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Design a Smart Active Filter for Solar Power System using V2G Technology

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Abstract*: The research introduces Vehicle to Grid (V2G) technologies for improving solar power quality by designing shunt active filters. A third-order battery model serves as the foundation for the presented dynamic PHEV model and complete system model which incorporates solar generation. The proposed power electronic interface enables a basic battery system to control both PHEV charging and discharging operations. The active filter controller derives its design from the p-q theory to correct the changing real and reactive power output from PHEVs thus improving wind power generation performance. Experimental evidence proves that electric vehicles linked to photovoltaic power generation systems provide filtering capabilities.*

Keywords*: Wind power, V2G, PHEVs, active filters, and battery schemes*

I. Introduction

Different forms of battery and hybrid electric power systems have experienced major developments during the recent period. The evolution of vehicles has made plug-in hybrid electrical vehicles (PHEVs) an attractive replacement for conventional automobiles while addressing energy security risks and financial costs and environmental matters despite increasing fossil fuel costs. About 25% of future PHEV vehicles align with future standards for battery plug-ins which will dominate auto construction by 2030 [3]. Studies evaluating solar energy continue to take place for implementing PHEV recharging systems. These vehicles enable charging through three possible methods which include charging stations and household electric connections and even parking lot power utilization during daytime periods.

The research project enables building an active filter system for photovoltaic generation by utilizing smart grid technology with the bidirectional charger. The photovoltaic energy system remains among the most environmentally friendly power-production systems available since it generates minimal pollution. The process of PV power generation depends on sunlight to create electricity without producing any waste matter and without generating sound or emitting air pollutants. The rise of photovoltaic energy collection reduces both our dependence on petroleum as well as our need for imported power generation.

Solar energy functions as an effective economic expansion engine. The global PV market reached its highest level at 7.3 GW because of a 20% growth compared to the previous year [4]. The generation of higher power losses in communication systems and power distribution networks and occasional electronic equipment malfunctions stems mainly from harmonics. Electric utility quality requires immediate attention due to harmonic phenomena generated by equipment installations [5].

Recent market conditions encourage this research to explore PHEV active technologies as harmonic filters linked with solar power while implementing PQ principles for control applications. The PHEV operates through its connection with a solar power system as shown in Figure 1.

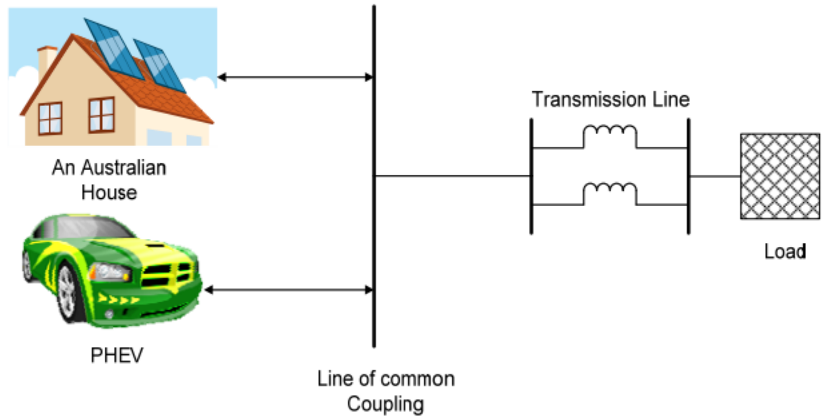

Fig 1: Infrastructure for integrating PHEVs with the electrical grid at an Australian home powered by solar

II. Model of PV Generator and Controller

An electrically equivalent circuit for a solar cell shows a current source connected in reverse with a diode structure displayed in Figure 2.

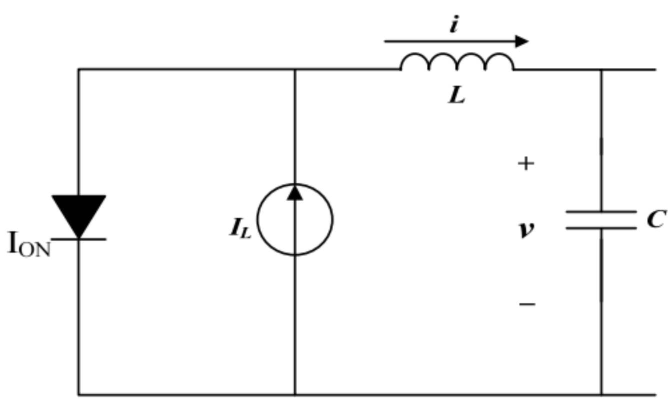

Fig 2: PV equivalent circuit

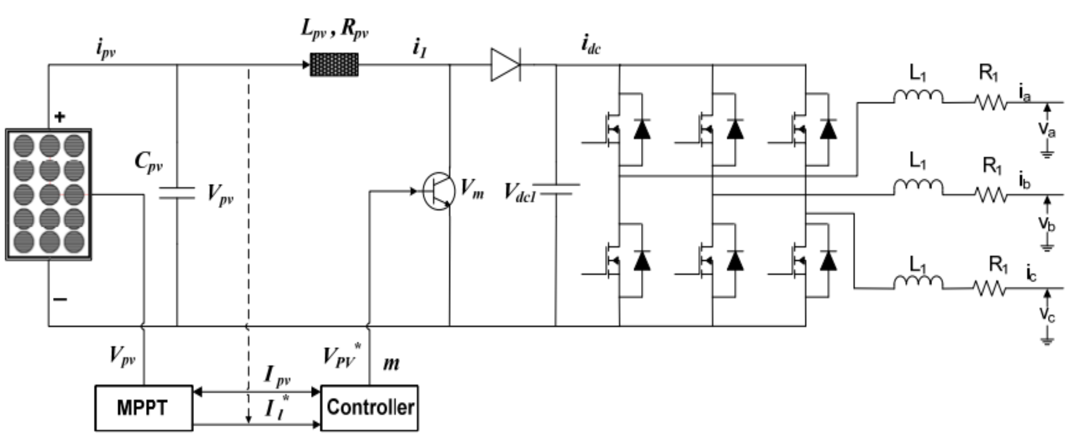

Fig 3: PV equvalent circuit

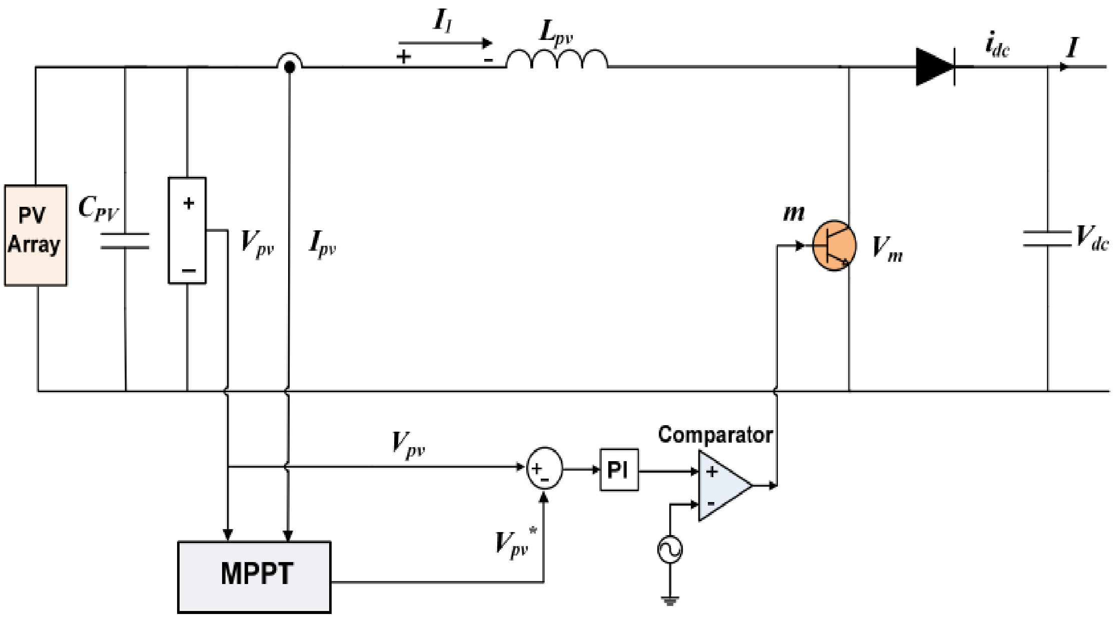

Fig 4: PV converter controller System

Temperature and radiation levels determine how PV energy draws current and produces voltage through a non-linear P-V characteristic. The energy output of PV cells depends heavily on MPP measurement because this variable changes when the air conditions alter. The cell achieves maximum power generation when operating at the knee point of its P-V curve according to Figures 3, 4, and 5.

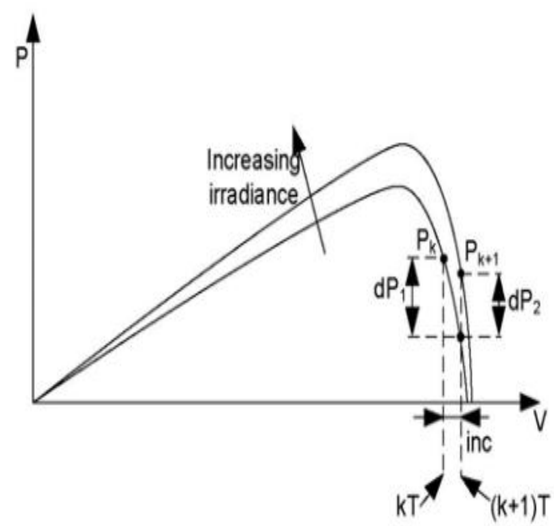

Fig 5: P-V characteristic curve of PV cell with MMPT

The P&O method shown in Figure 6 was chosen for this work through implementation in PSCAD due to its user-friendly operation and low computational need to find MPP [7]–[8].

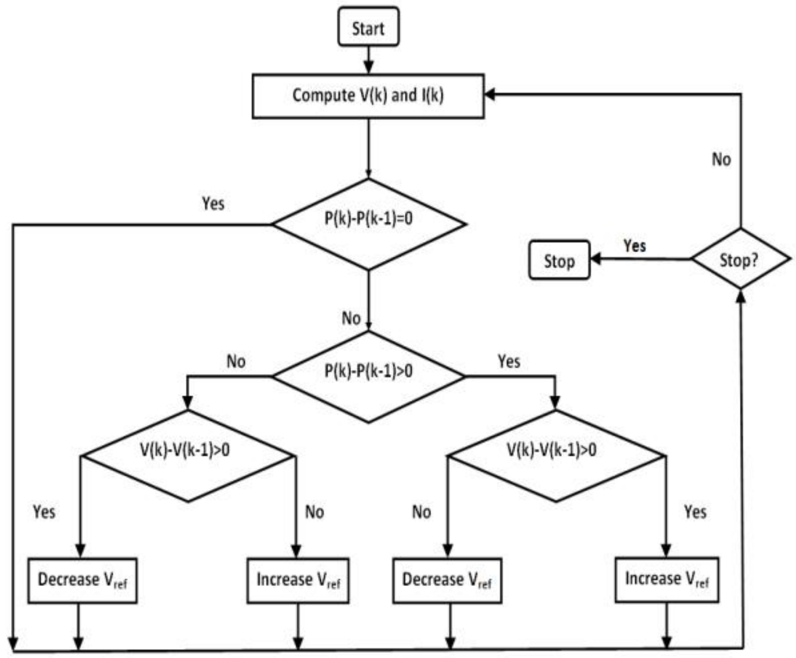

Fig 6: Flowchart of P & O method

III. Network Interfacing and PHEV Battery Modelling

A PHEV requires a dedicated electronic interface that enables its connection to electric distribution systems for battery recharging operations. The modeling process includes analysis of a charging system through electronic devices while studying the SOC and electrolyte temperature dynamic patterns of the battery system. Individuals operating vehicles in the United States use their cars to drive 25 miles per day in 50% of the vehicles on the road [9]. The evaluation of PHEV impacts includes a 40-mile daily driving range that determines a 12-kWh battery capacity when considering that each mile needs 0.3 kWh of battery power [10], [11].

A dynamic model of lead acid batteries from [12] was selected to develop the proper PHEV model because PHEV battery elements respond to state-of-charge (SOC) and electrolyte temperature. The battery equivalent network in Figure 7 represents the battery state-of-charge denoted as SOC while the electrolyte temperature is labeled as . The entire current I depends essentially on the component I_m

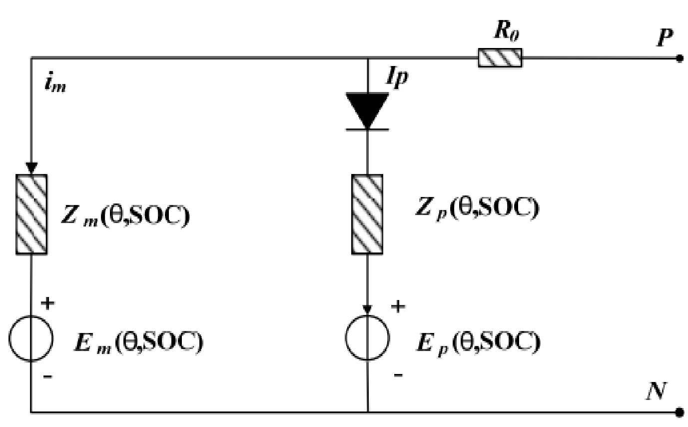

Fig 7: Battery equivalent network with parasitic branch

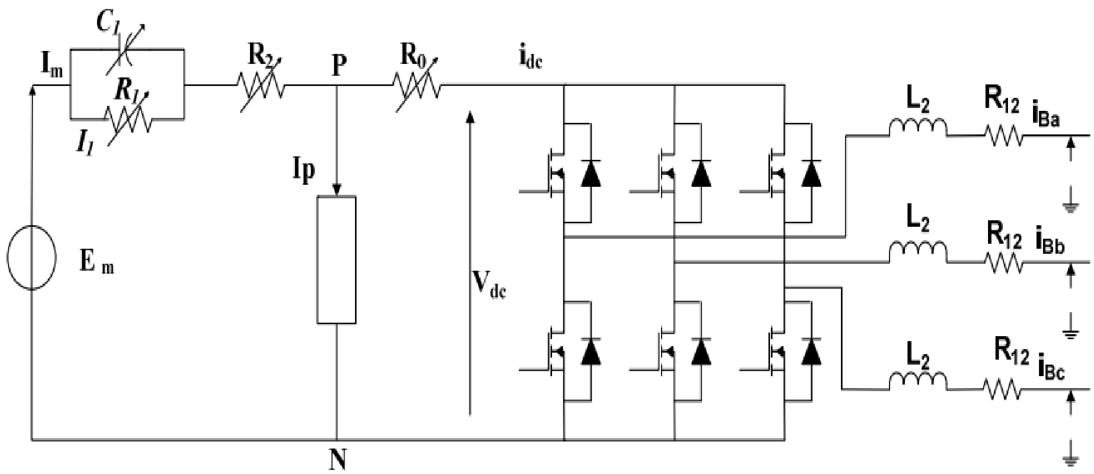

Fig 8: PHEVs connection with power system network

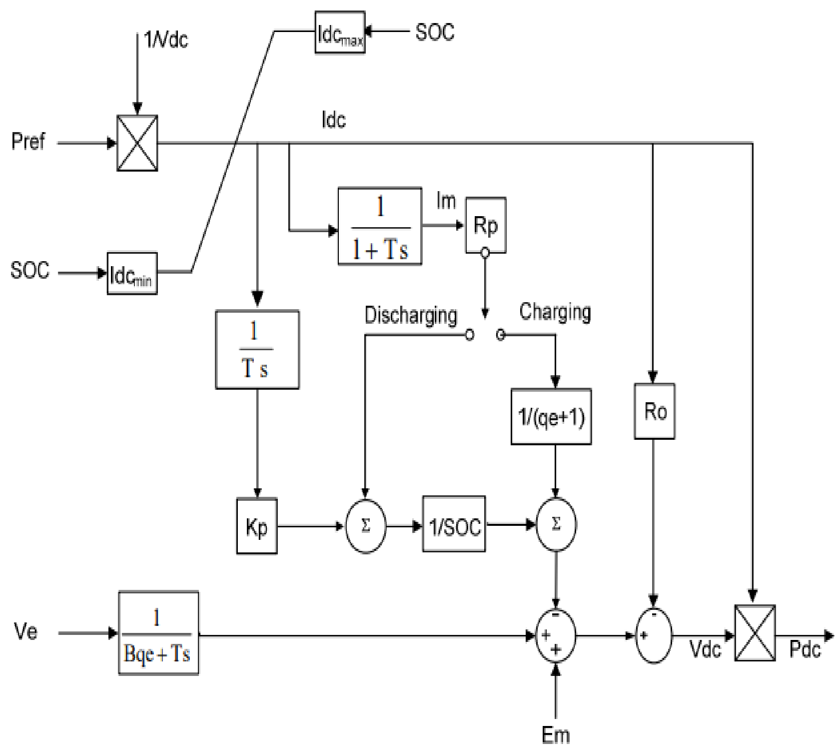

Fig 9: PHEVs battery scheme

IV. Controller Design

While designing the controller with P-Q theory this study excludes the neutral wire from calculations. The P-Q theory uses Clarke transformation to perform an algebraic conversion of three-phase voltages and currents from a-b-c coordinates to the α-β system. The dynamic equations which describe current behavior in α-β coordinates appear as shown in Figures 10 and 11 according to [16] and [17].

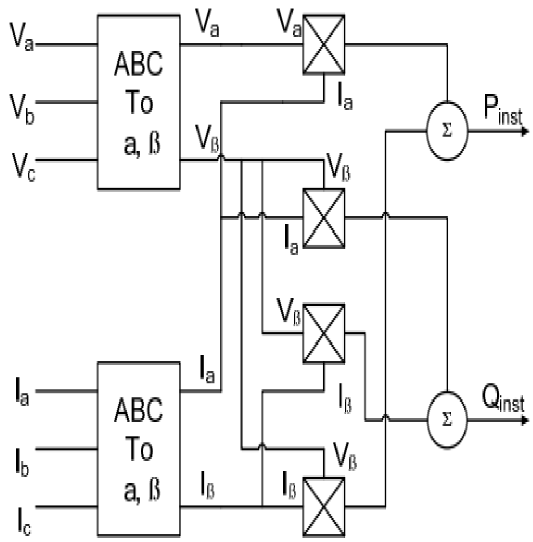

Fig 10: PQ generation in the controller

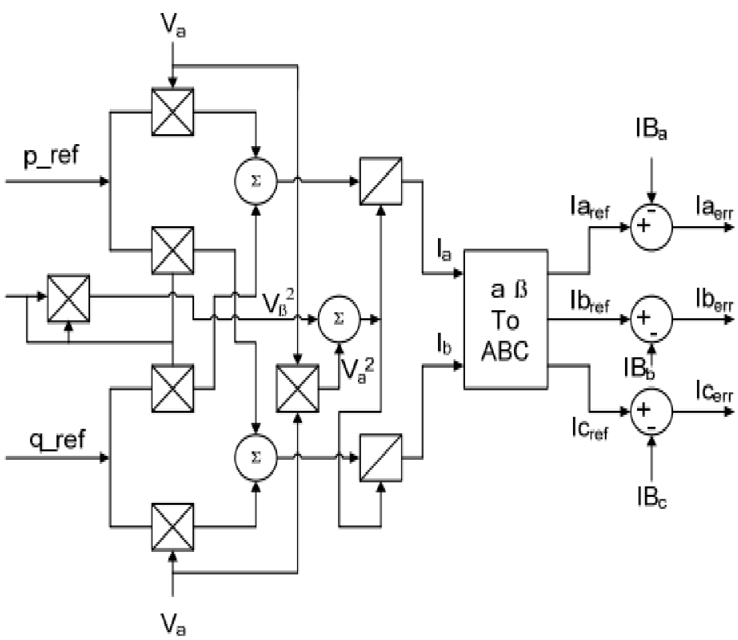

Fig 11: Signal generation for inverter switching

V. Simulation Results

The simulation results indicate PHEV operation as an active filter reduces the system harmonics together with load current harmonics (Figure 12 and Figure 13).

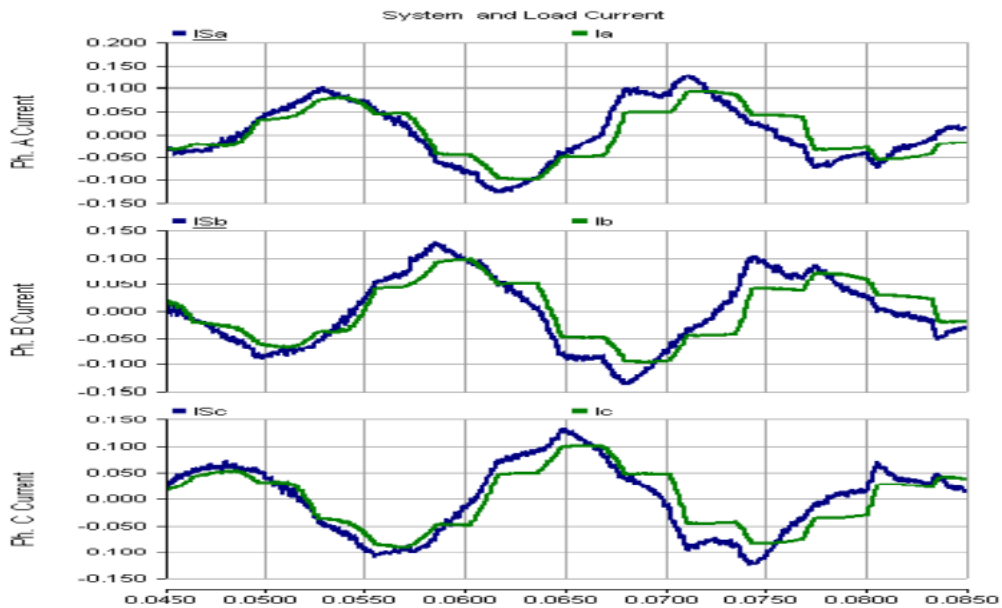

Fig 12: System and load current without filter

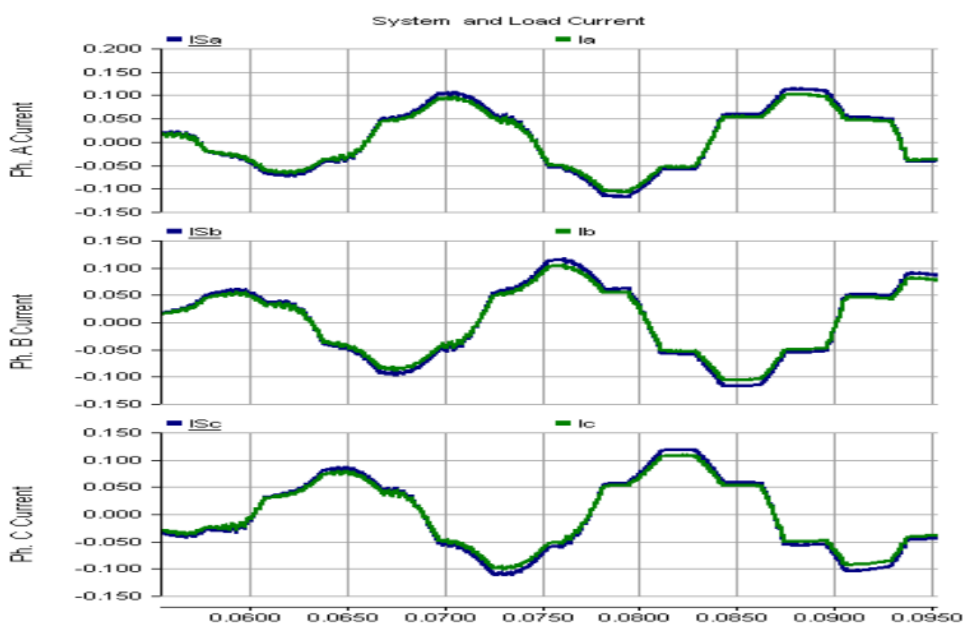

Fig 13: System and load current with filter

VI. Conclusion

The main topic of this work explores photovoltaic generator performance through active PHEV usage as a power quality enhancer. Researchers ran tests on system current and load current along with voltage from the load base conditions to when PHEVs operated as an active filter in the power system. Simulation outcomes revealed that implementing PHEVs operation as an active filter produced enhanced power quality performance. Extensive studies need development to determine V2G technology implementation approaches in solar power systems. Multiple issues affect the performance of the system including battery degradation alongside smart grid integration and grid-connected solar generation systems and autonomous solar power operation dependent on PHEVs and devices acting as active filters.

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