energy Technology, Naresuan University, Thailand). SERT's microgrid system have multi crystalline photovoltaic system as main energy source and have diesel engine generator for energy backup source. The components of microgrid system consist of 120 kW PV array, two sets of 60 kW PV inverters, 200 kWh battery bank, 150 kW battery inverter, 100 kW diesel engine generator, static var generator and general control panel. It supplies directly to the load and if there is no load in operation, then it sends electricity to the grid.

The main generator of SERT's microgrid is PV generator. Electricity from PV generator depends on solar irradiance which is uncontrollable and there are difficulties to manage system stability and optimal efficiency. Now a days, average utilization factor of the system (solar fraction) is about 50 % [3] . The solar fraction can be improved by using energy balance solution such as increasing PV modules and/or size of battery storage system, but this solution involves investment. Another alternative solution is the use of energy management system for microgrid system operation to achieve highest performance.

The data collected from microgrid system expands day by day and can't be used without implementing a database system. The concept of the software agent can solve this problem effectively. The software agent is a computer program that works as a representative of human to identify the information we need. Agent based technology is the name of software agent technology that will be used in this research. The data collecting system in SERT's microgrid, collects the significant parameters every minute during system operation. The collected data is transferred to graphic operation terminal for displaying and stored in compact flash memory. The data stored in the compact flash memory was downloaded to the computer manually every week for system performance evaluation.

2. Energy management system design

An Energy Management System (EMS) is the computer application for data collection and system management. It will help system administrator to manage energy use efficiently in the system. Normally, Energy management system consists of three main components namely; system monitoring unit, data management unit and system simulation unit. The energy management system can be applied to microgrid system to improve performance, system efficiency and reduce power losses. Energy management system will show production trends and system reports to system administrator for utilization in decision process to manage the microgrid system.

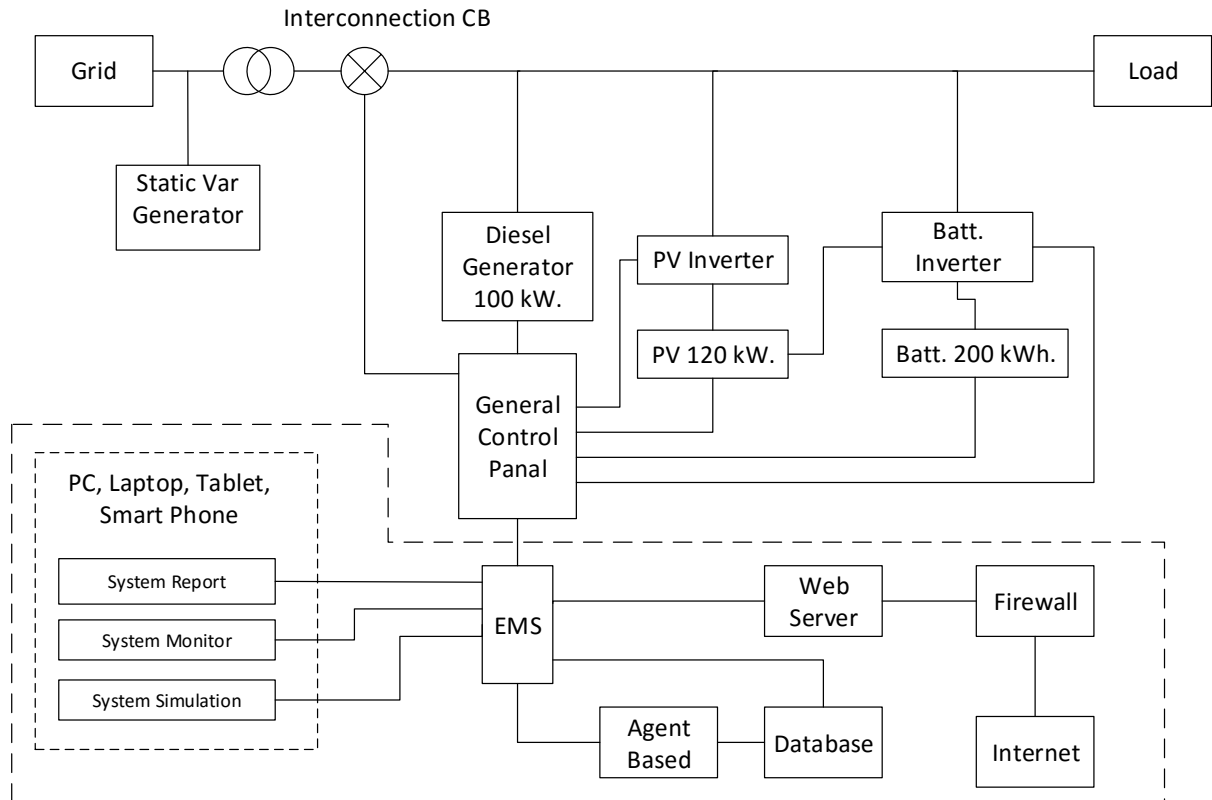


Figure 1 Microgrid EMS concept

3. Agent based technology

Agent based technology is a software technology used for making models to manage data. The software agent created acts like a human (agent) to do anything automatically according to the preset conditions. Agents have ability to think and analyze by themselves. Characteristics of agent based technology consist of autonomy (operate without direct intervention of humans, and have some kind of control over their own actions), Proactivity (react to external events but also have goal directed behavior) and Social Ability (co-operate with other agents by means of some communication language) [4].

Software agent design process in this research is based on FIPA agent management reference model. In agent-based modeling, a system is modeled as a collection of autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions on the basis of a set of rules. An agent-based model consists of a system of agents and the relationships between them. In addition, agents may be capable of evolving, allowing unanticipated behaviors to emerge. Sophisticated ABM sometimes incorporates neural networks and evolutionary discussion [5].

In this research, software agent was created to be used for selection of the necessary information it's preview and data simulation. The data for simulation will be obtained from a database that was created to be used in performance analysis.

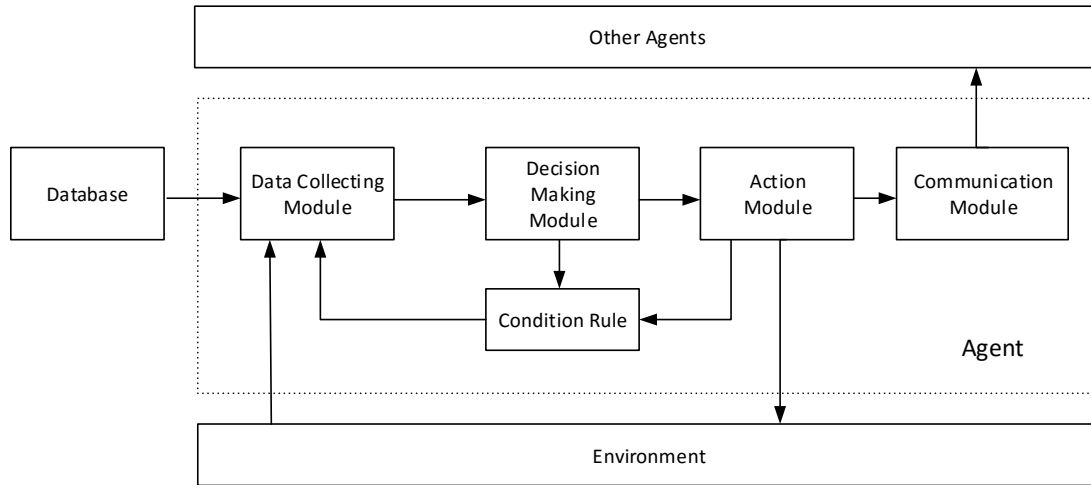


Figure 2 Agent design diagram

4. Methodology

The energy management system (EMS) was created using PHP language. Data was stored in SQL (Structured Query Language) file format and database created by mySQL using RDBMS (Relational database management system) theory. All programs used to developed EMS program are freeware. The application used to connect EMS program and SQL database is ODBC (open database connectivity) and installed on Microsoft windows server 2003 enterprise operating system for using EMS program over the internet. The advantage of data storage in SQL file format is smaller file size than CSV excel file. Twelve months CSV data size involved in this study was about 3.78 GB, when converted to SQL file its size decreased to 331 MB only(11.42 times less in size).

EMS consists of three main modules; Monitoring module, report module and simulation module. Monitoring module monitors nescessary information from microgrid system such as solar radiation, module temprature, ambient temprature etc. Report module can summarize data from microgrid system such as load, PV voltege and current, PV + DG power generation etc. Simulation module will consider energy management concepts like System efficiency, Energy loss and Utilization factor. The system efficiency indicators are performance ratio, array yield, final yield and reference yield. The utilization indicator is solar fraction and energy loss indicator are capture loss and system loss. Equeation used to calculate data were taken from international energy agency photovoltaic power systems (IEA-PVPS) task 2-performance, reliability and analysis of photovoltaic systems based on EU guidelines and IEC-61724 standards[6-10] as follow.

Performance ratio

$$PR = Y_f / Y_r \quad (1)$$

Where

PR = Performance ratio

Y_f = Final yield (h / d)

Y_r = Reference yield (h / d)

Solar Fraction

$$F_A = E_A / E_{in} \quad (2)$$

Where

F_A = Fraction of total system input energy contributed by PV array

E_A = Arrey output energy
 E_{in} = Total system input energy

Energy loss

$$L_c = Y_r - Y_A \quad (3)$$

Where

L_c = Array capture losses (h / d)

$$L_s = Y_A - Y_f \quad (4)$$

Where

L_s = System losses (h / d)

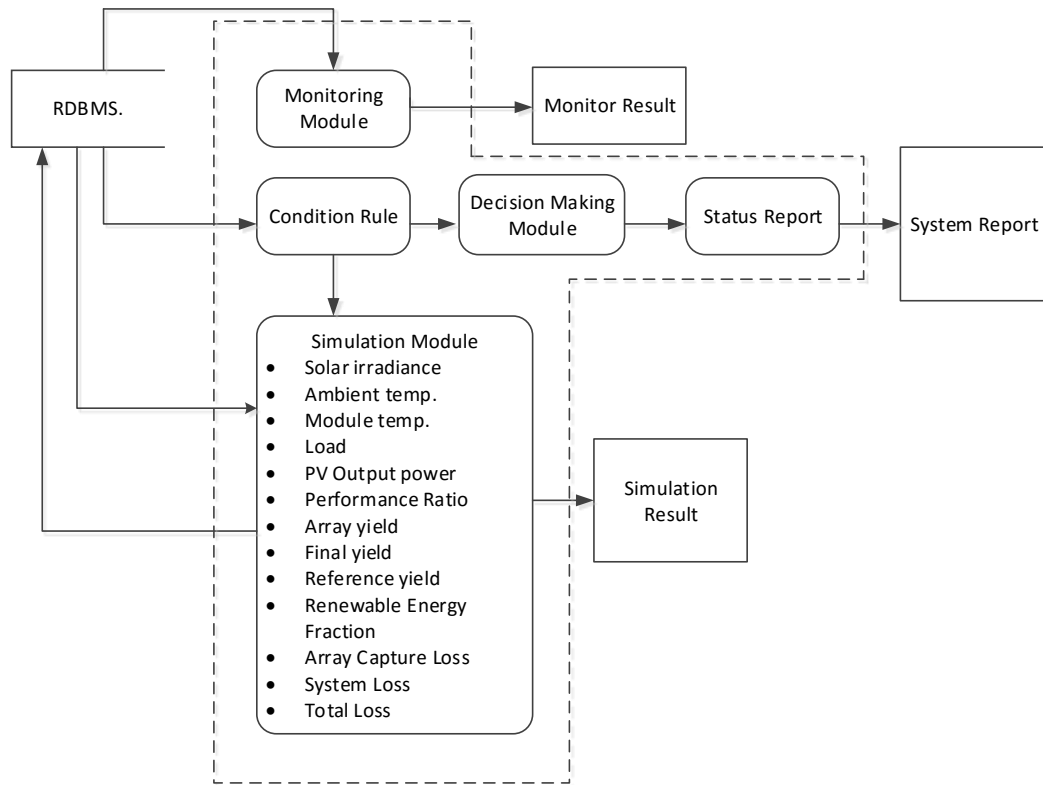


Figure 3 EMS process diagram.

5. Results and discussion

All the three functions, system monitoring, system status report and system simulation of the proposed microgrid energy management system have been shown in figure 3. In system monitoring module, software agent uses data from RDBMS to generate monitoring result. Monitoring result can be separated in to four period group data. Result can be displayed by date, month and/or season (winter, summer and rain) as shown in example in figure 4. In system status report, software agent compares data from RDBMS with conditions (rule) of EMS for making decision. And the last, simulation module is used to make simulation result of microgrid system by using data from RDBMS to generate system performance ratio, system loss and Utilization factor as shown in figure 5.

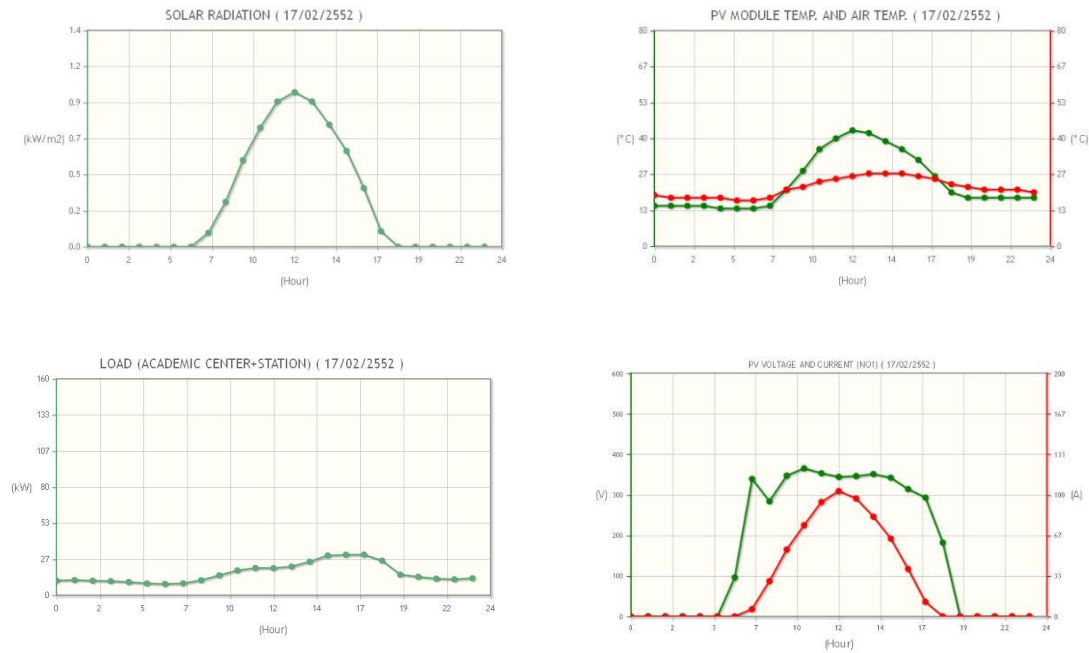


Figure 4 Graph information generate by monitoring module and report module

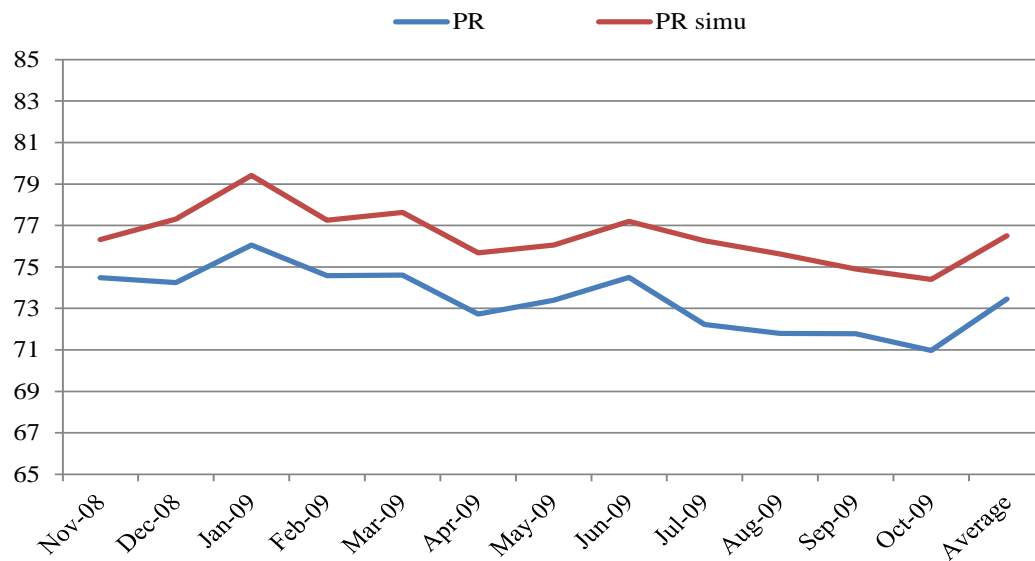


Figure 5 Comparison simulation result of performance ratio.

Table 1 Comparison of PV microgrid system efficiency

System efficiency	EMS	No EMS	Differences
Array yield	4.33	4.32	0.01
Final yield	3.99	3.84	0.15
Reference yield	5.21	5.21	0
Performance ratio	76.50 %.	73.45%	3.05%

From table 1 simulation result of array yield, final yield, reference yield and performance ratio are 4.33 h/day, 3.99 h/day, 5.21 h/day and 76.50% respectively while annual array yield, final yield, reference yield and performance ratio are 4.32 h/day, 3.84 h/day, 5.21 h/day and 73.45%

respectively. Differences of simulated array yield, final yield, reference yield and performance ratio with annual array yield, final yield, reference yield and performance ratio are 0.01 h/day, 0.15 h/day, 0 h/day and 3.05% respectively. Reference performance ratio of the PV generator is 75.48 %.[11]

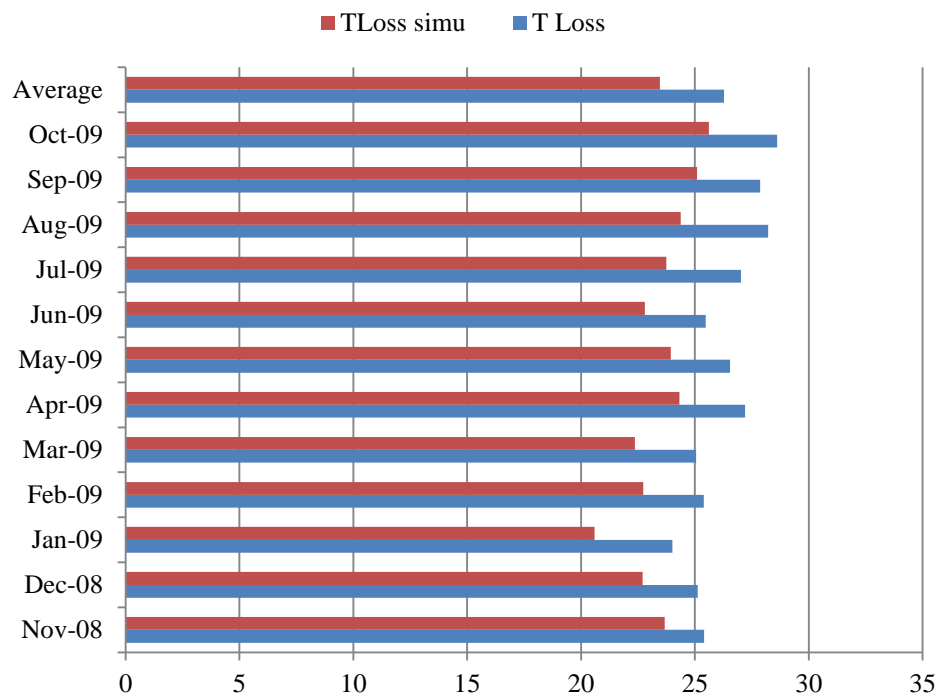


Fig 6: Comparison simulation result of energy loss.

Table 2 Comparison of PV microgrid system energy loss

Energy loss	EMS	No EMS	Differences
System loss	6.62%	9.06%	-2.44%
Capture loss	16.84%	17.21%	-0.37%
Total loss	23.46%	26.27%	-3.21%

Table 2 shows simulated system loss, array capture loss and total loss as 6.62%, 16.84% and 23.46% respectively while annual system loss, array capture loss and total loss are 9.06%, 17.21% and 26.27% respectively. Differences of simulated system loss, array capture loss, total loss with annual system loss, array capture loss, total loss are -2.44%, -0.37% and -3.21% respectively. Reference capture loss of PV generator is about 16 %. And reference system loss of PV generator is about 8 %. Reference total loss is about 26%[12]

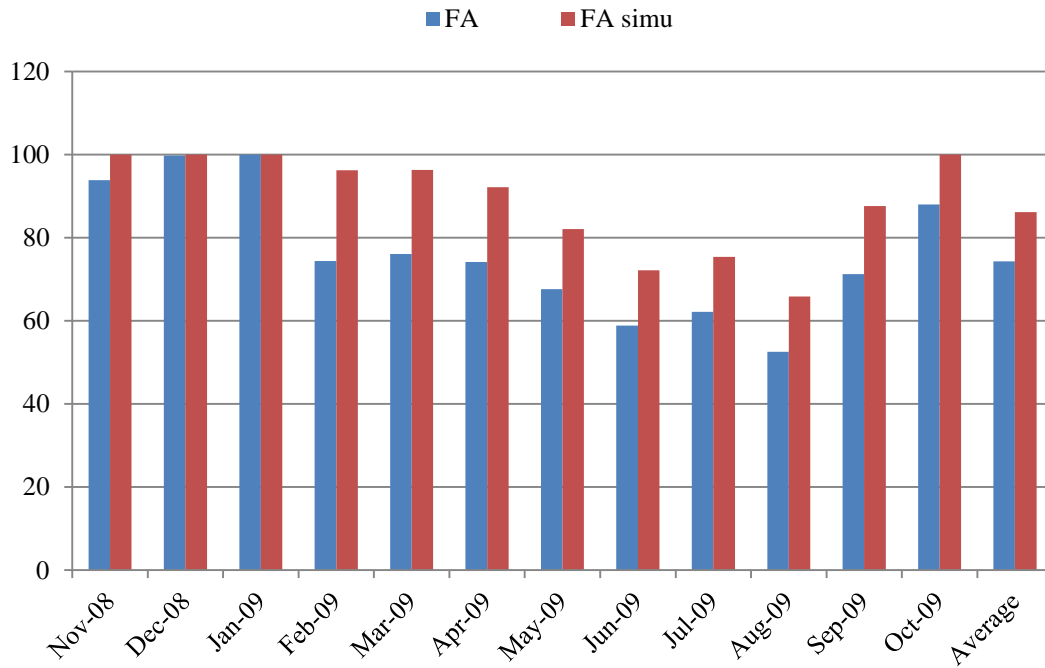


Figure 7 Comparison of solar fraction simulation result.

Table 3 Comparison of PV microgrid system utilization factor

Utilization factor	EMS	No EMS	Differences
Solar fraction	86.16%	74.30%	+11.86%

Table 3 shows that simulated solar fraction is 86.16% and annual solar fraction is 74.30%, difference is 11.86% and reference solar fraction is 50% [3].

6. Conclusion

The microgrid system have a large amount of daily data so over the longer periods of time it may become huge in size making it inconvenient to utilize. To solve this problem, a proper database system manager needs to be developed. This system administrator can easily control and operate the microgrid system. The advantage of developing microgrid energy management system are, ease of access to the microgrid system from everywhere, every time and data storage space minimization of as low as 11 times than XLS files.

The microgrid energy management system is used to present all conditions in the system and to inform the system administrator about status of the microgrid system. The system administrator can use data and simulation results from energy management system to estimate system performance and to set the production plan for matching the load demand with renewable energy resources. And in case of system errors, the energy management system can show system alarm to system administrator by system result report.

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