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IMPROVE TRANSIENT STABILITY OF TRANSMISSION LINE USING UPFC

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Abstract: **Fast progression in field of power electronics has already started influence of the power industry. So Flexible AC transmission system (FACTS) devices provide fast control of active and reactive power through a transmission Line. In this paper transient stability will improving by using UPFC. The Unified power flow controller is a member of FACTS family with very attractive features. This is the combination of the properties of STATIC Synchronous compensator (STAT com) and Static synchronous series compensator (SSSC). Here we have been developed two simulation model of single machine infinite bus (SMIB) system i.e. With or without UPFC. These simulation has been incorporated into MATLAB based Power system Toolbox (PST) for their transient stability analysis. This models has been analysed for transient fault at different locations, i.e. At the middle and receiving end of the transmission line keeping the location of UPFC fixed at the receiving end of the line. Transient stability has been analysed with the help of curves of voltage magnitude during fault.**

***Keywords*: UPFC, Transient Stability, MATLAB Simulation.**

1. INTRODUCTION

Power system stability is defined as the ability of power system to preserve its stability or recover its stability after any deviation in the system operation. Present time power systems are being operated nearer to their stability limits due to economic and environmental reasons. To Maintain the stable and secure operation of power system is very important and challenging issue. Recent year Transient stability has been given much attention by power system researchers and planners and it is being one of the major source of power system insecurity.

FACT devices play an important role for improving the transient stability, increasing transmission capability and damping low frequency oscillations. Flexible AC transmission system (FACTS) device provide fast control of active and reactive power flow through transmission line. In this paper transient stability has been improved by using UPFC. The Unified power flow controller is a member of FACTS family with very attractive features. This is the combination of the properties of STATIC synchronous compensator (STAT com) and Static synchronous series compensator (SSSC) [1].

Here we have been developed two simulation model of single machine infinite bus (SMIB) system i.e. with or without UPFC. These simulation incorporated into MATLAB based Power system Toolbox (PST) for their transient stability analysis. This models will analysed for Phase to Earth Fault keeping the location of UPFC at the receiving end of the line. Transient stability has been analysed with the help of curves of Voltage magnitude during fault time.

2. TRANSIENT STABILITY

Transient stability refers to the maximum flow of power possible through a transmission line without losing the stability with sudden and large change in N/W condition.

Transient stability is the ability of the power system to withstand large disturbances and survive transition in normal operating condition. These disturbance can be fault such as sort circuit fault on transmission line, loss of a generator, loss of load, gain of load or loss of a portion of transmission line etc.

3. PRINCIPAL OPERATION OF UPFC

A simplified scheme of a UPFC connected to an infinite bus via a transmission line is shown in Fig.1.

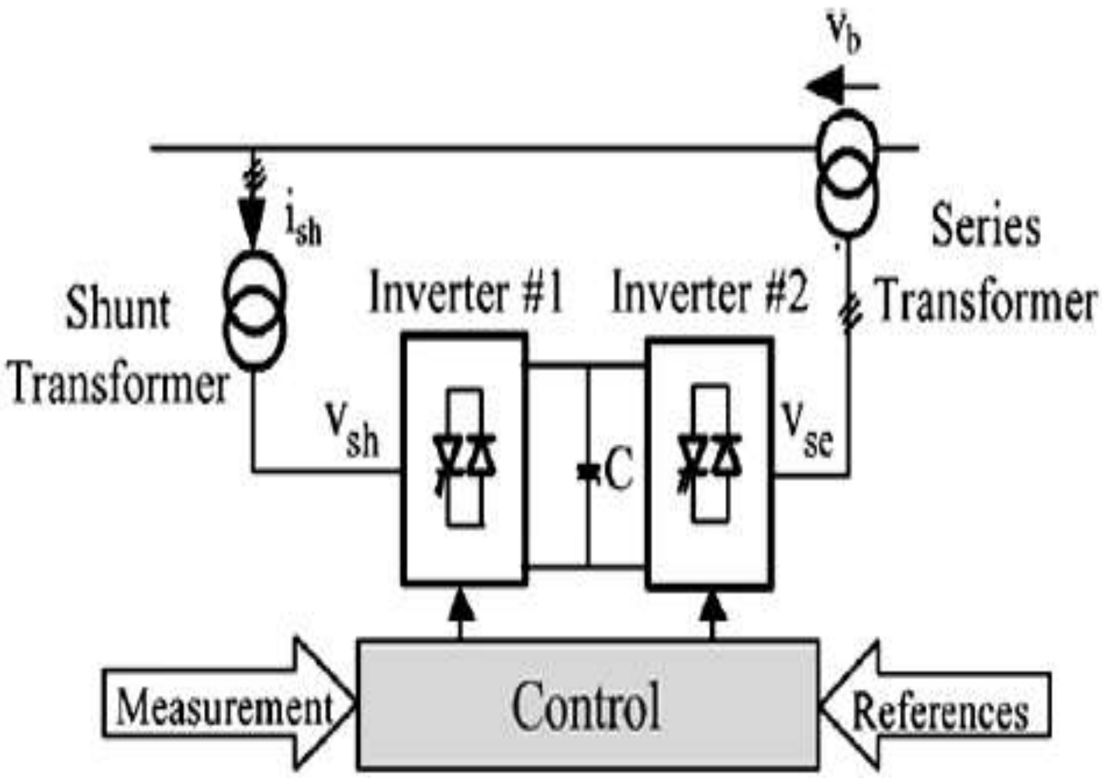

Fig.1. Unified power flow controller

UPFC consists of a parallel and series branches , each one containing a transformer , power –electric converter with turn off capable semiconductor devices and dc circuit. Inverter 2 is connected in series with transmission line by series transformer. The real and reactive power flows in the transmission line can be quickly regulated by changing the magnitude (vb) and phase angle (δb) of the injected voltage produced by inverter 2.

The basic function of inverter1 is to supply the real power demanded by inverter 2 through the common dc link. Inverter 1 can also generate or absorb controllable reactive power [2], [3].

4. CONTROL STRATEGY OF UPFC

For each part of UPFC, We have its proper control strategy below.

A. Shunt Part Converter has two duties:

1. Control the voltage magnitude at the sending end bus by locally generating (or observing) reactive power.
2. Supply or observe real power at the DC terminal as demanded by the series converter [3].

B. Series Part:

C. The SSSC can be operating in different mode such as voltage injection , phase angle shifter emulation, line impedance emulation, automatic power flow control etc. In each mode of operation, final outcome is such that inject voltage in series with the transmission line [4].

5. MATHEMATICAL MODEL OF UPFC

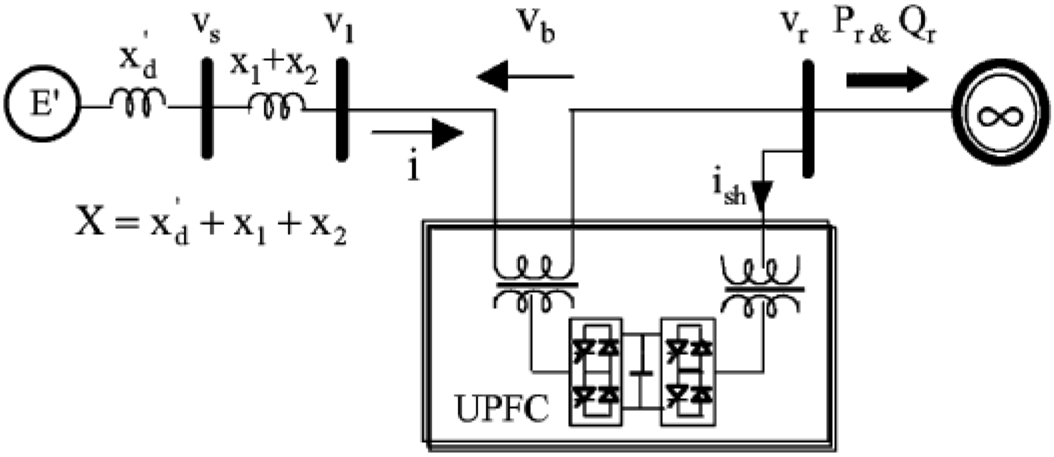

Fig.2:- Generator infinite bus system with UPFC

Fig.2 shows the single line diagram of a UPFC connected at the end of the transmission line. The vector diagram of an UPFC connected to the network (Fig.2) is presented in Fig.3.

According to Fig. 3, Vbp and Vbq are the components of the series voltage of UPFC. They are proportional to the voltage at the point of connection of UPFC and can be written as

$$V_{b}q = V_{r}\beta(t) \quad \text{and} \quad V_{b}p = V_{r}\gamma(t) \tag{1}$$

Where, β(t) and γ(t) are the control variables. Neglecting network losses, the electrical power can be expressed as:

$$P_r = \frac{E'V_1}{X}\sin(\delta - \theta) = \frac{E'V_1}{X}(\sin\delta\cos\theta - \cos\delta\sin\theta) \tag{2}$$

Where, X is the equivalent transient reactance which includes the transient reactance of generator, the reactance of the transformer, and the transmission line.

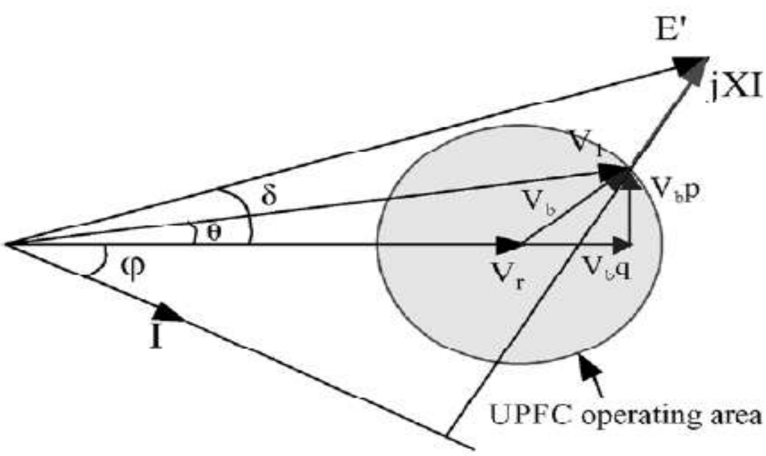

Fig. 3 Vector diagram of UPFC connected to a network

The generator swing equation is

$$M\frac{d^2\delta}{dt^2} = P_m - A\sin(\delta) - D\frac{d\delta}{dt} - P_{UPFC} \quad (3)$$

Where,

$$A = \frac{E'V_r}{X} \quad \text{and} \quad P_{UPFC} = -A\cos(\delta)\gamma(t) + A\sin(\delta)\beta(t) \quad (4)$$

Where, PUPFC introduces additional damping to the system if it is positive and proportional to the speed deviation (d δ /dt). This can be achieved through the following control strategy:

$$\gamma(t) = -K\cos(\delta)\frac{d\delta}{dt} \quad \text{and} \quad \beta(t) = K\sin(\delta)\frac{d\delta}{dt}. \quad (5)$$

By replacing (4) in (5), the damping factor is represented as below

$$P_{UPFC} = KA\frac{d\delta}{dt} = D_{UPFC}\frac{d\delta}{dt}. \quad (6)$$

The state variables defined by (9) can be approximately executed by using time derivatives of the receiving active and reactive powers (Pr and Qr).

According to Fig. 3, there are the following equations:

$$\begin{aligned} V_r + V_bq + XI\sin(\varphi) &= E'\cos(\delta) \\ V_bp + XI\cos(\varphi) &= E'\sin(\delta). \end{aligned} \quad (7)$$

Multiplying (7) by Vr, (8) will be obtained,

$$\begin{aligned} P_r &= \frac{V_rE'}{X}\sin(\delta) - \frac{V_rV_bp}{X} \\ Q_r &= \frac{V_rE'}{X}\cos(\delta) - \frac{V_rV_bq}{X} - \frac{V_r^2}{X}. \end{aligned} \quad (8)$$

The partial derivative of Pr is calculated as (9)

$$\begin{aligned} \frac{dP_r}{dt} &= \frac{\partial P_r}{\partial\delta} \times \frac{d\delta}{dt} + \frac{\partial P_r}{\partial V_bp} \times \frac{d(V_bp)}{dt} \\ \frac{dP_r}{dt} &= \frac{(-V_bp)E'}{KX} - \frac{V_r}{X} \times \frac{d(V_bp)}{dt}. \end{aligned} \quad (9)$$

The partial derivative of Qr is also calculated as (10)

$$\frac{dQ_r}{dt} = \frac{\partial Q_r}{\partial \delta} \times \frac{d\delta}{dt} + \frac{\partial Q_r}{\partial V_b q} \times \frac{d(V_b q)}{dt}$$
$$\frac{dQ_r}{dt} = \frac{(-V_b q)E'}{KX} - \frac{V_r}{X} \times \frac{d(V_b q)}{dt}. \qquad (10)$$

We can design the modulation controller for series-injected voltage by using (9) and (10). Fig. 4 shows the proposed block diagram of a modulation controller capable of producing a real differentiating element with a small time constant T. The value of K is chosen so that the injected series voltage remains at its nominal value. The values of Vr and E' are chosen as 1 p.u.

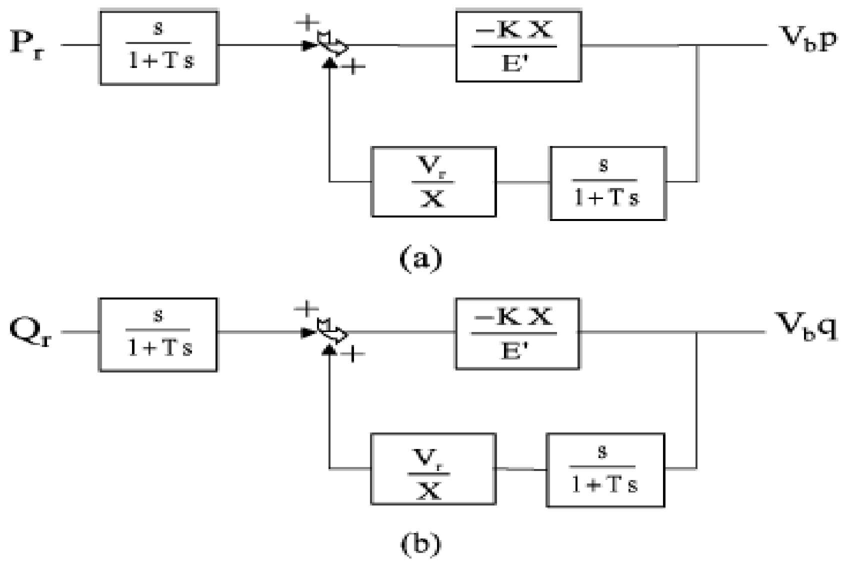

Fig. 4 Modulation controller for Vbp and Vbq

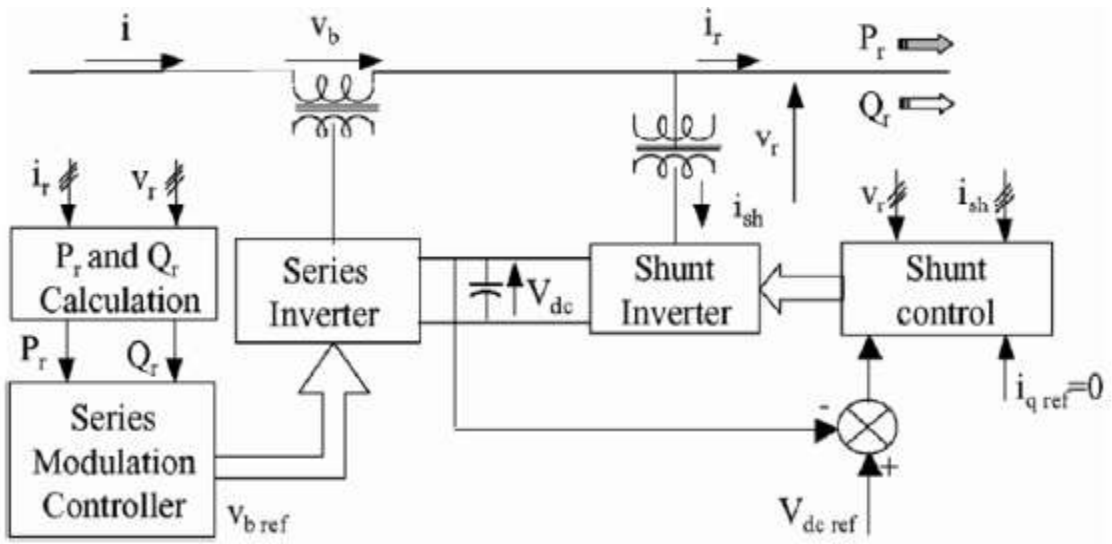

Fig. 5 Block diagram for inverter control

The injected series voltage is calculated as (11)

$$V_{b\ ref} = \sqrt{V_{bp}^2 + V_{bq}^2} \qquad \delta_b = \mathrm{Arctg}\left(\frac{V_{bp}}{V_{bq}}\right). \tag{11}$$

This voltage, which is applied to the control system, is presented in Fig. 5.

6. SYSTEM MODELLING

To show the transient stability improvement by using UPFC , Model is designed in MATLAB as shown in figure 6 . In this model three phase source of 400KV is connected with the three phase load of 250MW through a long 150km transmission line. Simulation is performed for 10 sec. And single line to ground fault (Transient Fault) is applied for 0.2 Sec. The UPFC used is 400KV, 100MVA. The series converter can inject a maximum of 10% of nominal line-to-ground voltage (23.09 kV) in series.

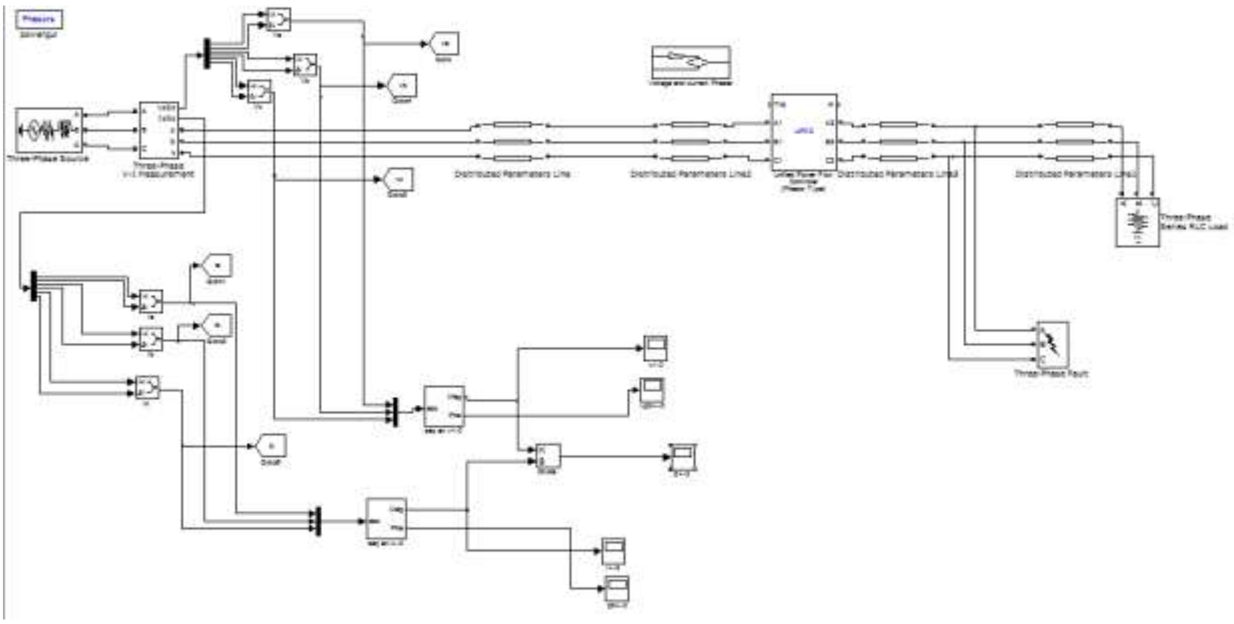

Fig. 6 MATLAB simulation model for improve transient stability of transmission line using UPFC

7. RESULTS

1. **Without UPFC:** Shows the voltage magnitude is unstable due to occurrence of single phase fault for 0.2 sec. when UPFC is not connected.

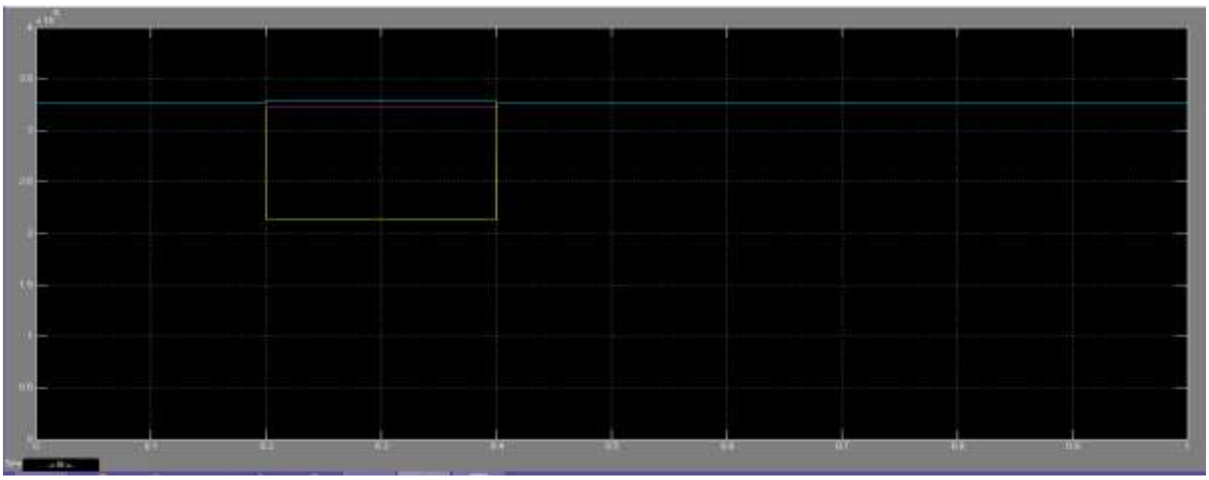

Fig. 7 Voltage Magnitude during single line to ground fault without UPFC

2. **With UPFC:** Shows the voltage magnitude during single line to ground fault for 0.2 sec. when UPFC is connected.

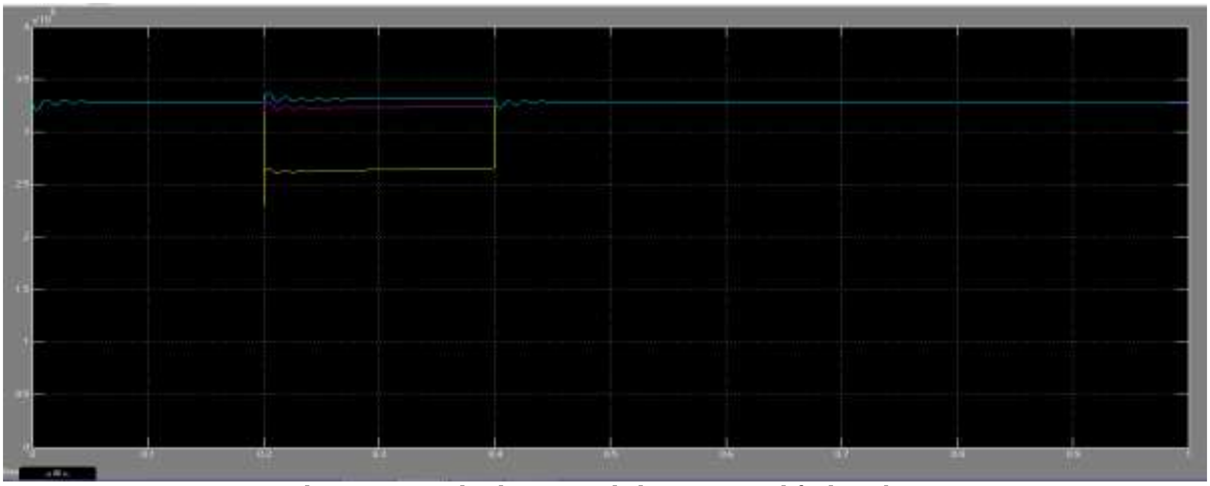

Fig.10 Voltage Magnitude during single line to ground fault without UPFC

8. CONCLUSION

This paper has investigated the voltage trend during transient fault with and without UPFC by developing simulation model of single line infinite bus system for single line to ground fault. The location of UPFC has kept fixed at the end of the transmission line. The transient stability of the transmission line was studied and compared by compare the voltage trend during fault time with and without UPFC.

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