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Modelling and Analysis of Microcontroller Based MPPT Method using FPGA

Maloth Naresh[1], T Manidhar[2], R Jagan[3], and G Pranay Kumar[4]

[1,2,3,4] **Guru Nanak Institute of Technology Hyderabad**

Department of Electrical and Electronics Engineering

[1]naresh219.m@gmail.com, [2]thulamanidhar@gmail.com, [2]jagan.gnit@gmail.com, and [4]pranaykumargajawada@gmail.com

Abstract. Now days, the renewable energy sources (RES) are the most accomplished system for power generation. In this paper, focus on FPGA based digital controller for the grid connected DG system. The study and performance analysis of grid-connected PV system as follows to improve the efficiency of the grid system and to extract the maximum power. This work is designed & development of FPGA. The DC power and battery capture on the DC bus system we have maintained the unity power factor and harmonics current in the DG system. The bi-directional battery systems also provide quick response & the performance under the variable DC voltage. Then, to develop the effectiveness control strategy is to manage the power flow equally AC & DC sides. This system simulated in MTTLAB Tools and FPGA System.

Keywords: DGR, PV, FPGA, MPPT and Battery

1. Introduction

In recent years, rising control and generation of power based on RES is one of the major sources. Scalable [1], it means low pollution at generating power. PV energy is freely available in adequate quantities which will never get exhausted. The power generation lowers priced renewable energy available today [2]. PV farms can be erected customer loads centres thus helping the economy in rural areas. Since the site of power generation is close to the consumers, the transmission costs and losses are reduced [3]. Power can be locally generated, controlled and monitored; it saves the expenditure on the fuels for running the gas or steam turbines. It doesn't cause any health hazards to the people [4]. In DGs are sustainable RES can be important of improve to the power generation and it's instantaneously reduce green pollution, in particularly greenhouse gases, due to effect on weather conditions [5]-[8].

The customer demands in standalone hybrid system, requirement, and extra generated power of the utility network, deficit between generation and demand can be met from the utility network [9]. Nowadays global major power demand is met by fossil fuels and nuclear power. In deregulated environment, DG has numerous advantages for utility such as prevention of transmission line capacity upgrade, peak load saving improved reliability, reduction in transmission lines and distribution losses etc [10-11]. The PV systems are depending on climatic conditions, time of sunlight hours & the amount of clouds [12]. In addition the battery energy system (BES) also provides taking on the remaining power to maximum power tracing (MPP) output [13]-[14]. And also, control mode exchanging of several converters interfacing in corresponding to the bus bar & the consistent changes can deliver over voltage & current [15]-[16]. The main benefits of the implemented MPPT method are low cost and good velocity [17]. A microcontroller-based battery charge controller with MPPT is designed for harvesting the maximum power available from the PV system [18]. The real-time identification need of this application requires an FPGA platform [19]-[20]. The sun tracking control scheme is based on a fuzzy logic control (FLC) algorithm [21].

The use of limited generators in distribution networks for the protection system. In this paper, using renewable energy sources interfaced with gird connected as well as the PCC in the distributed generation system (DGR) are discussed. The main challenges of the power generation and dynamic characteristic of DGs is control and demanding of stability its conventional power grid. The various grid disturbances get imposed on the DG interface. With increased DG penetration, various issues arise which must be taken care in order to protect the system.

2. Proposed and Implemented System

The Fig. 1 shows the complete block diagram of the proposed and developed system. The various sources like PV, battery and battery is connected in the system. The primary source of PV is solar energy system, which is freely available in nature and it has zero pollution. It operates only when sun is in shining conditions. Various other sustainable energy sources like wind, geothermal, waves, and biomass can be used for generation of electricity. The bidirectional battery is having used to controlling the charging and discharging condition. And finally we are connected to grid. The battery is provides the when system working a stand-alone mode, battery will charge along with load. The inductor and capacitor is have been used for charge and discharge purpose of battery. The PV system is generating the DC power it will converts the DC-AC power using power electronics converter (PEC) in system. The main methodology of the system based on FPGA capture the harvesting the maximum power available from the PV system. This method is very simple and easily implemented.

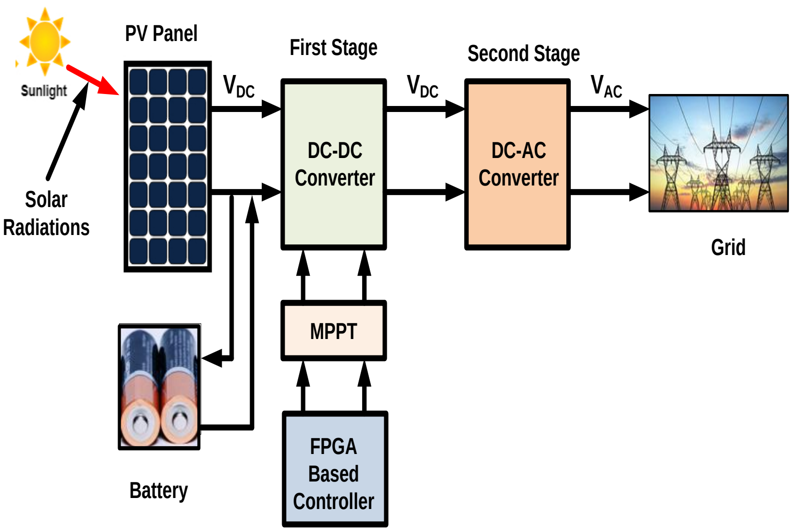

Figure. 1 Proposed System Block diagram

A. *PV cell/array modelling*

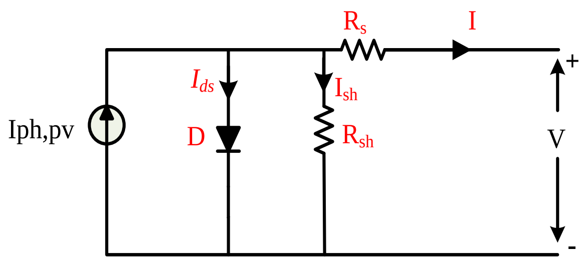

Figure 2 Equivalent Electrical circuit of Solar cell [15]

The electrical equivalent circuit as shown in Fig.2, using the PV, applying KCL net current I is the variance between the light current $I_{ph,pv}$ and a nonlinear diode current I_{ds}, and the current through shunt resistance I_{sh}, of the PV cell is given as bellow

Mathematical model of single diode equation is written as,

$$I = I_{ph,pv} - I_{ds} - I_{sh} \tag{1}$$

Where $I_{ph,pv}$ is PV current; I_{ds} is diode saturation current

$$I_{ph,pv} = \left(\frac{S}{S_{ref}}\right)\left[I_{ph,ref} + C_T(T - T_{ref})\right] \tag{2}$$

$$I_{ds} = I_{s,ref}\left(\frac{T}{T_{ref}}\right)^3 e^{\left[\frac{qEg}{\alpha k}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)\right]} \tag{3}$$

$$I = I_{phpv} - I_{ds}\left(e^{\frac{q}{\alpha kT}(V+IR_s)} - 1\right) - \frac{1}{R_{sh}}(V + IR_s) \tag{4}$$

Where $I_{ph,pv}$ is PV current; I_{ds} is diode saturation current; q is an electron charge (1.6x10^{-19}C); α is ideality factor of diode k, R_s & R_{sh} is series & parallel resistance of cell respectively, and where S is the PV insolation (W/m^2); T Cell temperature in °C, C_T is coefficient of temperature (A/K). At standard test diode saturation current is $I_{s,ref}$ and energy gap in semiconductor material is represented as E_g respectively.

B. *Modelling of Boost Converter*

The basic boost converter modeling of switching duty cycle main switch is ON or OFF [12].

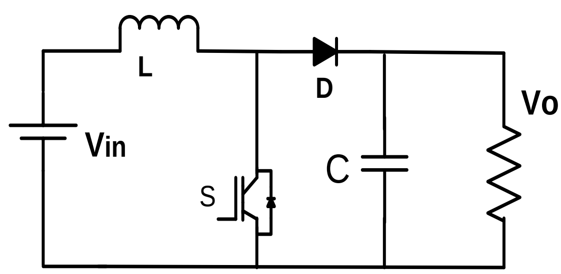

Figure 3 Boost Converters

When the switch is ON

$$\begin{cases} \dfrac{di_L}{dt} = \dfrac{1}{L}(V_{in}) \\ \dfrac{dv_o}{dt} = \dfrac{1}{C}(-\dfrac{v_o}{R}) \end{cases}, \quad 0 < t < dT \tag{5}$$

When switch is OFF

$$\begin{cases} \dfrac{di_L}{dt} = \dfrac{1}{L}(V_{in} - v_o) \\ \dfrac{dv_o}{dt} = \dfrac{1}{C}(i_L - \dfrac{v_o}{R}) \end{cases}, \quad dT < t < T \tag{6}$$

C. Bi-directional Battery System

To fulfil the peak load need, an additional energy source, for example, battery is fundamental as PV together are now and then lacking to flexibly the peak load. The aim of the battery energy system (BES) is too used for controlling the charging and discharging purpose. The battery system is stabilizing the charging and discharging of voltage, the dc bus can be stabilizing the constant value of battery voltage. The battery is provides the when system working a stand-alone mode, battery will charge along with load. The PV system is generating the DC power it will converts the DC-AC power using power electronics converter (PEC) in system.

3. Field Programmable Gate Array (FPGA)

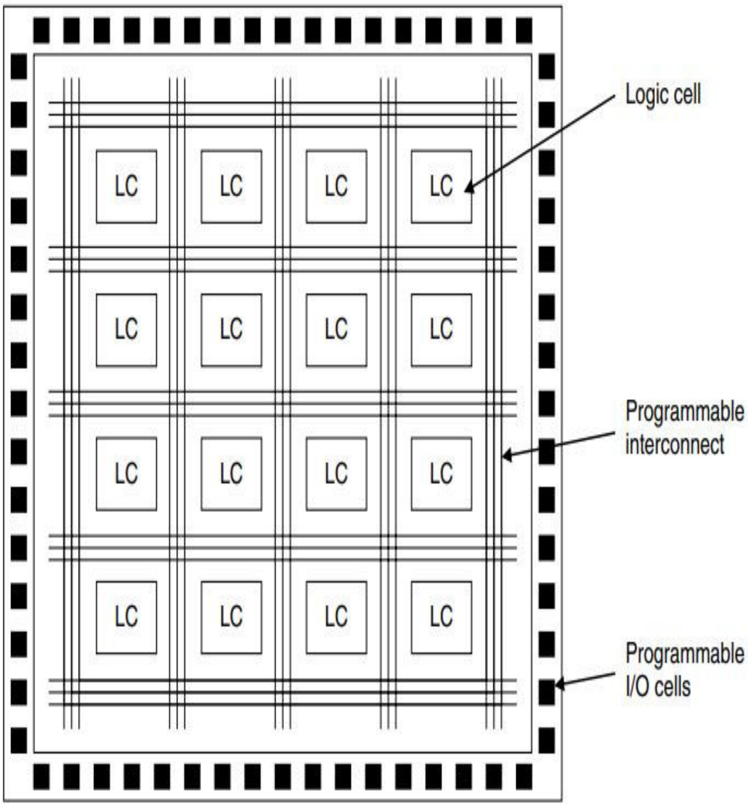

Figure.4 FPGA Block Diagram

The proposed system is design and developed by using FPGA Toll. This FPGA is basically using for design the controller part. The FPGA is providing the very fast responses compare to other controllers like DSP and Microcontroller, LabVIEW and such other existing controller. The basic structure FPGA system block diagram as shown in Fig 4

4. Simulation and Results

The study and performance Modelling and Simulation of Microcontroller Based MPPT Method using FPGA system is as shown in Fig. 1. The total system has been implemented in MATLAB/Simulink. The simulation parameters are exposed in Table I.

Table 1 Simulation Parameters

Parameters	Values
Reference Voltage	450 V
Grid voltage	220 V
Boost inductor value	1mH
Frequency	50 HZ
DC-link voltage	340 V
Boost capacitor value	6000 μ F
PV series Cells	8
PV Parallel Cells	12
Simulation Time	8 sec
FPGA simulation time	8 sec

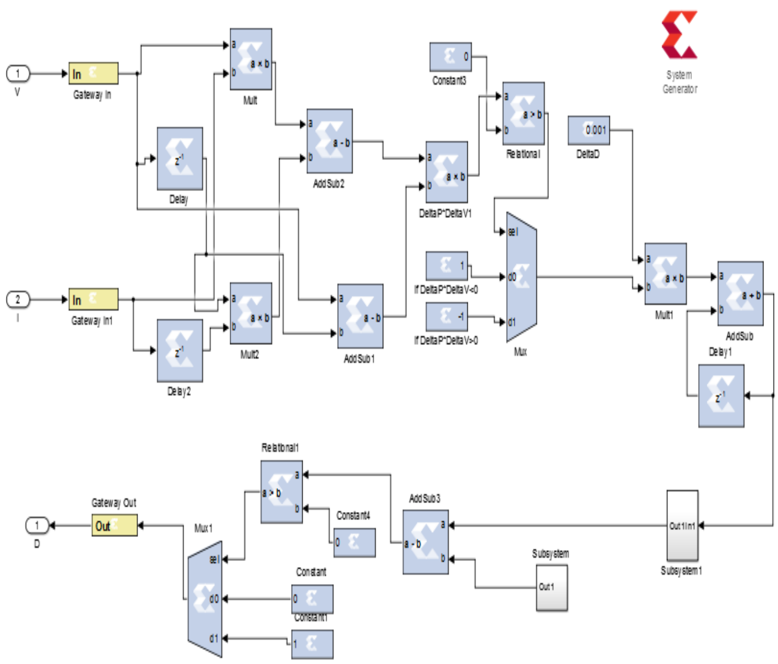

Figure 5.FPGA Based MPPT Controller simulation model

The Fig.5 is shows the FPGA based MPPT controller simulation program system. When we are doing the simulation I have observed that in the simulation when we are using FPGA system the responses are very fast and smooth. Here I have given three input signals.

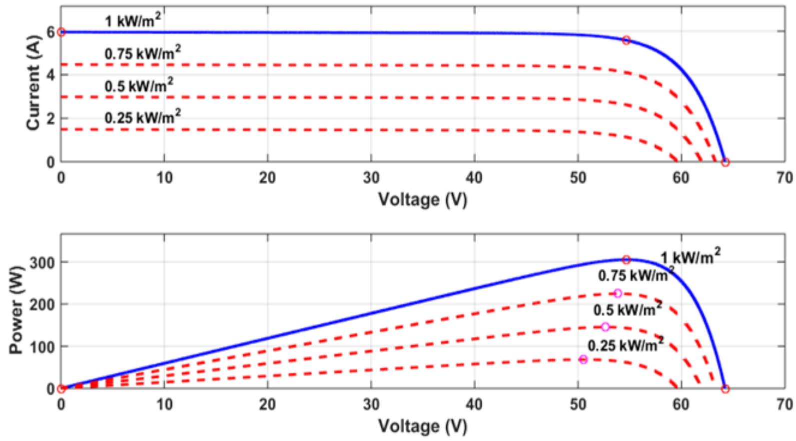

Figure 6 I-V and P-V Characteristics of one module at 25^{0}C

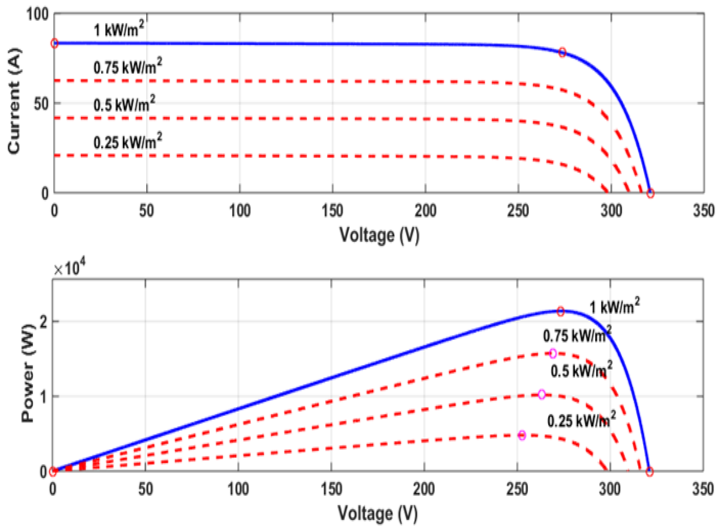

Figure 7 I-V and P-V Characteristics of array at 25^{0}C

Fig6 and Fig 7.a shows I-V and P-V Characteristics of one module at 25^{0}C and Figure 5-6 a shows the I-V and P-V Characteristics of array at 25^{0}C depends on the solar radiation. Figure 8 is shows irradiance levels that are incident on the surface of 80 W modules at constant temperature equal to 25°C.

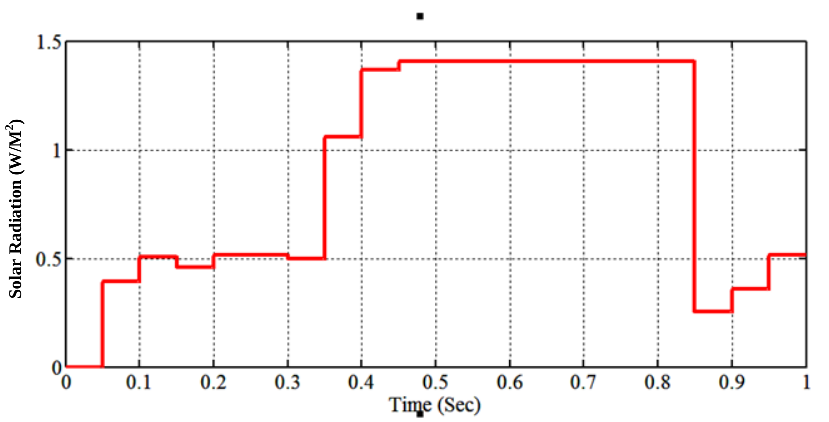

Figure 8 Solar irradiance levels

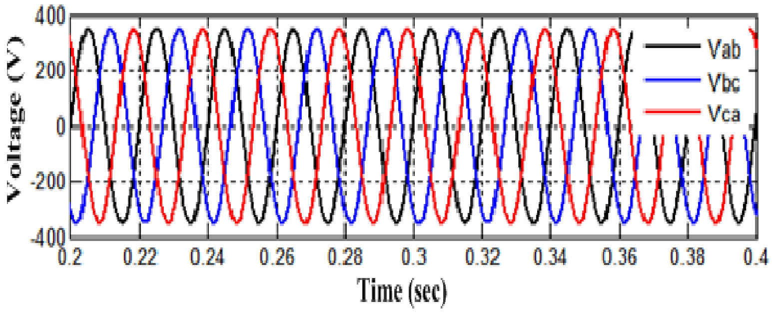

Figure 9 (a)

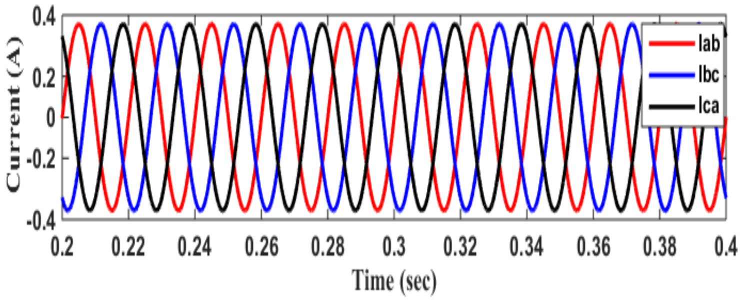

Figure 9 (a)

Figure 9 (a) Grid Voltage Waveforms and (b) Grid Current Waveforms

Fig.9 shows the 3-phase output current & voltage response at grid side. The peak value of voltage is 380 V and peak value of current is 0.3.7 A under grid connected mode

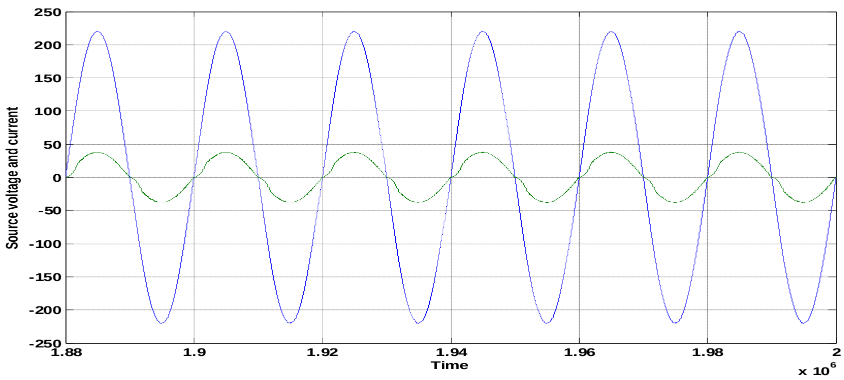

Figure 10 Source current and Source voltage

The above plot shows that the regulated output voltage is tracking the given reference voltage i.e, 450 V and the output ripple of the voltage is 1.21%. Figure 10 shows the plot of the Source current and Source voltage, from these plot it is observed that current is sinusoidal and in phase with the source voltage.

The PV voltage range of maximum power is between (15.66-17.6) V as indicted in Fig. 12. The MPP tracker will Increase the PV voltage up to (20-25) V on each power switch of inverter via DC/DC boost converter. Normally, the grid voltage has maximum amplitude voltage of 311+10%. The transformer turns ratio should be (1/18) to satisfy synchronism with utility grid.

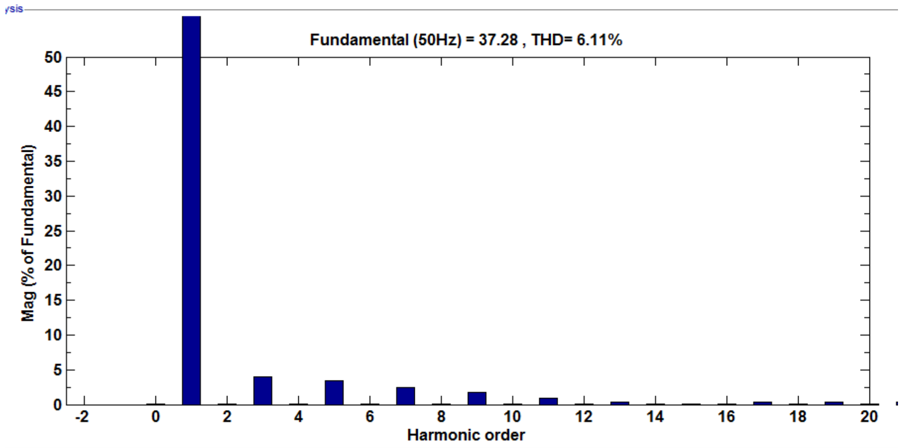

Figure 11 FFT analysis at rated load

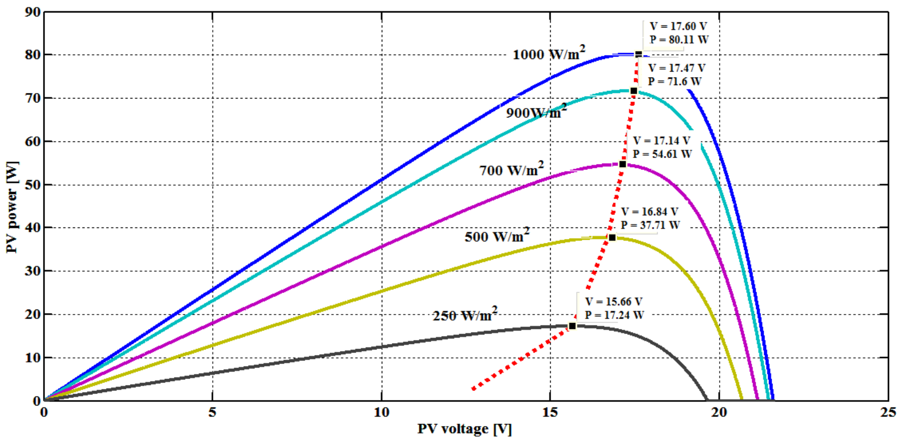

Figure 12 PV voltages at maximum power for different irradiance levels.

5. Conclusion

In this paper, study and performance analysis of grid-connected PV system as follows to improve the efficiency of the grid system and to extract the maximum power. This work is design & developed on FPGA system. The DC power and battery capture on DC bus system we have maintain the unity power factor and harmonics current in the DG system. The THD is below 5 %, to maintain the constant voltage. The FPGA control strategy has been used to manage the power flow both on the DC and AC sides. The battery system is gives fast reaction & upgrades the showing under the variance of wind turbine and improves the voltage stability of the system.

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