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Power System Stability Enhancement using UPFC

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Abstract: In this paper the focus is on studying the effect of Unified Power Flow Controller (UPFC) on the stability of a Single Machine Infinite Bus (SMIB) system. In a transmission line the real and reactive power flowing can be controlled simultaneously by using UPFC, it also helps to regulate voltage at the connected bus. Here, two simulation models of Single Machine Infinite Bus (SMIB) system one in which UPFC is present and other in which it is absent have been developed. The Flexible Alternating Current Transmission (FACTS) devices such as UPFC are one of the most important in suppressing power system oscillations and improving damping. To study the stability the waveforms of real power, reactive power at receiving end, shunt injected voltage as well as its angle, series injected voltage as well as its angle and excitation voltage can be observed. Therefore we can conclude that the stability of Single Machine Infinite Bus (SMIB) system is improved with the use of Unified Power Flow Controller (UPFC)

Index terms: Power System Stability, Unified Power Flow Controller, Single Machine Infinite Bus

I. INTRODUCTION

Power system is more compound nowadays because it satisfies the increasing request and demand of power. Rearrangement of the line and increasing demand on the consumers end, there is a huge burden on the connected system which leads to stability as well as security problem for the whole existing system. It has been found that large number of black out have been caused by the lack of appropriate reactive power management which has to be mitigated. Also one important thing is to improve the quality of power supplied to the distribution side.

The major problem now days are to mitigate the fault as soon as possible or the fault clearing time should be minutest. One other thing is also creating the stability problem is the frequent change in load demand and the excitation system. Transient stability of a transmission is a major area of research from several decades.

Transient stability restores the system once the fault is cleared. Any type of unbalance between the generation and load, initiates transients that causes the rotor of the synchronous machines to ‘swing’ because net accelerating torques are exerted on these rotors. If these net torques becomes sufficiently large to cause some of the rotors to swing far enough then it lead to loss of synchronism. So the calculation of transient stability needs to be enhanced to optimize the load ability of the system, where the system can be loaded closer to its thermal limits.

UPFC is a device which gives both the series and the shunt compensation. It also enhances the real and reactive power capacity of the system. To study the steady state operating condition of the electrical network such as SMIB system with low frequency oscillations for sudden load change or excitation. The steady state may be determined by finding out the flow of active and reactive in the whole system with and without FACTS devices. To investigate the effect of FACTS devices (basically UPFC) for enhancing transient stability of the system to which it is connected will be discussed. One of the thing is that it is the application of UPFC to damp the oscillation for single machine power system in most possible fault clearing time.

II. MODEL OF UPFC

A unified power flow controller consists of two voltage source inverters (VSI) connected back to back with a common DC coupling capacitor as shown in Fig 1. Such an arrangement allows for all the three functions namely series, shunt and phase angle compensation to be unified into one unit. Inverter-1 is connected to the power system through a transformer T1 in shunt and the inverter-2 is connected to the power system through another transformer such that the secondary of the transformer T2 is in series with the transmission line. The transformers T1 and T2 would be referred to as shunt and series transformers respectively for the purpose of clarity.

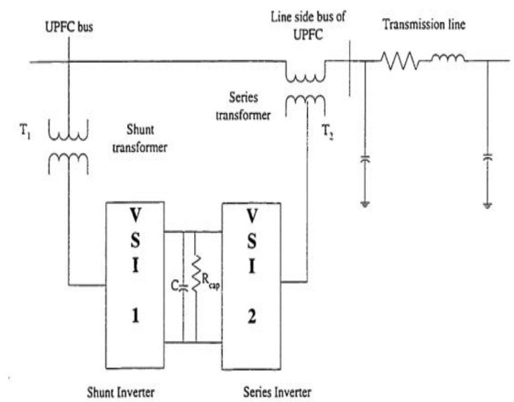


Figure 1: Unified Power Flow Controller Configuration

The model given in reference where the shunt inverter and series inverter of a UPFC are modeled as a voltage source in series with their transformer reactance is the simplest of all the models. The model provides for detailed interaction between the series and the shunt inverter. Fig 2 shows the UPFC model. X_{sh} and X_{se} represent the reactance of transformers T_1 and T_2 respectively. V_{sh} and V_{se} represent the voltage generated by the shunt and the sense inverter respectively. Bus-E and bus-F represent the UPFC bus and the transmission line side bus of UPFC respectively.

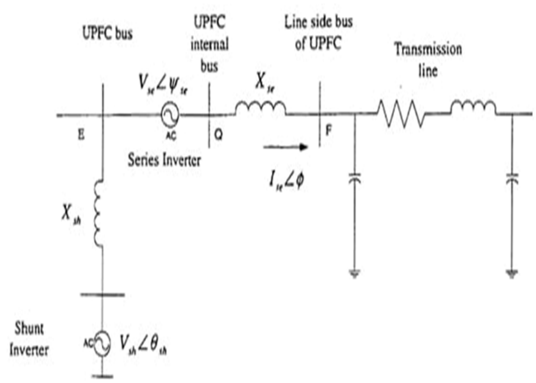


Figure 2: UPFC Model

The shunt and series voltage sources phasors can be mathematically represented as :

$V_{sh} = V_{sh}\ (\cos\theta_{sh}+j\sin\theta_{sh})$

$V_{se}= V_{se}\ (\cos\psi_{se}+j\sin\psi_{se})$

Where V_{sh} and V_{se} are the mean squared magnitudes of shunt and series voltage sources.

III. PHILLIPS-HEFFRON MODEL OF SMIB

The SMIB system is synchronous generator connected to an infinite bus through a transmission line. The non linear generator equations are linearised around a nominal operating point to get a simplified model of SMIB system. The shown figure is known as Phillips-Heffron model. By introducing many new constant a very compact model is achieved. The model enables the user to directly implement usable representation of an SMIB system, which can be used for stability studies. The constants K_1 to K_6 is derived in Phillips-Heffron model, which governs the system configuration and operation are as follows:

$K_1=\{E_bE_{qo}\cos\delta_o/(X_e+Xq)\}+ \quad \{EbIqosin\delta o(Xq-Xd')/(Xe+Xd')\}$ (3.1)

$K_2 = \{i_{qo}(X_e+X_q)/(X_e+X_d')\}$ (3.2)

$K_3 = (X_e+X_d')/(X_e+X_d)$ (3.3)

$K_4 = E_b\sin\delta o(X_d-X_d')/(X_e+X_d')$ (3.4)

$K_5 = \{(-X_qV_{do}E_b\cos\delta o)/((X_e+X_q)V_{to})\}-$
$\{X_d'V_{do}E_b\sin\delta_o/(X_e+X_d')V_{to}\}$ (3.5)

$K_6 = X_eV_{qo}/((X_e+X_d')V_{to})$ (3.6)

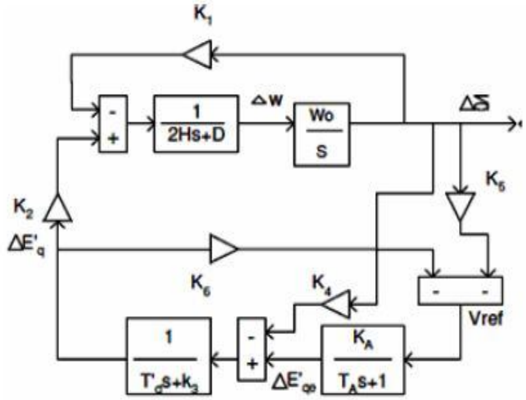


Figure 3: Phillip-Heffron Model of SMIB

The linearised constant, K_1,K_2 are from electric torque equation,K_3,K_4 are from field emf equation and K_5,K_6 are from the mechanical damping coefficient and T'_{do} is the transient time constant. K_A and T_A are the exciter amplifier constant and time constant where,

E_b=Infinite bus voltage

E_{q0} = Initial quadrature axis component

δ_0 = Initial power angle

i_{q0} = Initial armature current quadrature axis components

X_d, X_q= Direct and quadrature axis reactance

X_e = Exciting reactance

V_d,V_q = Stator terminal voltages of direct and quadrature axes

This simplified model can be described by state space representation as follows:

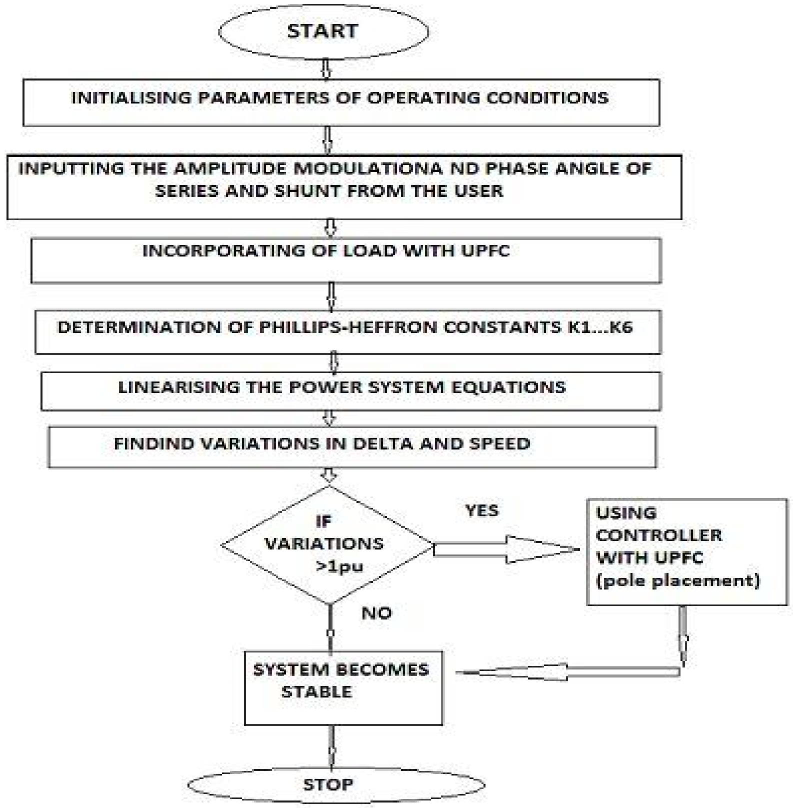
X[t] = AX[t] + BU[t] (3.7)

Y[t] = CX[t] + DU[t] (3.8)

$$A=\begin{bmatrix} 0 & \omega_R & 0 & 0 & 0 & 0 \\ \frac{-K_1}{2H} & \frac{-D}{2H} & \frac{-K_2}{2H} & 0 & 0 & 0 \\ \frac{-K_4}{\tau'_{do}} & 0 & \frac{-1}{K_3\tau'_{do}} & \frac{1}{\tau'_{do}} & 0 & 0 \\ 0 & 0 & 0 & \frac{-K_E}{T_E} & \frac{1}{T_E} & 0 \\ \frac{-K_AK_5}{T_A} & 0 & \frac{-K_AK_6}{T_A} & 0 & \frac{-1}{T_A} & \frac{-K_A}{T_A} \\ 0 & 0 & 0 & \frac{-K_EK_F}{T_ET_F} & \frac{K_F}{T_ET_F} & \frac{-1}{T_F} \end{bmatrix} \quad (3.9)$$

Where X[t], Y[t] and U[t] are the state vector, output and input signal vector respectively. [A],[B] and [C] are all real constant matrices of appropriate dimensions.

IV. FLOW CHART



V. RESULTS

A. The following results have come by putting parameters at following loading conditions:

1) Damping factor = 0(unstable system)
2) Amplitude modulation of shunt VSC-E= 1pu
3) Phase angle of shunt VSC-E = 1
4) Amplitude modulation of series VSC-B=1pu
5) Phase angle of series VSC-B = 1
6) Magnitude of load = 0.8pu
7) Power factor = 0.85 lagging

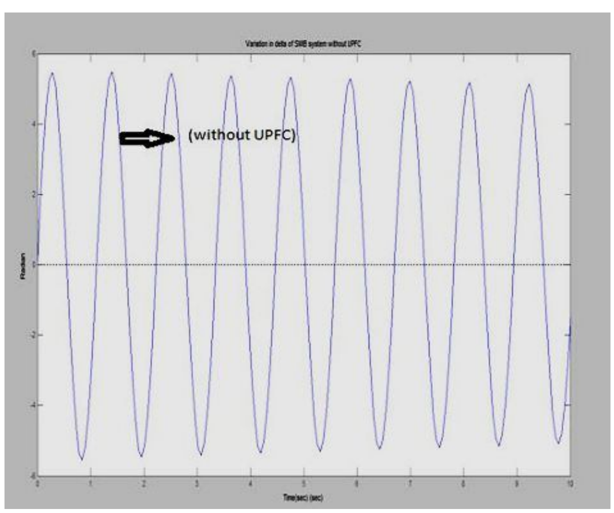


Figure 4: Variation in delta of SMIB system without UPFC

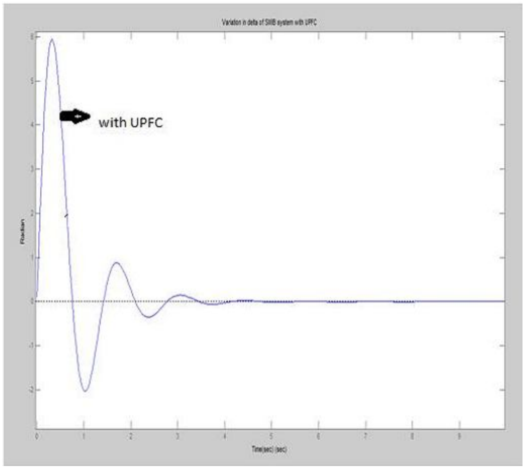


Figure 5: Variation in delta of SMIB system with UPFC

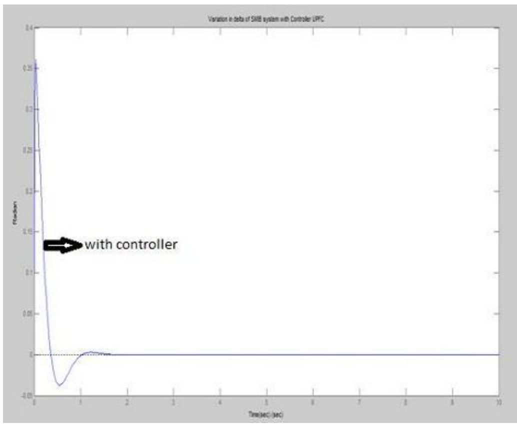


Figure 6 : Variation in delta of SMIB with controller UPFC

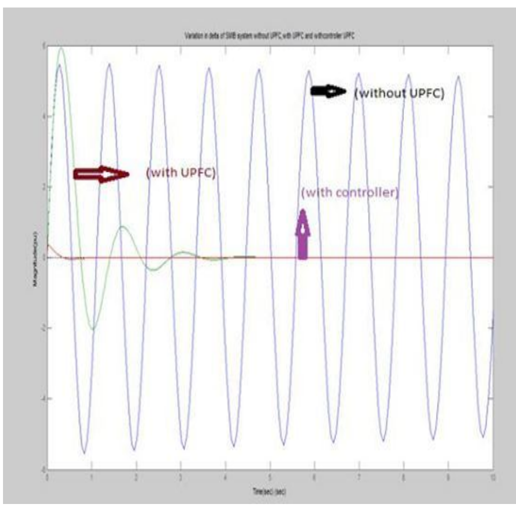


Figure 7 : Variation in delta of SMIB without UPFC,with UPFC and with controller

B. The following results have come by putting parameters at following loading conditions:

1) Damping factor = 4 (Weaker damping)

2) Amplitude modulation of shunt VSC-E= 1pu

3) Phase angle of shunt VSC-E = 1

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4) Amplitude modulation of series VSC-B=1pu
5) Phase angle of series VSC-B = 1
6) Magnitude of load = 0.8pu
7) Power factor = 0.85 lagging

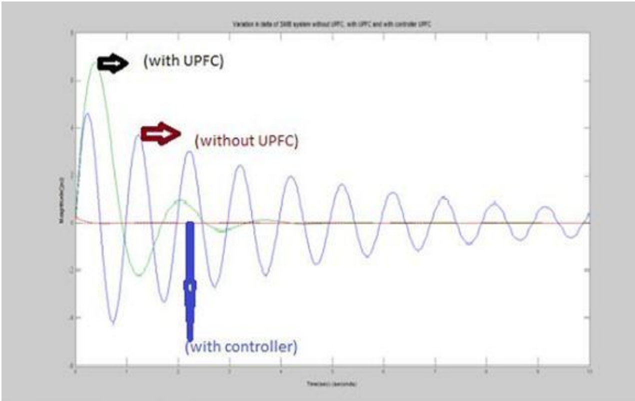

Figure 8 : Variation in delta of SMIB without UPFC,with UPFC and with controller

C. The following results have come by putting parameters at following loading conditions:
1) Damping factor = 8 (Stronger damping)
2) Amplitude modulation of shunt VSC-E= 1pu
3) Phase angle of shunt VSC-E = 1
4) Amplitude modulation of series VSC-B=1pu
5) Phase angle of series VSC-B = 1
6) Magnitude of load = 0.8pu
7) Power factor = 0.85 lagging

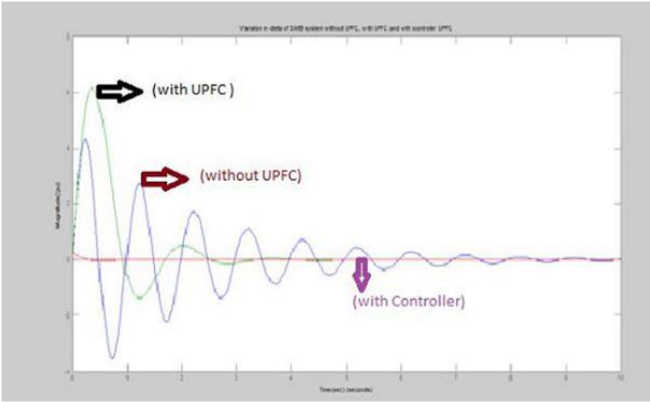

Figure 8 : Variation in delta of SMIB without UPFC,with UPFC and with controller

VI. CONCLUSION AND FUTURE WORK

A control system/control strategy for UPFC has been designed in this thesis. MATLAB computer simulations have been conducted to show the improvement in power system damping with UPFC using the designed control system/control strategy. A UPFC was constructed using the MATLAB software. The issues are concerning the ratings of the shunt/series inverters, their transformers and the DC link capacitor. Further, with the proposed control strategy, the need for reactive power coordination controller is eliminated, MATLAB computer simulations have been performed to show the validity of the proposed control strategy and to show the improvement in power oscillation damping and enhancing the stability. Very little research has been done in the area of designing a control system and operating a UPFC under unbalanced condition-The future work will include the design of a control system that allows the UPFC to operate reliably under unbalanced power system conditions.

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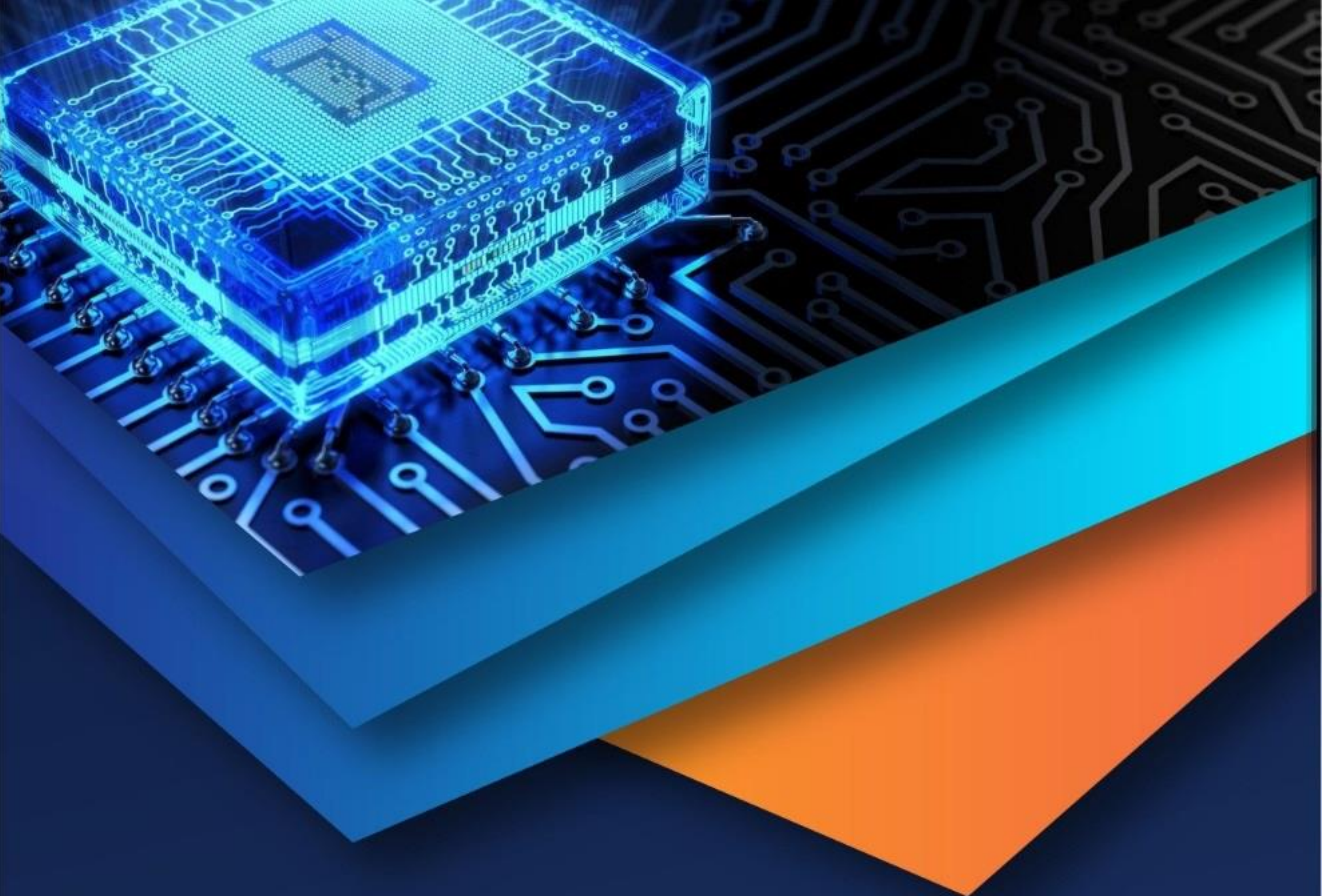

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