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RESEARCH ARTICLE

A REVIEW ON HYBRID SYSTEM AND ITS MATHEMATICAL DERIVATION WITH VALIDATION CHECKING

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ABSTRACT

In order to provide a reliable source of energy we have to think for some other sources of energy because the fossil fuel is limited and can last for another 50 years. The other source of energy must be clean and easily accessible to anywhere. The efficiency of the system can be increased by integrating the solar and wind to the grid. Harvesting the energy from these type of renewable sources of energy is nature dependent and hence are not reliable for the grid. However the integration of these sources with some storage devices can increase the reliability of the system to a great extent. The major problem associated with this type of system is the successful management of power control and its dispatch during the power swing. The quality of power decreases due to dynamic properties of both the hybrid system and that of the conventional system. The power quality of the system can be increased to a great extent with the use of some power electronic equipment like maximum power point tracking system in solar photovoltaic system and gear box in wind generator. This paper describes the strategic view of hybrid system and its economic analysis with conventional system.

INTRODUCTION

The demand for energy is increasing around the world from time to time. It becomes an in detachable property for human life. It is not only required for an individual but also required for industry and for other resources sector. Energy is basically extracted from either non- renewable sources or from renewable sources. All most all the energy demand is generally fulfilled by the non renewable energy sources like fossil fuel and from oils like diesel, petrol. According to a report about 81% of the world energy is supplied from fossil fuel where as 15% from renewable sources and the rest are supplied from the other types of sources. With the penetration of renewable energy sources the world is gradually moving towards a clean and sustainable environment. The renewable sources find its applications in almost all the sector like rural electricity from solar and wind, power generation in terms of standalone system and heating and cooling. The pollution produced from the burning of fossil fuel has knocked the global thinkers to think for an alternate source of energy. Harvesting the power from solar, wind and water energy is a clean and green source of energy. But they are not reliable sources of energy because of their unpredictability and weather dependency. Instead of these disadvantages it is best suited for grid interconnection and hybrid system of energy. The best design for a hybrid system is a solar photovoltaic system, a wind system and a fuel cell. Solar and wind together can be integrated to the grid and can act like a base load where during the absence of these sources the fuel cell can supply the required energy and can meet the demand. The battery or the storage device can store the charge and can utilize it whenever there is an requirement the surplus charge produced from the solar and wind system can be stored in the storage device. This hybrid system is best suitable for base load but for the peak load it becomes in effective. This type of hybrid design is not only cost effective but also energy efficient.

Table 1. Simulation Result

Time	Voltage	Current	Power
0	4.404	0	0
0.2	2.7167	2.1734	5.904476
0.4	1.4135	2.2616	3.196772
0.6	0.9516	2.2837	2.173169
0.8	0.7168	2.2939	1.644268
1	0.5749	2.2997	1.322098
1.2	0.4799	2.3035	1.10545
1.4	0.4118	2.3061	0.949652
1.6	0.3606	2.3081	0.832301
1.8	0.3208	2.3096	0.74092
2	0.2888	2.3108	0.667359

The demand for green energy is increasing worldwide because of its various advantages and eco friendly property. The solar photovoltaic and wind energy are the greatest resources for green energy. Although the solar and wind system has many advantages but it suffers from many problems such as economic dispatch between the various loads and the control strategies for its successful operation. The instability in the operation caused due to mismatch of power level or because of the dynamic characteristic of the hybrid system to that of the

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power grid system. Sometimes the instability produced by this type of system is much more severe than that of the conventional system. Power quality of the system is also affected by the system disturbances. Hence a detail strategy of managing the power flow is a great challenge. According to a report more than 33 percent of the world population are living in remote areas which are not connected to the grid power supply. For them the solar and wind based hybrid system acts like a standalone system. So from this the hybrid system has a great opportunities of market value which can increase both the economic and GDP value for any country.

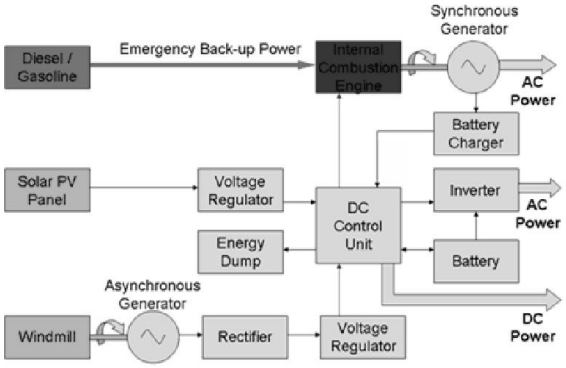

Fig. 1. Hybrid Model

Energy from the solar photovoltaic is best suited in terms of its operation throughout the year while harvesting the wind energy is most suitable for those areas which are located near the sea. In a grid interactive system the system utilizes the produced energy for its own requirement and supplies the surplus energy directly into the grid system. Similarly during the time interval when this system fails to produce required amount of output the hybrid system draws the power from the grid and can meet the load demand. This type of system avoids the use of extra cost of storage device and hence economically beneficial to the hybrid system owner.

Sources for Hybrid System

Solar Energy

Solar energy is generally generated from the sun. It is regarded as if a non reducible source of energy. Solar energy can be utilized in different ways like it can be directly used for heating the water through solar water heater or can be trapped by solar photovoltaic cell so as to produce electricity. The solar collector which is used to convert the solar energy directly into electricity is of flat plate type, or focusing collectors. Most of these cells are prepared from silicon type material. Initially when it was first discovered its efficiency was found to be very small whereas after technical growth now these are readily used for hybrid grid connected system. The current efficiency of solar photovoltaic cell is generally 25-30percent which is not industry fit. So extract maximum amount of energy from solar cell some power electronic equipments are used in its vicinity like maximum power point tracking system. It is actually a buck-boost converter which always tries to drive the operating point at the maximum power only.

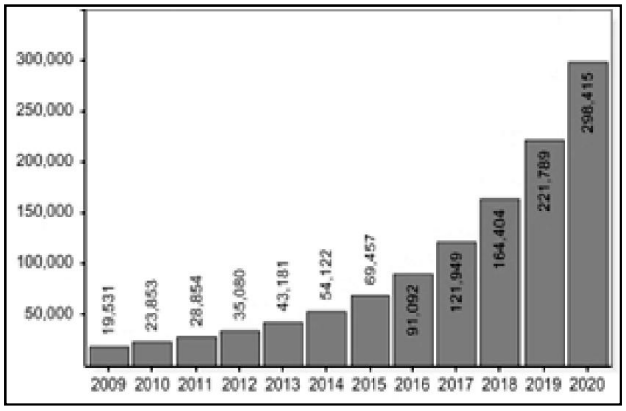

Fig. 2. Global Solar Photovoltaic Growth

After the year 2000 there is a rapid growth in the demand of solar photovoltaic. Average annual growth of solar photovoltaic system is 5-7 percent worldwide. This is because of decrease in the cost of solar cell, the government incentives and promotion motivation to install the photovoltaic system in order to create a clean and green system. Another point to this context can be added like the cost of fossil fuel is increasing day by day because of its scarcity where as the cost of solar cell is decreasing because of technological development.

Wind Energy

Wind is regarded as a great source of energy for many years. After 1973 the ever biggest oil crises government has promoted many researcher to design an efficient system which can extract energy from wind. The wind turbine is a device which simply transfers the wind kinetic energy into mechanical energy and finally the mechanical energy is converted into electrical energy. The generated electrical energy is not just a function of kinetic energy but also it is a function of both kinetic energy and wind speed. Depending upon the wind speed different types of system are there like ranging from few watts to several mega watts.

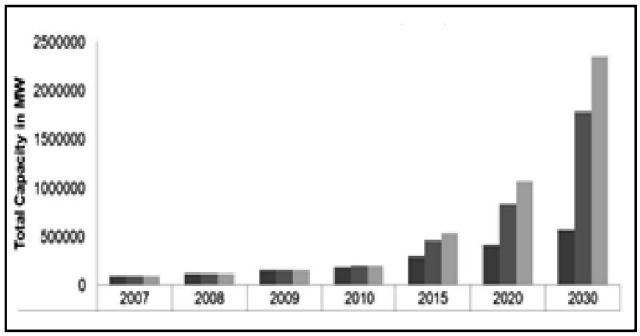

Fig. 2. Global Wind Power Generation Growth

Mathematical Modelling of Solar Photovoltaic Model

The main difference between one diode model and two diode model is that the number of parameters to be taken into account for modelling the solar photovoltaic system. According to the model the current can be found out with the following equation

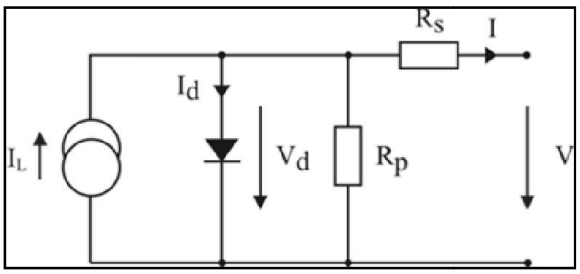

Fig. 3. One Diode Model

$$I = Is\left(e^{\frac{Vd}{nVt}} - 1\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

And $V_t = \frac{KT}{q}$ $\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$

Where,

I=Diode current
I_s= Reverse bias saturation current
V_d=Voltage across Diode
V_t=Thermally generated voltage of the solar cell
n= Ideality factor/Emission Coefficient
k=Boltzman constant
T=Temperature of p-n junction
q=Charge of an electron, 1.602 X 10^{-19}C

The 'n' determines the charge recombination across the depletion layer. The more the recombination the more the n value and hence the more in the short circuit current. The value for thermally generated voltage is generally 25.84mv at STC. Under reverse bias condition the recombination process is almost negligible or very less hence the exponential term is zero. With zero in exponential term the total current becomes equal to the negative of short circuit current i.e. I=-I_S. If the solar insolation is very small then it is similar to a very small forward bias voltage under that condition the exponential component is very large as compared to one. So the current equation under a very small forward voltage becomes

$$I = Is\left(e^{\frac{Vd}{nVt}}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The more simplified form of current equation generated by solar cell becomes (Tulpule *et al.,* 2011)

$$I = Ig - Is\left(e^{\frac{q}{KbFTc}(V+IRs)} - 1\right) - \frac{V+IRs}{Rp} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where

Tc=Cell absolute temperature
R_S=Series resistance of the cell
R_P=Parallel resistance of the cell
I_g= Photo generated current of the cell

The resistance of the solar photovoltaic system is because of the contact point where the external lead is connected into the system. More the thick of the contact point or junction more is the series resistance of the system. The photo generated current is basically depends upon the amount of solar insolation. So the equation for photo generated current can be written as

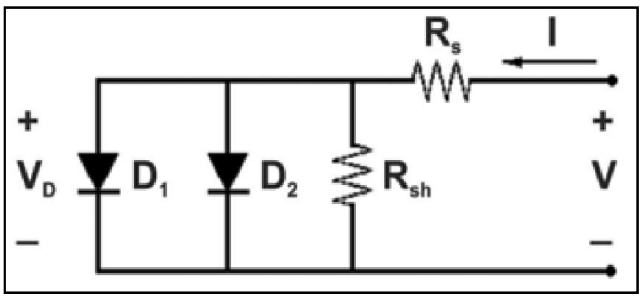

Fig. 4. Two Diode model

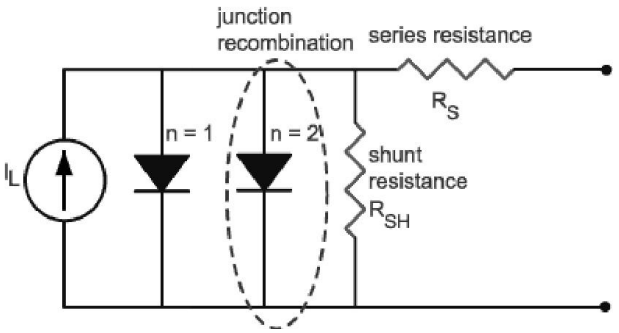

Fig.5. Recombination Process across the junction

$$Ig = [\mu sc(Tc - Tr) + Isc]G \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where
I_g=Photo generated current of the system
I_{SC}=Short circuit Current
μsc= Temperature coefficient of the cell
G= Solar radiation of the system
Cell saturation current

$$Ids = Io\alpha\left(\frac{Tc}{Tr}\right)^3 e^{\left(\frac{qVg}{KbF}\left(\frac{1}{Tr} - \frac{1}{Tc}\right)\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

and

$$Io\alpha = \frac{Isc}{e^{\left(\frac{qVoc}{KbFTc}\right)} - 1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where

$I_{o\alpha}$=reverse saturation current of the cell
V_g=Band gap of the cell

The net power output from a system is depend on the weather or the region where it is installed. Therefore the power output can be calculated by multiplying the regional factor with that of the capacity of solar cell.

Simulation and Validation Checking

The one diode model characteristics can be verified by using matlab simulation. The design module is free from maximum power point tracking system. The main objective of the simulation is to design a masking model and to verify the one diode model.

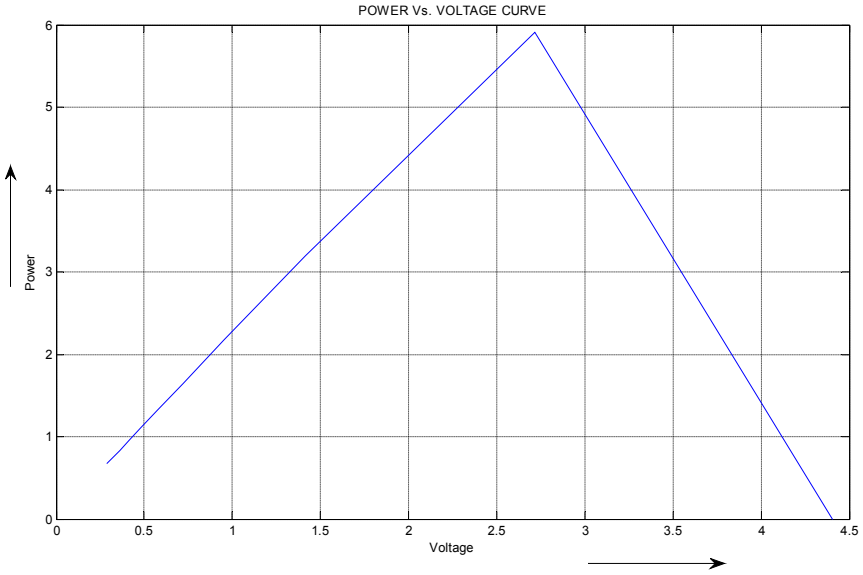

Fig. 9. Power Vs. Voltage Curve

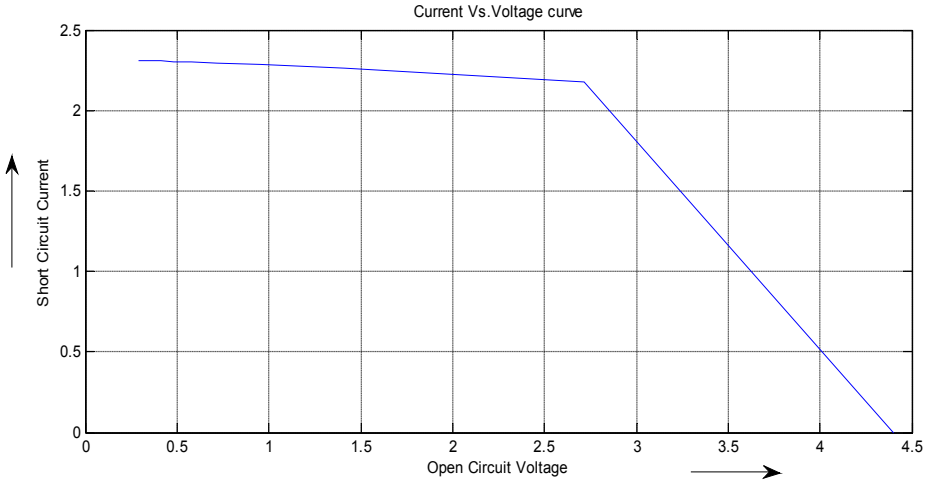

Fig. 10. Current Vs. Voltage Curve

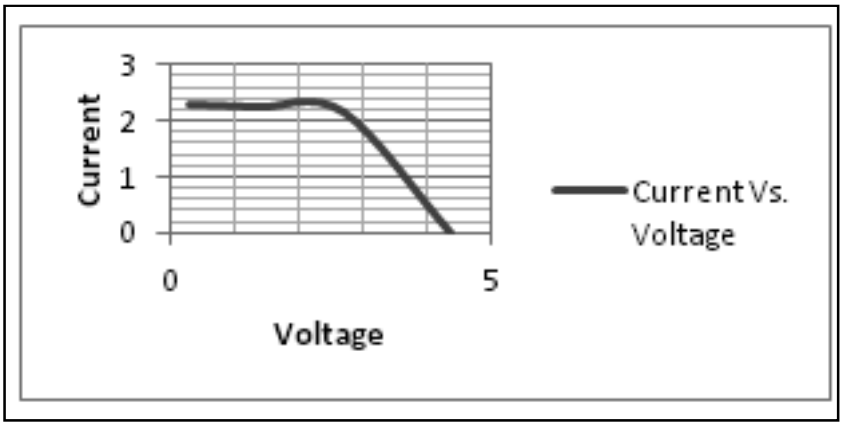

Fig. 11. Current Vs. Voltage Curve

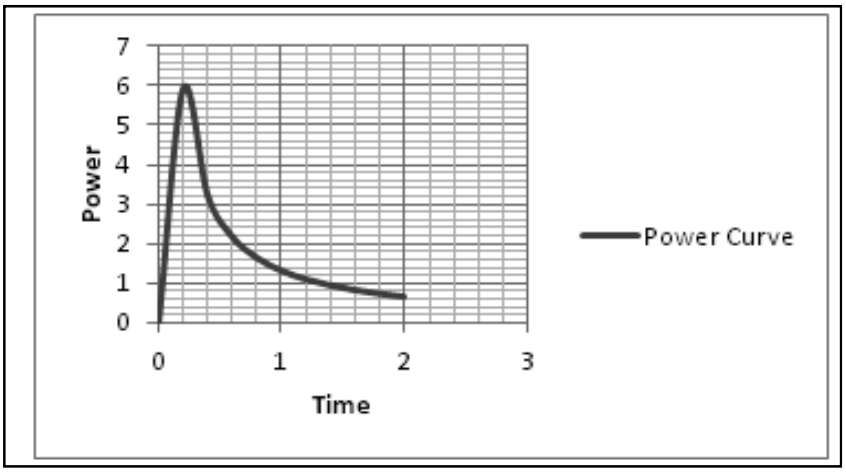

Fig. 12. Power Vs. Time Curve

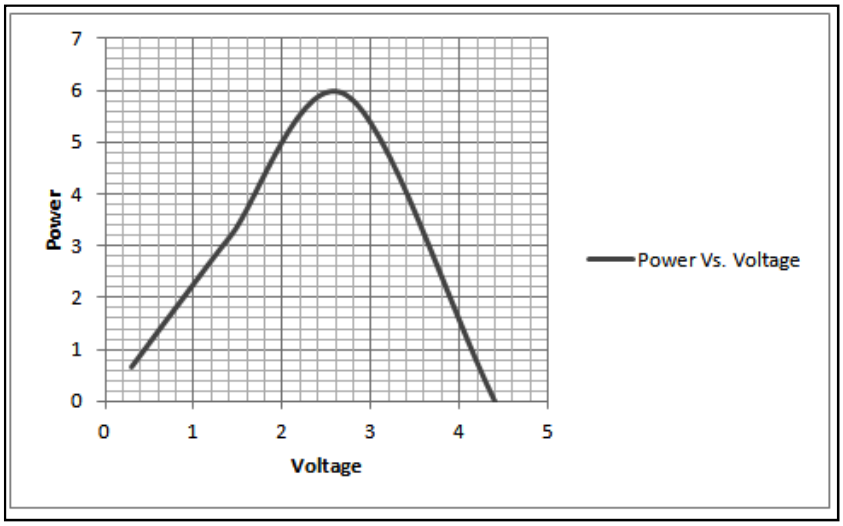

Fig. 13. Power Vs. Voltage Curve

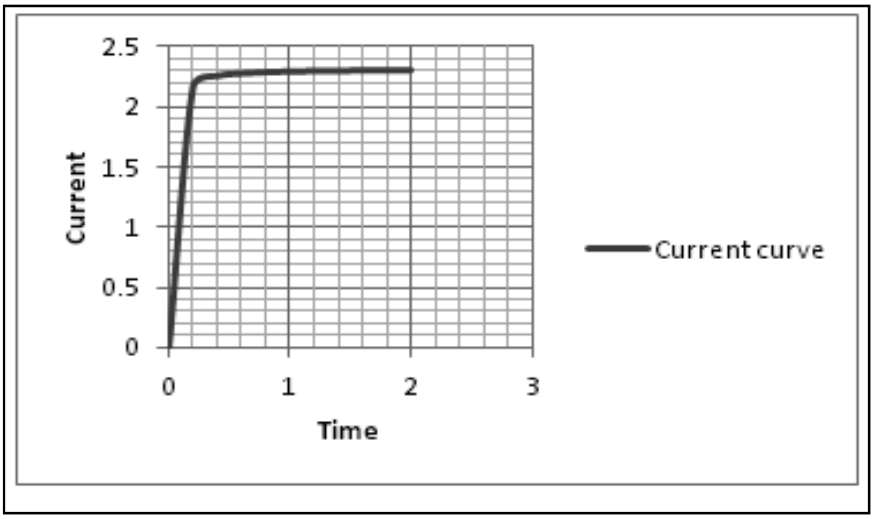

Fig. 14. Current Vs. Time Curve

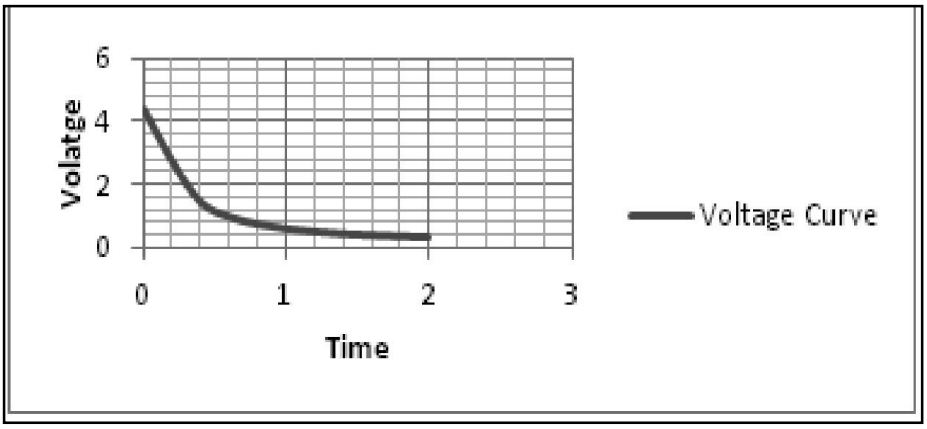

Fig. 15. Voltage vs. Time

The designed solar system is a 72 Watt system having open circuit voltage of 2V each. The cell parameters are reflected on the output characteristics of the system.The solar radiation for the system is set to 1000watt/m^2 i.e. at atc and the operating temperature is about 300K. As the temperature increases the short circuit current is also increased and similarly if the solar irradiance increases and hence short circuit is also increased. The open circuit voltage has a logarithimic function with respect to solar irradiance and hence shows logarithimic decrement or exponential decrement. The slope of the curve depends on the series resistance of the system. More the series resistance less is the slope. Higher ideality factor softness the knee point of the system.

Conclusion

The main objective of the paper is to design and simulate the solar cell or panel with respect to the derived mathematical equation. The electrical characteristic is derived from the output curve. The model can be further designed by incorporating a MPPT and can be connected to grid so as to increase the reliability of the system and hence the efficiency of the system can be increased.

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