Fuzzy Logic Control Based Energy Management in Hybrid Microgrid System

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***Abstract* —Hybrid microgrids are attractive design that can be used for a variety of purposes, especially in stand-alone power generation systems like lighting, water pumping, etc. Energy management control will be required due to the variety of energy sources. The oversight of a hybrid Wind/Photovoltaic system with battery storage is discussed in this study. The proposed system's power balancing is based on an intelligent supervisor that uses fuzzy logic control. It enables the determination of the various operating processes of the hybrid energy system based on weather conditions. The research was conducted using Matlab/Simulink. The presented results demonstrate the viability of the proposed control system.**

***Keywords*— PV, wind, *B*attery, Fuzzy Logic controller (FLC), Hybrid Energy System, Hybrid microgrid (HMG), Energy management control (EMC).**

I. Introduction

Due to the numerous benefits of PV/Wind energy systems, they have received considerable attention [1]. The primary benefit of these systems is their capacity to supply uninterrupted power irrespective of load & weather conditions [2-5]. Different power management controls (PMC) have been suggested for various hybrid energy system architectures. Some are based on logical conditions, while others are based on intelligent algorithms. Particularly for isolated applications (remote control), the lathers are more appealing [6-9].

A number of studies on PMCs have been published in the literature. In general, management is generally predicated on power balance. Some authors have come up with different ways to control power management, such as fuzzy logic control[10], flatness-based control[11], frequency deviation control[12], and control with a microcontroller[13].Mathematical models that are well known are used to describe the different sources. FLC has been used in Maximum Power Point Tracking (MPPT) of solar system. It was also used to change the frequency [14-18] and control the amount of charger power going out to the batteries. FLC was also used to improve the accuracy of wind power predictions [19-21] and to control the voltage of a combined energy system (wind and batteries). Fuzzy Logic Control (FLC) is a flexible instrument with rules based on human knowledge and experience which can deal with unpredictable uncertainties. FLC can be used in hybrid energy systems with imprecise inputs, variables, and disturbances, especially if renewable energy sources supply electricity to variable and unpredictable demands[22]. Several studies have also addressed the use of FLC for hybrid energy system and storage battery energy management. According to a predetermined rule, FLC has been utilised to provide an appropriate power distribution between solar PV, wind, and storage batteries. In the research described in Ref. [23], an FLC was used to control the state of charge (SOC) of storage batteries in a HMG [24]. This was done to enhance the performance of a hybrid generating system that had a lesser energy capacity of storage batteries. Using a Fuzzy Logic Controller (FLC) for precise timing of source selection to power telecommunication loads and overall hybrid power system management is proposed. A fuzzy logic-based controller will be used to control the state of charge of the battery in the hybrid solar photovoltaic and wind power system that was built. Fuzzy based controller will be used to limit battery state of charge and charging/discharging power regardless of load and renewable source power.

This article demonstrates improved power management of a hybrid system with battery storage. Here, FLC is used as intelligent controller for power management. Compared to conventional state-based strategies, it is easier to resolve the various operating point of the HMG based on the atmospheric conditions. It maintains the condition of charge of the battery in order to avoid blackouts and prolong battery life. The model was developed using Matlab/Simulink.

II. System Configuration

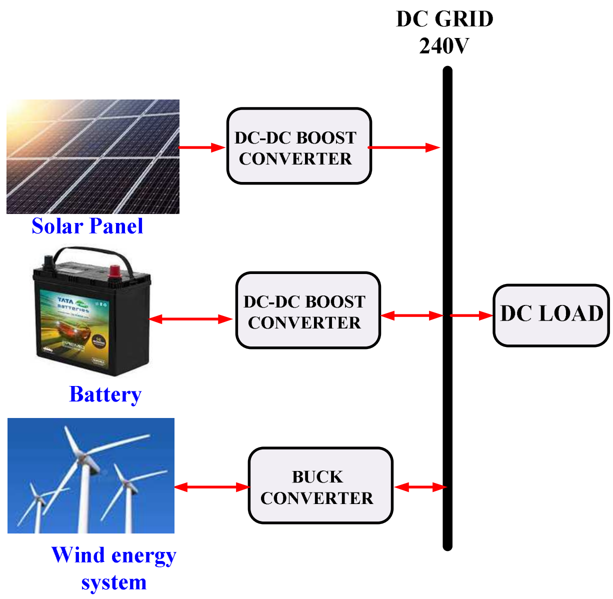


Figure 1. topology of HMG

Figure 1 depicts the structure of the HMG system under study in this article. Our research focuses on a hybrid energy system that consists of two renewables (solar and wind system), and a battery system. The investigated system is designed with a DC grid. The primary goal of proposed PMC based on fuzzy logic control is to satiate the load. The second goal is to regulate the SoC of the battery in order to avoid blackouts & increase the lifespan of the batteries, despite fluctuations in PV irradiance & wind speeds.

The analysed system setup is the DC bus-based architecture depicted in Figure 4. The prposed control scheme used is to make sure that the voltage sources for renewable energy are always the same as the voltage at the DC bus, even if solar irradiance and wind speed change.

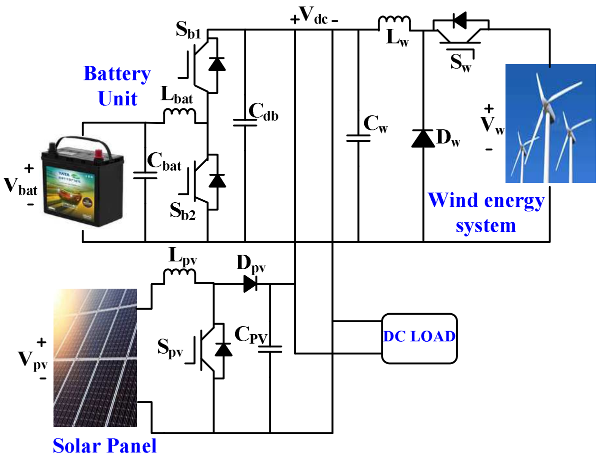


Figure 2. Detailed structure of HMG

III. Fuzzy Logic Control for Energy Management in a Hybrid System

The management approach for an autonomous, stand-alone HMG is to meet the load in different weather situations and control the flow of power while making sure the different energy systems work well. The main focus of the management plan should be to use the power from the PV & wind systems to meet the load needs.

The FLC works by making three control signals (k_{pv}, k_w) from two inputs: the amount of sunlight G, the speed of the wind V_{wind}, and the amount of charge in the battery SOC.

Where: k_{pv}, k_w: Control signal for the switch of the PV & wind generators respectively.

Table 1 illustrates the rule table for a fuzzy controller with fuzzy sets of SOC, G, and Vwind as inputs to the matrix. The two output, k_{pv}, k_w are displayed in this table. Table 2 illustrates the limits of parameters. Figure 3 represents the general design of the proposed HMG system with FLC based energy management scheme.

Table 1. Input/Output rules for Fuzzy controller

SoC	G	Vw	k_{pv}	k_w
Low(L)	L	L	off	on
	L	MD	off	on
	L	MX	off	on
	MD	L	off	on
	MD	MD	off	off
	MD	MX	on	off
	MX	L	off	on
	MX	MD	off	on
	MX	MX	on	off
Medium (MD)	L	L	off	on
	L	MD	off	on
	L	MX	off	on
	MD	L	off	on
	MD	MD	on	on
	MD	MX	off	on
	MX	L	on	off
	MX	MD	on	on
	MX	MX	on	on
Max(MX)	All G	All Vw	on	on

Table2. Limits for Fuzzy controller parameters

	L	MD	MX
G(W/m^2)	0-220	220-620	620-1000
Vw(m/s)	0-2.5	2.5-7	7-12
SoC(%)	0-25	25-75	75-100

There are a 4 modes obtainable by varying the (On/Off) states of the k_{pv}, k_w switches; these modes are represented by the following notation for the power delivered to the load:

$$P_{load}(t) + P_b(t) = P_{pv}(t) * k_{pv} + P_w(t) * k_w$$

Where: Pb>0: if battery is charged

Pb<0: if battery is discharged

Mode 1: The load is supplied by the two sources PV, Wind, via boost & buck converters respectively. The total energy has been enough to support the load, with the excess being used to charge batteries in this period.

Mode 2: If the energy from the PV is enough to charge the load, the PV does all of the work. Most of the time, this mode happens on a sunny day in the summer.

Mode 3: In this situation, the PV source may not be enough to give. The only source of energy is wind, which is the case when there is no sunlight in the winter or when there is a strong wind at night. So, in this situation, it is enough to get the load energy.

Mode 4: There are no sources or enough power to give.

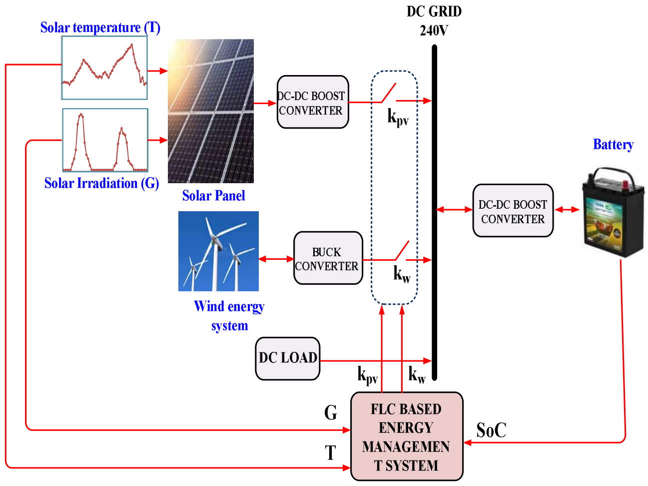


Figure 3. General design of the proposed HMG system

IV. Simulation Result

To evaluate the efficacy of the proposed EMC, it has been applied to HMG. The simulation results was conducted using Matlab/Simulink over the course of 48 hr.. Table 3 lists the various parameters of each subsystem employed.

Simulation studies have been conducted to verify the system's efficacy in a variety of circumstances. To check the robustness of the proposed method, the following profiles are selected: load power , solar irradiance, temperature for two distinct days.

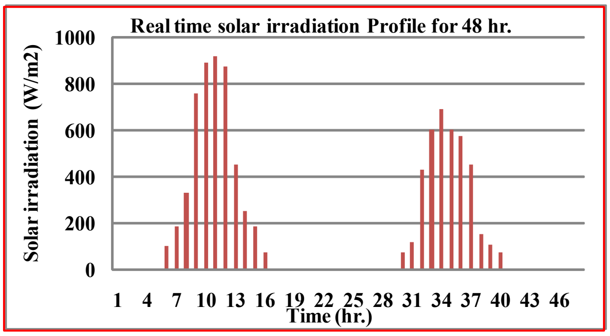
Table 3. Values of different parameters

PV system	**values**
PV power	11.3 kW
Solar irradiation	0~1000W/m2
Wind energy system	**values**
Wind power	5 kW
Wind speed	0~12 m/s

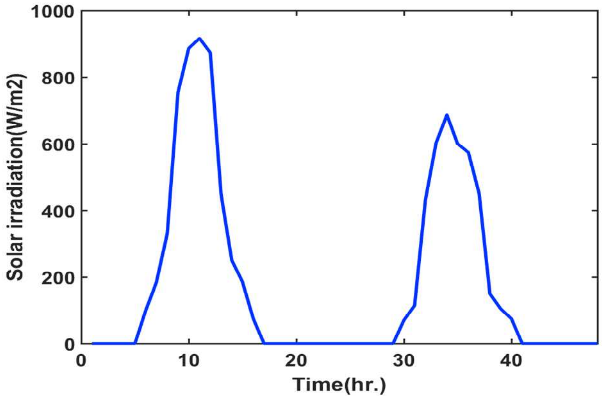
Radius of wind turbine	3.14 m
Battery energy system	**values**
capacity	48 Ah
DC grid voltage	**240V**

Case-1: (variation in solar irradiation)

In this case, solar irradiation is varied while the other parameters like load , solar temperature and wind speed are remain constant. Figure 4(a) & (b) depicts the real variation in solar irradiation in 48 hr. Figure 1(c) depicts the power distribution among different sources like (PV, wind), battery and load demand. Figure 4(d) depicts the voltage in dc bus which is constant at 240 V due to the proposed power mangement scheme. Figure 4(e), (f), (g) represents the SoC level, current & voltage of battery.



(a)



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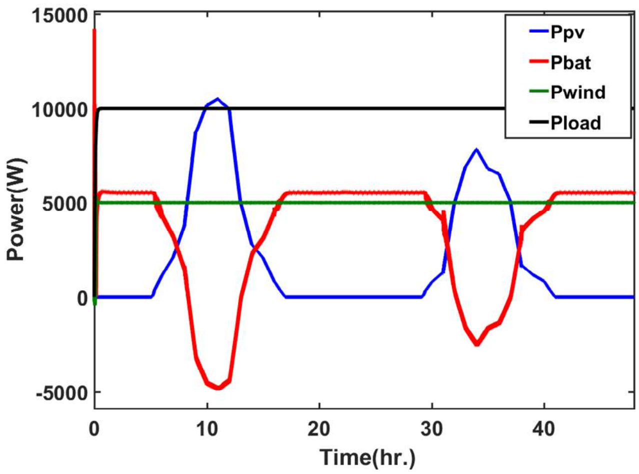
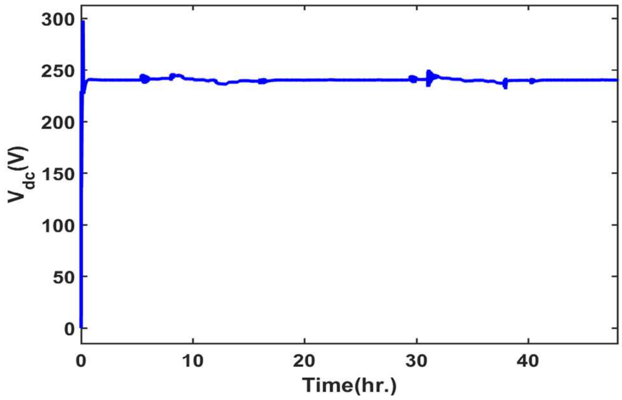
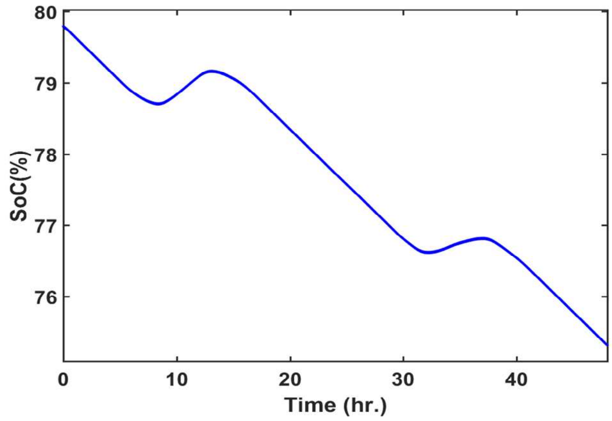


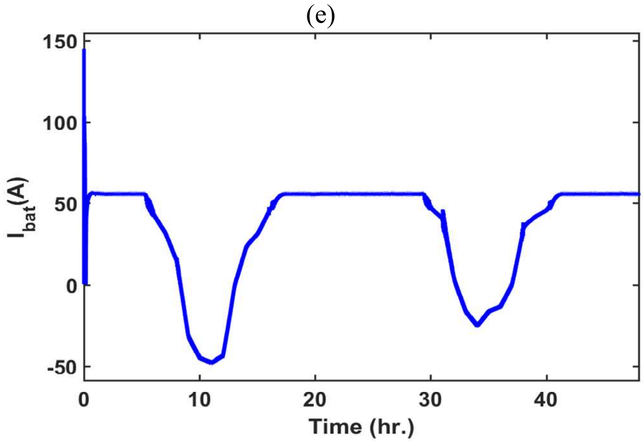
(c)



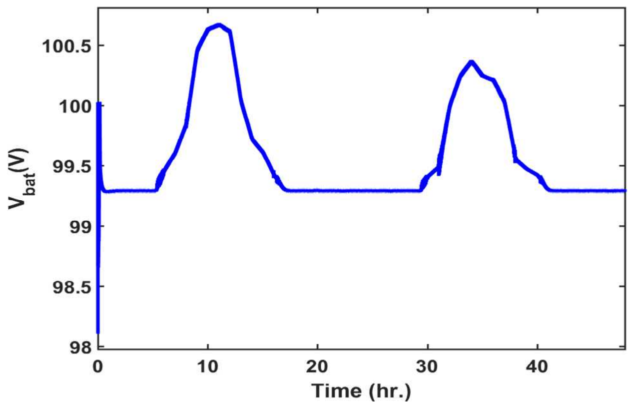
(d)



(e)



(f)

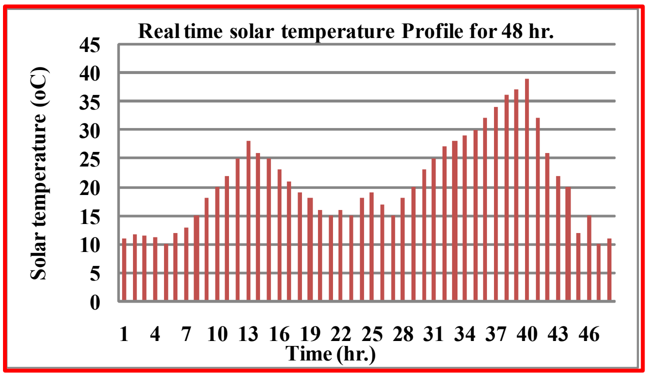


(g)

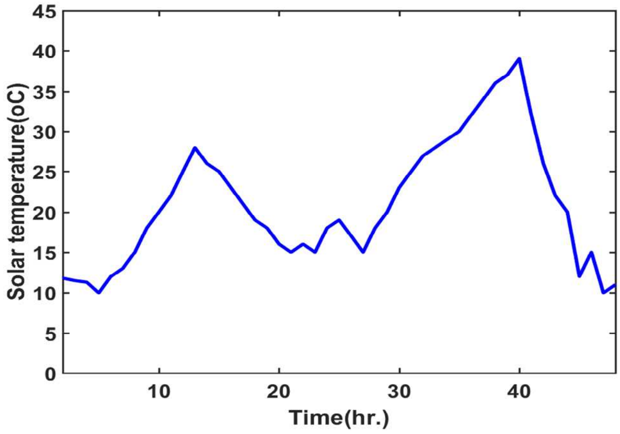
Figure 4 (a). real time variation of solar irradiation for two day (48 hr.) (b) simulation diagram of solar iiradiation (c) power distribution among different sources (d) voltage at dc bus (e) SoC value of battery (f) battery current (g) battery voltage

Case-2: (variation in solar temperature)

In this case, solar temperature is varied while the other parameters like load , solar irradiation and wind speed are remain constant. Figure 5(a) & (b) depicts the real variation in solar temperature in 48 hr. Figure 1(c) depicts the power distribution among different sources like (PV, wind), battery and load demand. Figure 5(d) depicts the voltage in dc bus which is constant at 240 V due to the proposed power mangement scheme. Figure 5(e), (f), (g) represents the SoC level, current & voltage of battery.



(a)



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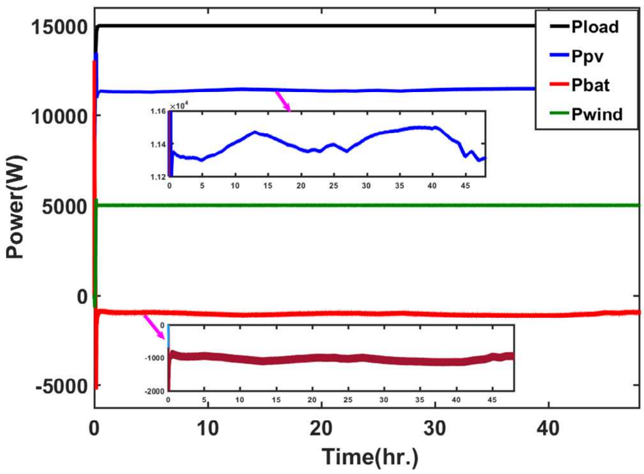
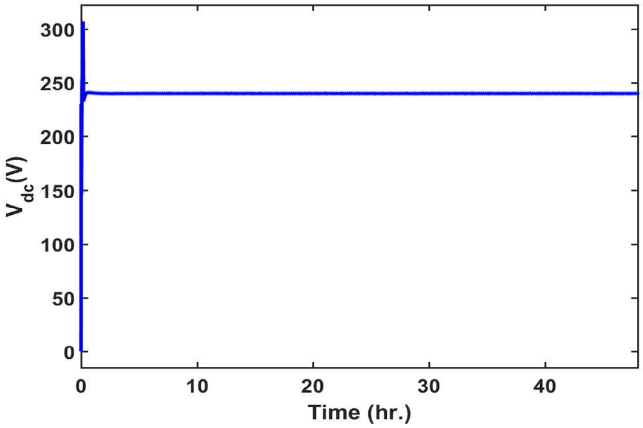


(c)



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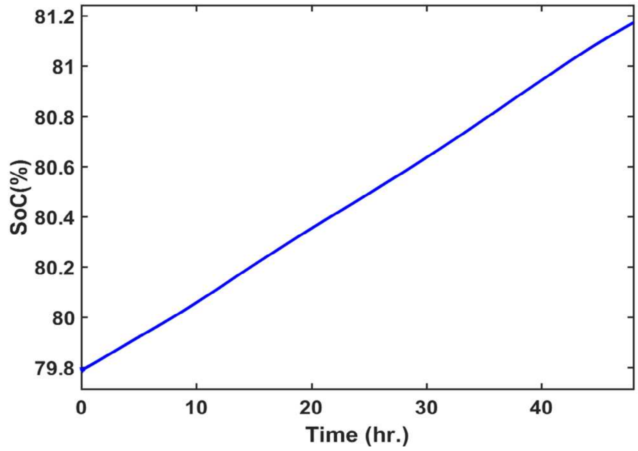
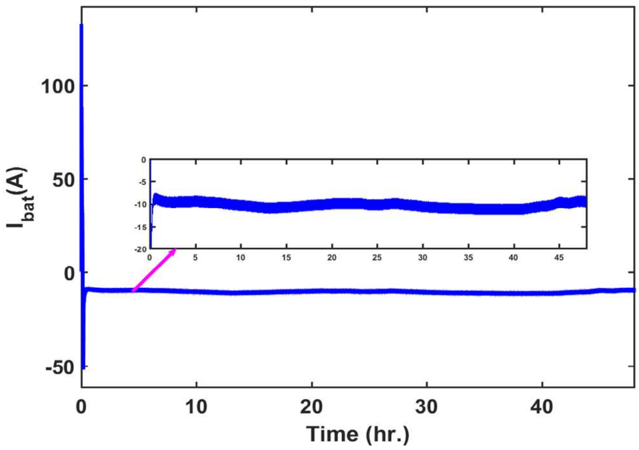
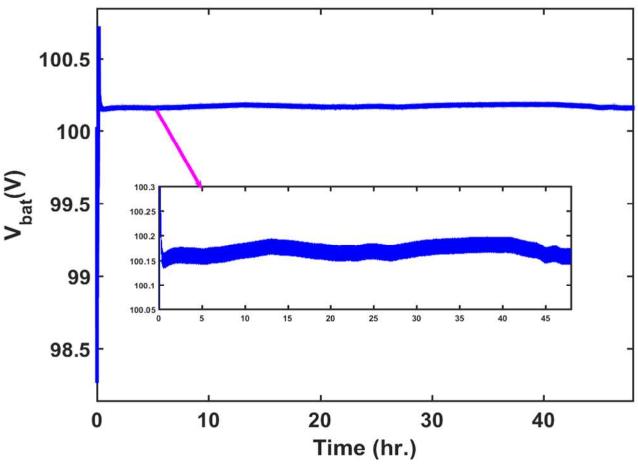


(e)



(f)



(g)

Figure 5 (a). real time variation of solar temperature for two day (48 hr.) (b) simulation diagram of solar temperature (c) power distribution among different sources (d) voltage at dc bus (e) SoC value of battery (f) battery current (g) battery voltage

V. Conclusion

This study proposes FLC-based HMG energy management with storage battery. The hybrid system is tested under variable solar irradiation and temperature which shows the system's robustness. The simulation results represents the efficacy of proposed energy management technique at different weather circumstances. It would be intriguing to realize the model in multiple areas, like electrification and water extraction.

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