



Microgrid fed optimisation from hybri energy sources using swarm intelligence

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Abstract

An opportunity and a challenge for efficient power generation, regulation, and distribution are presented by the rising penetration of renewable energy resources in microgrids. Optimal operation is complicated by the intermittency and nonlinearity of hybrid energy systems that incorporate wind, solar photovoltaic (PV), and other renewable sources; nonetheless, these systems provide improved sustainability and dependability. An optimization framework for a microgrid that uses swarm intelligence approaches to accomplish robust energy management and load balancing is proposed in this paper. The microgrid would be fueled by hybrid renewable energy sources. Taking into account the ever-changing nature of generation, load demand, and storage state-of-charge, the best power dispatch method is determined using Particle Swarm Optimization (PSO). To reduce the need for backup systems powered by fossil fuels, the model incorporates real-time weather forecasting data to enhance the accuracy of predictions for wind and solar output. Under different load profiles and climatic circumstances, the performance is assessed by MATLAB/Simulink simulations. When compared to more traditional control strategies, the swarm intelligence method achieves better results in reducing costs, reducing power loss, and improving voltage stability. On top of that, the suggested solution meets demand-side needs and keeps the grid stable by making the most of renewable resources. Intelligent optimization algorithms have the ability to manage complicated hybrid microgrid systems, encourage the integration of sustainable energy sources, and decrease emissions of greenhouse gases, according to the research.

Keywords: Microgrid Fed, Optimisation, Hybri Energy, Swarm Intelligence microgrid fed optimisation from hybri energy sources using swarm intelligence

Introduction

Integrating various distributed energy resources like solar photovoltaic (PV) panels, wind turbines, biomass plants, small hydro units, and energy storage systems into a dependable, efficient, and ecologically friendly microgrid is an innovative and long-term strategy for contemporary power generation. Power generation may be localized to meet specific load demands, and there will be less pollution and less reliance on fossil fuels thanks to the integration of these various renewable energy sources into a microgrid (Goel, P. K. 2017). On the other hand, operational complexity is introduced by the hybrid structure of these systems because of the intermittent and stochastic nature of renewable energy sources, the fluctuation of load demands, and the requirement to maintain voltage and frequency stability. To guarantee lowest operational costs, maximum energy usage, and enhanced power quality, effective optimization of such systems is vital. From the collective behavior of biological systems like ant foraging, fish schooling, and bird flocking, swarm intelligence has arisen as a potent optimization tool in this environment. Hybrid microgrid operations have unique optimization challenges that can be addressed by algorithms such as Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Artificial Bee Colony (ABC), and Grey Wolf Optimization (GWO) (Das, S. K. 2019).

With their iterative refinement of cooperative search and adaptive learning-based possible solutions, these algorithms

are perfect for making decisions in real-time in dynamic contexts. Swarm intelligence-based optimization in hybrid energy microgrids ensures dependability, economic efficiency, and environmental sustainability while addressing various essential objectives, such as efficient power dispatch, load scheduling, storage management, and grid interaction. Swarm intelligence's distributed architecture is a good fit with microgrids' distributed control philosophy, which allows for reliable operation in the face of uncertainty, communication lags, or partial system failures (Agarwal, V. 2015). As an added bonus, this method is compatible with adaptive energy management systems, which can safely react to unexpected shifts in the weather or load profiles. When put into practice, swarm intelligence can maximize efficiency in energy allocation across various sources and storage devices, integrate renewable generators with backup systems like diesel gensets, and optimize the charging and discharging cycles of batteries to extend their lifespan (Dell'Aquila, A. 2013). To top it all off, these algorithms may make decisions based on more than one criterion, meeting economic and environmental targets by minimizing costs while simultaneously increasing energy efficiency and decreasing emissions. The use of swarm intelligence to optimize microgrids powered by hybrid energy sources is growing in importance as the world's energy systems shift towards decentralized designs and more use of renewable energy. To fulfill the needs of future smart grids and sustainable energy

infrastructures, it provides scalability, resilience, flexibility, and increased operational performance (Singh, B. 2016).

Methodology

1. Hybrid Renewable Energy Systems

As an affordable substitute for fossil fuels, renewable energy sources are good for the environment since they don't release greenhouse gases. Renewable energy resources are a solution to the various problems associated with conventional energy sources. When contrasted with conventional energy sources that rely on fossil fuels, renewable energy is quickly gaining economic ground. Power generation from renewable sources, such as solar and wind, is now more cost-effective than that from fossil fuels. The pros and cons of renewable energy sources are summarized in Table 2.1.

Table 1: Advantages and disadvantages of Renewable resources

Advantages	Disadvantages
Uses free resources like sunlight, wind and geothermal energy for fuel	Renewable energy production is dependent on natural cycles
Operation and maintenance requirements are low	Initial cost of these systems is higher than comparably sized conventional generators
No problem of pollution or waste	Cannot handle the peak loads without storage system.
Good for regional areas	Site specific generation

2. Mathematical modelling

Wind turbine generators, solar photovoltaic arrays, hydro turbines, and other RE conversion technologies are all part of the HRES, which also includes more conventional generators like microturbines and diesel engines. Batteries and hydrogen storage tanks are also part of the HRES's storage system. Complete or partial use of the units is possible for the HRES. Simulations of the system under actual operating circumstances, including appropriate weather, insulation levels, wind speeds, and electrical loads, are vital for ensuring the correctness of the sizes of the various components for the microgrid. Imprecise text from the user.

- Solar Photovoltaic system
- Wind Turbine Model
- Biogas generator
- Converter Modelling

3. Optimization Problem

Managing reactive and actual power, size, economic operation, controller design, voltage, frequency, and reliability control are the main issues in the HRES optimization challenge. Optimal operation, cost optimization, battery life, regulation of voltage and frequency in grid-connected systems, overall environmental impact, availability of renewable resources for power generation, design of hybrid systems (including storage options and sizing), interconnection of different sources using converters, area load curve to be met, and so on are all factors that make up the optimization problem. Utilizing advanced approaches and algorithms, several studies have been carried out to ascertain the optimal economic design of hybrid renewable energy systems (HRES).

4. Objective Function

The goal of an optimization problem can be expressed mathematically as an objective function of the suggested

HOA. The determined decision factors constitute the basis of its formulation. The proposed Hybrid Renewable electricity System (HRES) is the focus of this study, which aims to decrease the overall cost of electricity while also reducing carbon emissions. The quantity of solar arrays (NPv), wind turbines (NwT), biogas generator size (Nbio), and inverter size (Ninv) are the optimization parameters. There is a maximum and minimum value for each of these parameters, and they are all optimized within that range.

Results

1. Results for Dataset 1

The different results for dataset 1 are shown in Figures 3.1 to 3.5. Here, we had a look at the model's simulation findings. The simulation results showing the weekly energy consumption demand at the charging station, broken down by hour, are shown in Figure 3.1. Figure 3.2 shows the wind turbine's weekly energy generation. Figure 3.3 shows that the suggested wind turbine system can adapt the load to meet the demand. Figure 3.4 shows the results of the demand-and supply-based energy consumption analysis for fuel capacity (FC) and hydrogen storage. Lastly, Figure 3.5 compares the yearly net cost with and without FC.

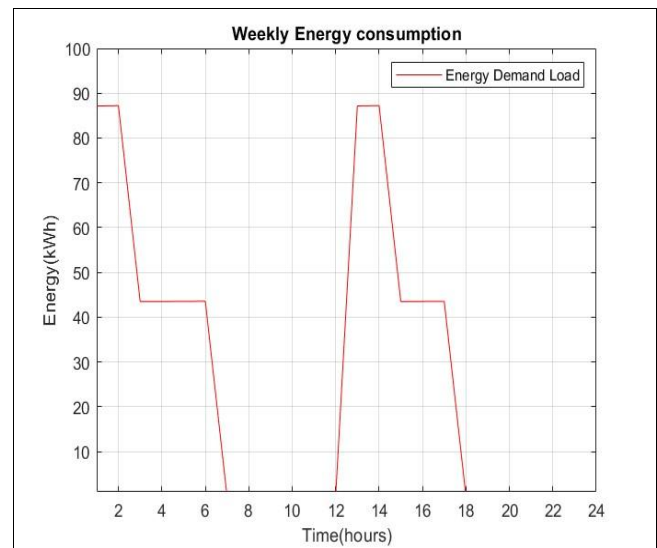


Fig 1: Weekly demand for the energy using dataset 1

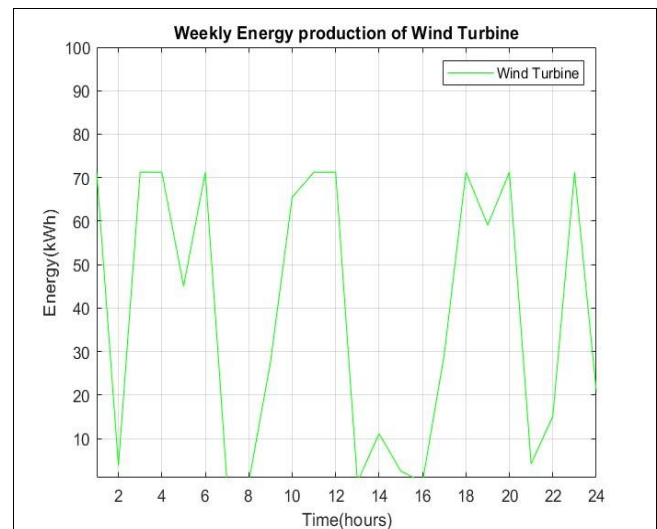


Fig 2: Weekly production for the energy using dataset 1

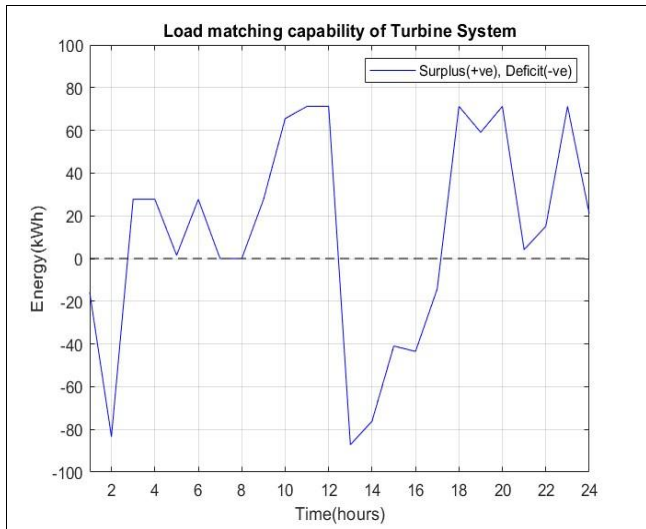


Fig 3: Weekly load matching capability of the wind turbine using dataset 1

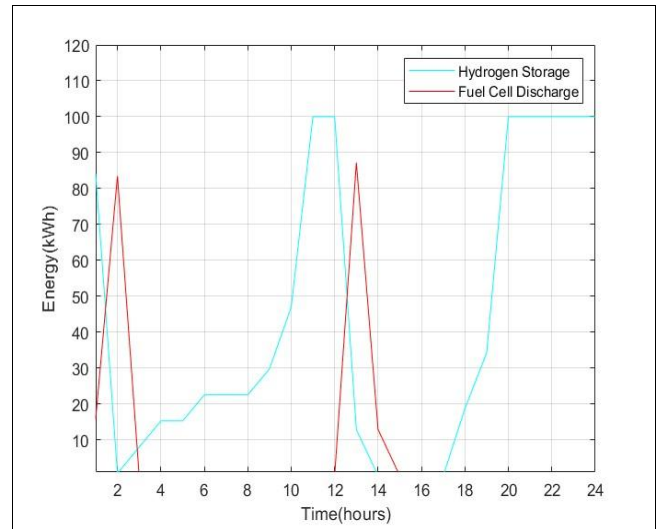


Fig 4: Energy consumption analysis for hydrogen storage and fuel cell discharge using dataset 1

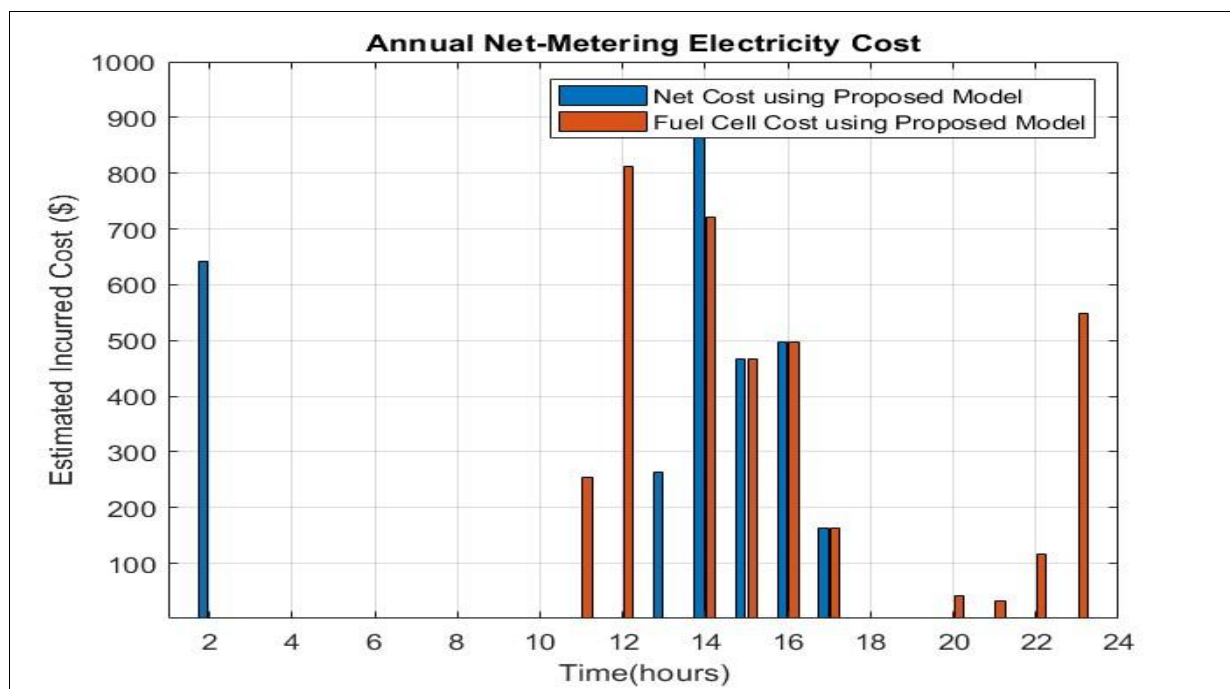


Fig 5: Annual net metering electricity cost using dataset 1

Table 2: Results analysis using dataset 1

Methods	Loss of Power Supply	Hydrogen Gas Utilization (Kg)	NPC (\$)
Hybrid Energy System (Conventional)	0.55	8.04	5488
Hybrid Energy System using PSO	0.31	7.07	3021
Hybrid Energy System using CPSO-MPC	0.28	6.82	2987
Hybrid Energy System using IGWO	0.27	6.1	2983
Hybrid Energy System using HOA	0.25	4.84	2970

Table 3.4 shows that there are seven hours of energy generation shortfall and seventeen hours of excess for the system. There are 20 operating hours in a year, and the hydrogen storage tank is only full for 7 of those hours. The proposed HOA-based hybrid energy integrated system has a 46% savings rate when compared to the current systems.

3.2 Results for Dataset 2

Dataset 2's many results are shown in Figures 3.6–3.10. Figure 3.6 shows the results of the simulation for the

charging station's energy consumption needs throughout a week, broken down by each hour. The energy production of the wind turbine on a weekly basis is shown in Figure 3.7. The ability of the suggested wind turbine system to match the load according to demand is shown in Figure 3.8. In Figure 3.9, the research on energy consumption for hydrogen storage and fuel capacity (FC) was assessed in relation to supply and demand. The annual net cost was compared with and without FC, as shown in Figure 3.10.

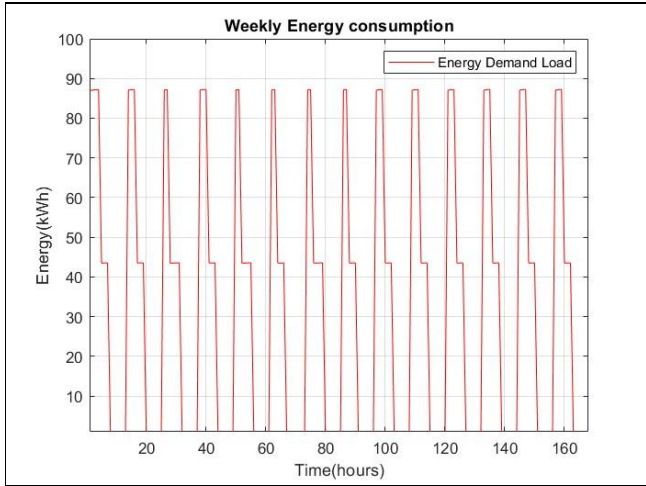


Fig 6: Weekly demand for the energy using dataset 2

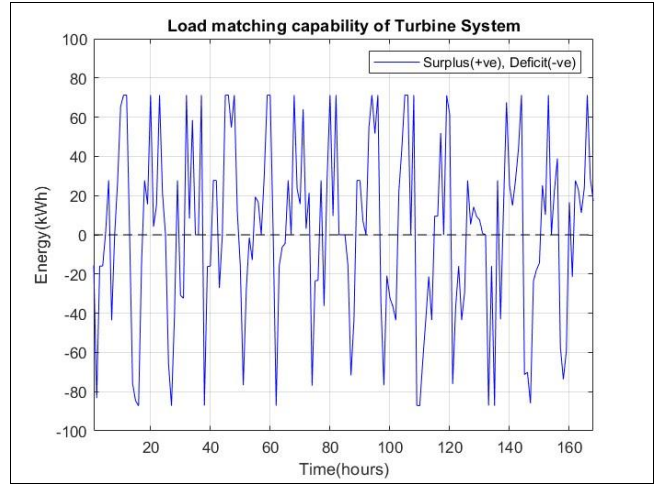


Fig 8: Weekly load matching capability of the wind turbine using dataset 2

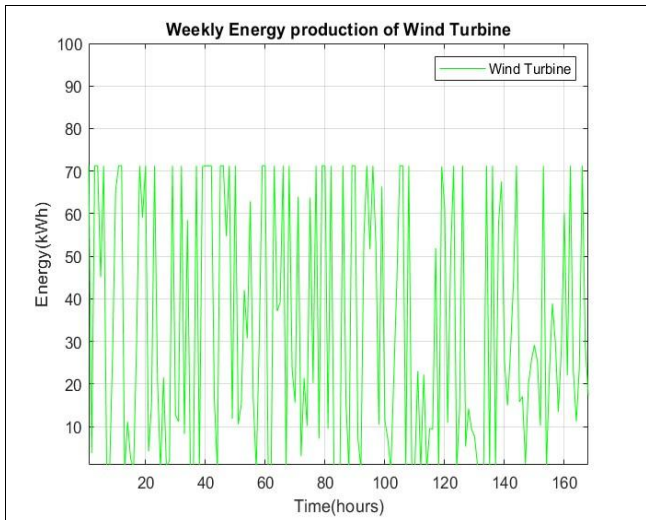


Fig 7: Weekly production for the energy using dataset 2

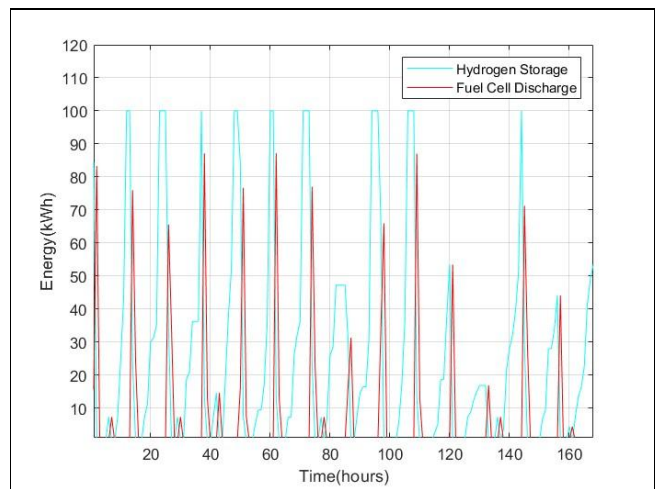


Fig 9: Energy consumption analysis for hydrogen storage and fuel cell discharge using dataset 2

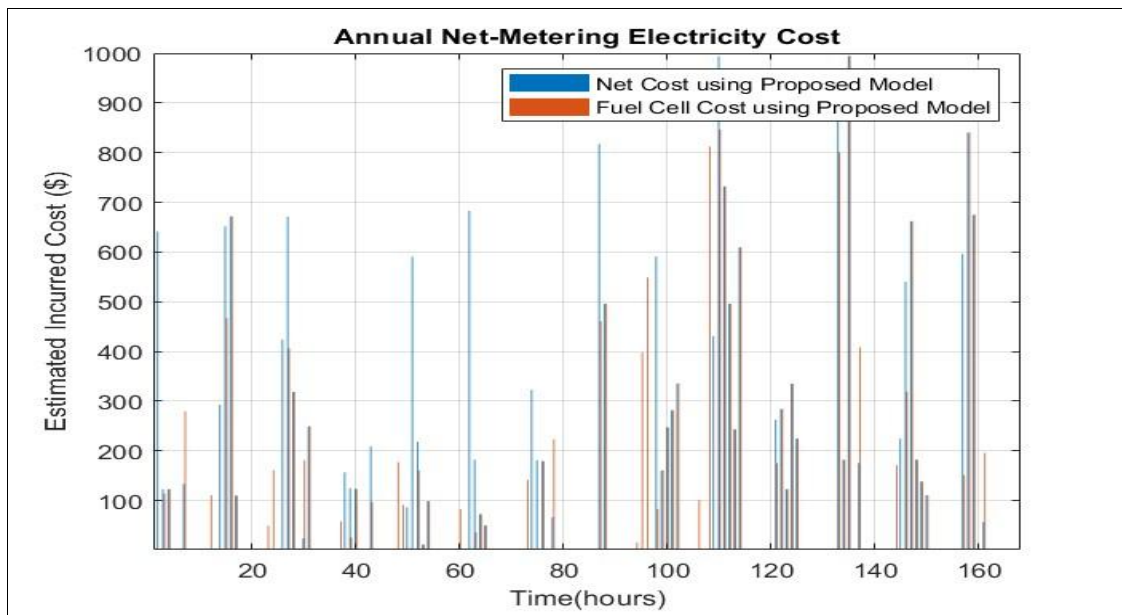


Fig 10: Annual net metering electricity cost using dataset 2

Table 2: Results analysis using dataset 2

Methods	Loss of Power Supply	Hydrogen Gas Utilization (Kg)	NPC (\$)
Hybrid Energy System (Conventional)	0.55	40.4	47088
Hybrid Energy System using PSO	0.23	39.43	21559

Hybrid Energy System using CPSO-MPC	0.21	39.18	21319
Hybrid Energy System using IGWO	0.19	38.46	21289
Hybrid Energy System using HOA	0.17	37.2	21199

Table 3.2 displays the results of the study for dataset 2. For 65 hours, the system doesn't generate enough energy, and for 103 hours, it generates more than enough. Each year, the Hydrogen Storage Tank runs for 113 hours, with 20 of those hours being used at full capacity. There is a 55% reduction in energy consumption as compared to the current system while using the suggested HOA-based Hybrid Energy Integrated System.

Conclusion

Swarm intelligence optimization of microgrids powered by hybrid energy sources offers a flexible and efficient way to guarantee sustainable, affordable, and dependable power production. Improved energy efficiency and stability may be achieved by the microgrid through the integration of renewable sources with suitable storage systems. These sources include solar, wind, and small-scale hydropower. Hybrid energy systems are complicated, nonlinear, and dynamic; swarm intelligence approaches, which are based on collective behavior in nature, provide a strong answer for dealing with these issues. To minimize operating costs and losses, algorithms like Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO) can find the best solutions for energy dispatch, load management, and power scheduling. The capacity to swiftly adjust to changes in demand, weather, and the availability of renewable energy sources is another way these technologies improve resilience. In addition, grid interfaces, storage devices, and distributed generating units may be coordinated using swarm-based optimization to maintain frequency and voltage stability. This method allows for the simultaneous pursuit of technical, economic, and ecological objectives through multi-objective optimization. Swarm intelligence is a powerful tool for contemporary energy management systems because it increases the reliability and efficiency of hybrid microgrid operations and speeds up the shift to a power grid that is less centralized, smarter, and powered by renewable energy.

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