Asian Research Consortium

Asian Journal of Research in Social Sciences and Humanities
Vol. 6, No. 6, June 2016, pp. 1421-1430.

Asian Journal of Research in Social Sciences and Humanities

ISSN 2249-7315
A Journal Indexed in Indian Citation Index
DOI NUMBER: 10.5958/2249-7315.2016.00296.3

www.aijsh.com

Category: Science and Technology

# Prioritized Load Balancing and Power Quality Improvement in MVDC Grid

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## Abstract

Micro grids are maturing technically as well as commercially over the past few years. Micro grids are now used for islanded operations where conventional energy sources are not available. This is very helpful to remote mine sites and also for electrifying isolated islands.

Maintaining reliability is a crucial matter for islanded micro grids. Hence load and supply balancing is very essential. This paper suggests a prioritized load balancing technique which ensures reliability of service. The loads are studied and prioritized based on which balancing is done. The micro grid is powered by renewable sources like wind energy, solar PV panel and a backup DC generator. This approach always ensures continuity of crucial services while shutting down unnecessary loads during shortage of power.

In the advanced stage, in order to improve power quality FACTS devices are installed. Also to harness maximum energy, Maximum power point tracker (MPPT) is installed for wind mill and solar PV panel.

# I. Introduction

T Mine sites are often in remote places where mineral resources are abundant. However, it is important to have a secure and reliable power supply for running the mining operations efficiently and reliably. Recent technological trends show an increased interest in medium-voltage dc (MVDC) systems. Hence it is essential develop various schemes to maintain reliability and protection to MVDC systems.

The islanded MVDC micro grid at the mine site is assumed to use a diverse array of distributed energy resources (DERs), such as solar/photovoltaic (PV) arrays, wind turbines, a fuel-cell stack, and a battery energy storage system. Among these DERs, the wind turbines and the PV arrays work at their maximum power points (MPPs) .The fuel cells are controlled to regulate the dc-bus voltage at ~6 kV, and a battery energy storage system aims at balancing. There also exist diesel generators, which have quick start characteristics, for backup generation and dc-bus voltage regulation.

The faults occurring in MVDC are categorized to load side, transmission side, supply side and distribution side. Solid state relays are developed to identify and detect faults in transmission and distribution areas. But the faults in supply side creates a serious impact on reliability of micro grid. Hence a prioritized load balancing system is suggested that can improve the reliability of system.

# II. Minesite Microgrid: Concept of MVDC Grid

The medium-voltage dc (MVDC) concept is ultimately a collection platform designed to help integrate renewables, serve emerging dc-based and constant-power loads, inter-connect energy storage, and address future needs in the general area of electric power conversion, all in a more optimized manner. The need for MVDC technology development has been driven by the liberalization of the energy market, which has led to installations of large-scale wind and solar farms at the transmission and distribution level.

The penetration of these renewable energy technologies, both onshore and offshore in the United States, is rapidly increasing and will ultimately require a dc integration link to realize efficiency and optimization gains. The same is true of the various end-use consumer loads, in particular, electric vehicles, as well as sensitive power electronics– based loads, many of which are operating at low-voltage dc levels is not simply a technological comparative of HVDC or a simple scaling of voltage level from HVDC but rather a new development concept with various and diverse applications.

## III. Experimental Setup

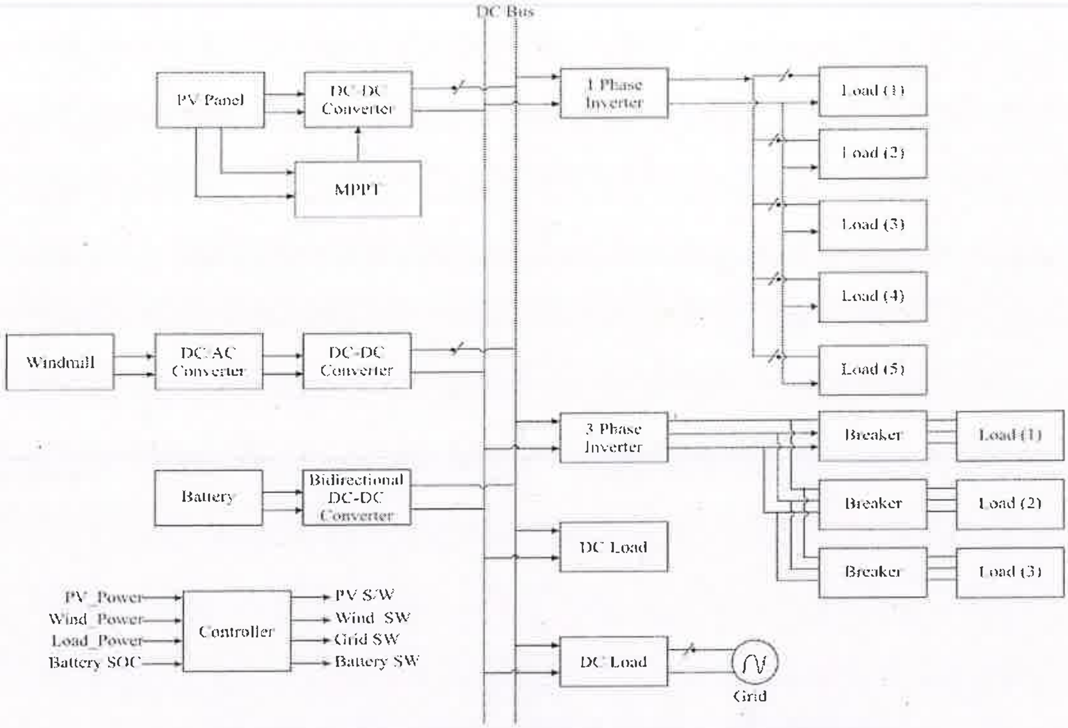


**Fig.4.3 Output of PV Cells for various Irradiation**

The islanded MVDC microgrid at the mine site is assumed to use a diverse array of distributed energy resources (DERs), such as solar/photovoltaic (PV) arrays, wind turbines, a fuel-cell stack, and a battery energy storage system, as shown in Fig. 1. Among these DERs, the wind turbines and the PV arrays work at their maximum power points (MPPs) , the fuel cells are controlled to regulate the dc-bus voltage at ~6 kV, and a battery energy storage system aims at balancing the supply and demand. There also exist diesel generators, which have quick start characteristics, for backup generation and dc-bus voltage regulation. A visual depiction of the overall control strategy for the microgrid.

## IV. Modelling of System

Medium voltage Dc grid is designed using MATLAB. Individual components of grid are designed and combined together to form fully functional DC grid for coal mines.

### PV System Design using Matlab

A photovoltaic system converts sunlight into electricity. The basic device of a photovoltaic system is the photovoltaic cell. Cells may be grouped to form panels or modules. Panels can be grouped to form large photovoltaic arrays. The term array is usually employed to describe a photovoltaic panel (with several cells connected in series and/or parallel) or a group of panels. Most of time one are interested in modeling photovoltaic panels, which are the commercial photovoltaic devices. This

paper focuses on modeling photovoltaic modules or panels composed of several basic cells. The term array used henceforth means any photovoltaic device composed of several basic cells. In the Appendix at the end of this paper there are some explanations about how to model and simulate large photovoltaic arrays composed of several panels connected in series or in parallel. The basic equation from the theory of semiconductors that mathematically describes the I -V characteristic of the ideal photovoltaic cell is:

$$I = I_{pv,cell} - \underbrace{I_{0,cell}\left[\exp\left(\frac{qV}{akT}\right) - 1\right]}_{I_d}$$

where Ipv,cell is the current generated by the incident light (it is directly proportional to the Sun irradiation), Id is the Shockley diode equation, I0,cell [A] is the reverse saturation or leakage current of the diode [A], q is the electron charge [1.60217646 • 10−19C], k is the Boltzmann constant [1.3806503 • 10−23J/K], T [K] is the temperature of the p-n junction, and a is the diode ideality constant. The following diagram shows a practical device.

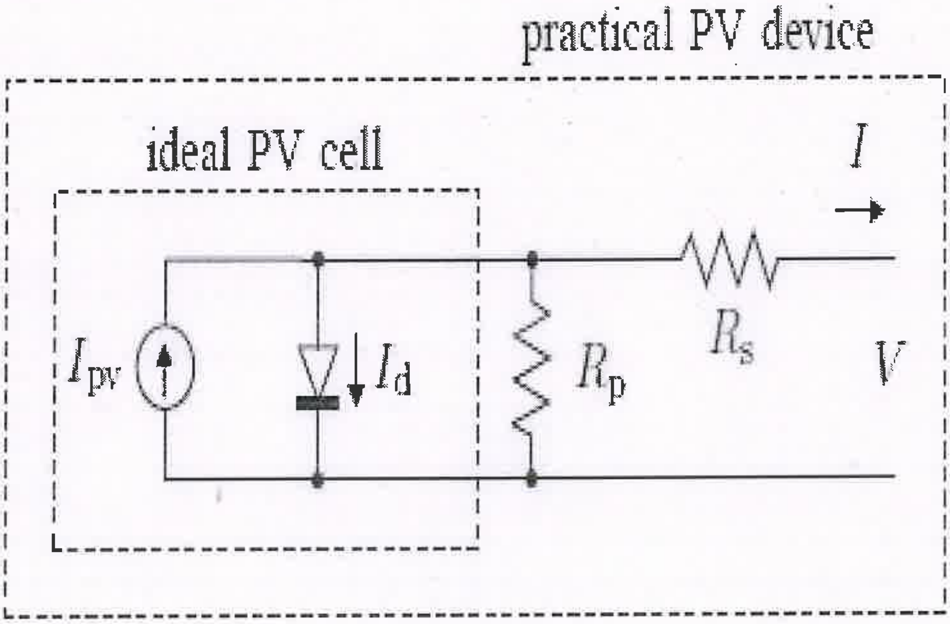


**Fig.4.1 Ideal PV Cell**

The output of solar PV cells depends upon the irradiation. The irradiation is designed using interpolation input values in MATLAB. The output of PV cells for different temperature and P-V model curves for different temperatures are also observed before final modelling. The following diagrams shows the performance of PV cells. Based on all these design parameters and observing its performance the final design is modelled using MATLAB.

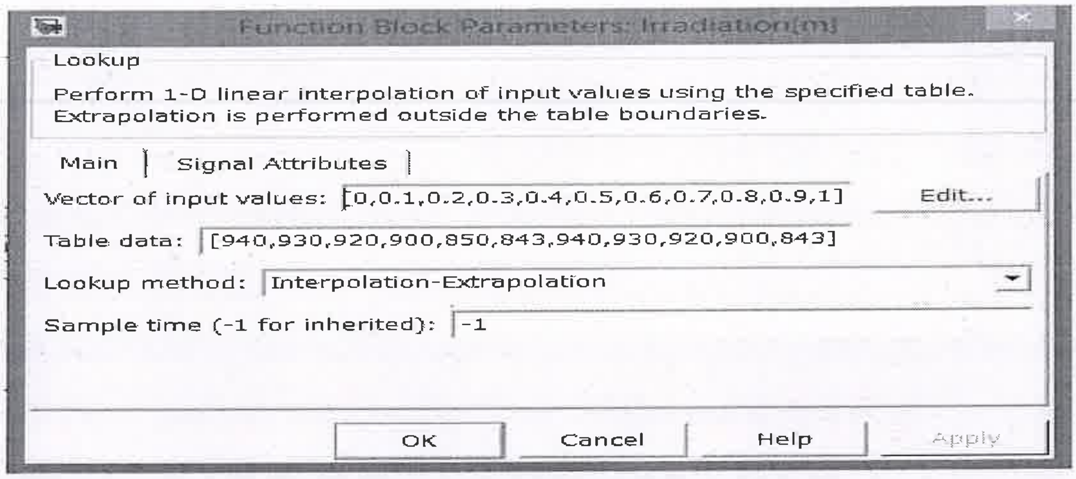


**Fig.4.2 Irradiation input using Interpolation**

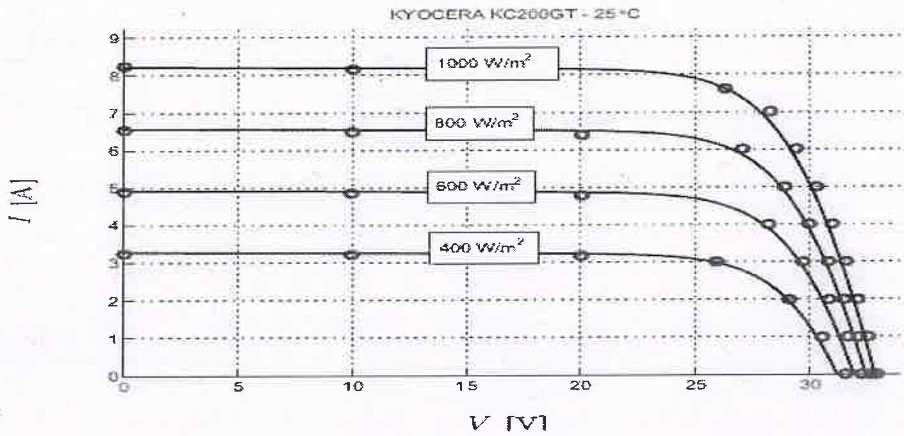


**Fig.4.3 Output of PV Cells for various Irradiations**

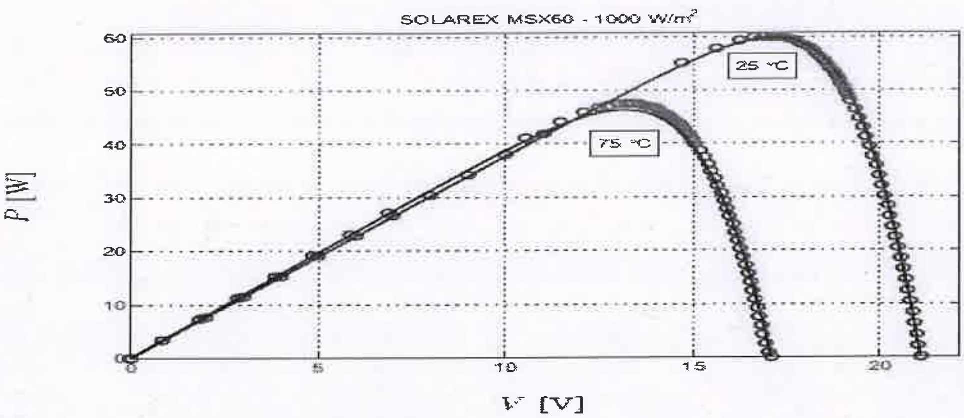


**Fig.4.4 P-V Curves for various Temperatures**

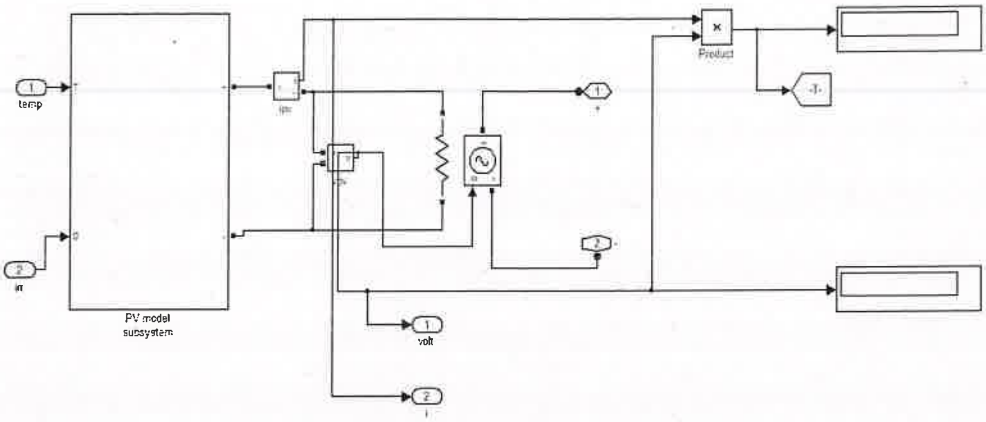


**Fig.4.5 Design of PV System using MATLAB**

## Designing Wind Power

The wind power also contributes a major share to the DC grid. A permanent magnet synchronous machine (PMSG) is used for wind power generation. The following diagram shows the layout of wind mill power generation model.

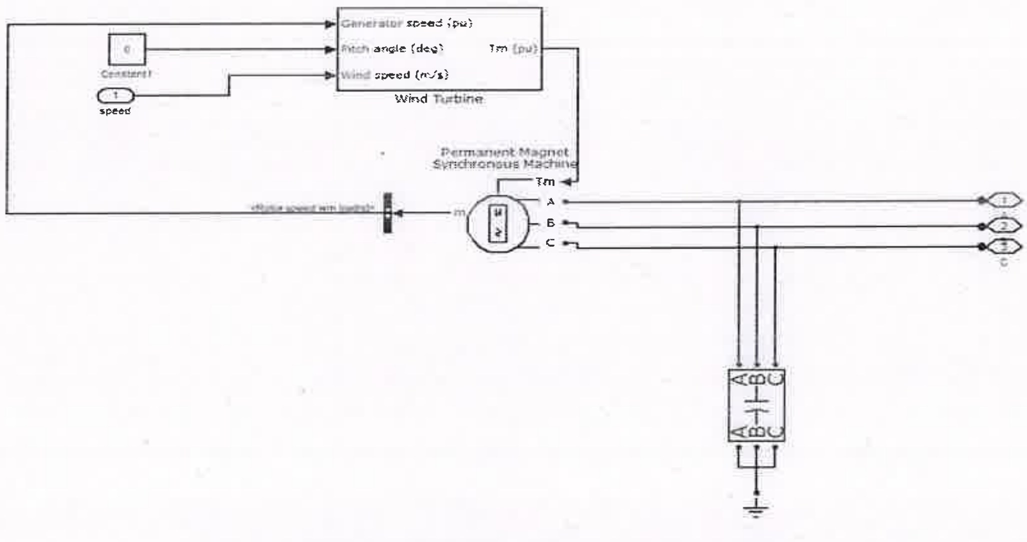


**Fig 4.6 Design of Wind Power Generation**

## Interleaved Boost Converter Design

This converter is non-isolated boost converter, which can level up DC voltage from 24 V DC input voltage to 230 V DC output voltage. This is adequate suitable in order to develop and apply with any dc output renewable energy source, such as PV generation system. The proposed converter has totally four modules of DC boost converter, which are connected in parallel. At the same purpose,

these switching devices are controlled by 90 Degree shifting to each other, due to an interleaving technique. This will leads to a smoother output dc current. Nevertheless, the High gain DC boost converter in this project was done by MATLAB / SIMULINK based Digital Signal Processing Board (here is TMS320F2812) implementation.

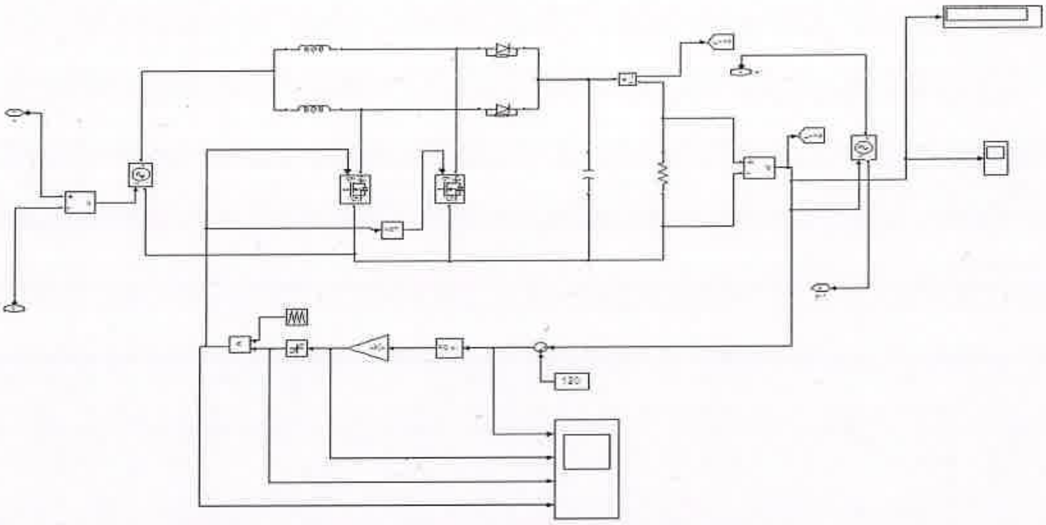

**Fig 4.6 Interleaved Boost Converter**

## Controller Model

The controller is used to continuously monitor various supply sources and the load conditions. The controller balances load according to supply conditions. The controller used is PIC IC 16F877A

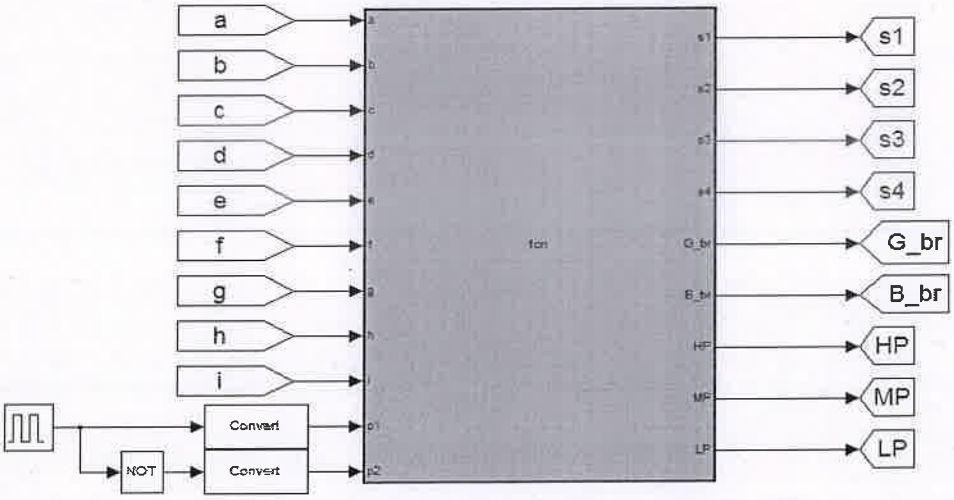


**Fig 4.8. Controller**

## Load Model

The constant power resistive loads are used. The loads are also marked with their priority number in the grid.


**Fig 4.9 Load**

## V. Simulation and Results

The designed model is simulated using MATLAB. The grid is provided with various supply sources like wind power, diesel generator, solar cells and a battery storage unit. 12 possible combinations of supply sources are simulated and the prioritized load balancing based on algorithm is found to run successfully.

Based on the availability of supply source and load priority, the loads are allocated. Under all cases, the high priority load is allowed to meet requirements while low priority loads are disconnected if sufficient supply is not available.

| Sl. No | Battery | E.b | Hybrid | High Priority Load | Medium Priority Load | Low Priority Load |
|---|---|---|---|---|---|---|
| 1 | Available (90-100%) | Available | Available(max power produced) | On , hybrid to hp load | On , hybrid to mp load | On , hybrid to lp load |
| 2 | Available (90-100%) | Not available | Available(max power produced) | On , hybrid to hp load | On , hybrid to mp load | On , hybrid to lp load |
| 3 | Battery (75-90%) | Not available | Available(max power produced) | On,hybrid to hp load + battery charging | On ,hybrid to mp load + battery charging | On ,hybrid to lp load + battery charging |
| 4 | Not available | Not available | Hybrid energy produced only 70% | On | On | Off |
| 6 | Not available | Available | Hybrid energy produced only 50% | On , eb to hp load + battery charging | On ,eb to mp load + battery charging | On ,hybrid to lp load + battery charging |
| 7 | Available (90-100%) | Available | Not available | On ,battery to hp load | On ,battery to mp load | On ,battery to lp load |
| 8 | Battery (75-90%) | Available | Not available | On , eb to hp load + battery charging | On ,eb to mp load + battery charging | On , eb to lp load + battery charging |
| 9 | Battery (75-90%) | Not available | Not available | On | On | Off |
| 10 | Battery (40-75%) | Not available | Not available | On | Off | Off |
| 11 | Battery (0-40%) | Available | Not available | On ,eb to mp load + battery charging | On ,eb to mp load + battery charging | On , on ,eb to mp load + battery charging |
| 12 | Not available | Not available | Not available | Off | Off | Off |

## VI. Conclusion

The MVDC microgrid comprises a diverse set of distributed energy and storage resources such as PV arrays, wind turbines, a fuel-cell stack, a battery energy storage system, and mobile diesel generators. This paper has presented technique to balance the load according to supply variations in a MVDC microgrid located at a remote site. The loads are prioritized based on their importance in

the firm and balancing in load is carried out in times of supply problems. By using this technique, the high priority load will always be connected and continuity is ensured. This improves reliability of service and also reduces cost to company.

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