ASYNCHRONOUS MACHINE MODELING USING SIMULINK FED BY PWM INVERTER

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Abstract:

The number of industry applications in which induction motors are fed by static frequency inverters is growing fast and, although much has already been done within this field, there is still a lot to be studied/understood regarding such applications. The advance of variable speed drives systems engineering increasingly leads to the need of specific technical guidance provision by electrical machines and drives manufacturers, In this paper we have studied and developed a simulink model with PWM inverter and find out the various characteristics and analysis them.

Keywords: *ASM (Asynchronous Machine), PWM (pulse width modulation)*

I. INTRODUCTION

A three-phase The Direct Current (D.C.) machine, the synchronous machine, and the asynchronous machine, also known as an three phase induction machine. Induction machine are the major electromechanical conversion devices in industry. The merits of the squirrel cage induction machine are: lightness, simplicity, ruggedness, robustness, less initial cost, higher torque-inertia ratio, capability of much higher speeds, ease of maintenance, etc. The most important feature which declares it as a tough competitor to D.C. machines in the drives field is that its cost per KVA is approximately one fifty of its counter-part and it possesses higher suitability in hostile environment. Unfortunately, induction machines suffer from the drawback that, in contrast to D.C. machines, their speed cannot be easily and effectively adjusted continuously over a wide range of operating conditions. On the other hand, the synchronous machine has the merit of being operated under a wide range of power factors, both lagging and leading, and are much better suited for bulk power generation. In the induction motor, alternating current is applied to the stator and alternating currents are induced in the rotor by transformer action.

In the synchronous machine, direct current is supplied to the rotor and Alternating Current (A.C.) flows in the stator. On the other hand, a D.C. machine is a machine that is excited from D.C. sources only or that itself acts as a source of D.C. It is a common practice in industry to employ A.C. motors whenever they are inherently suitable or can be given appropriate characteristics by means of power electronics devices. Yet, the increasing complexity of industrial processes demands greater flexibility from electrical machines in terms of special characteristics and speed control. It is in this field that the D.C. machines, fed from the A.C. supply through rectifiers, are making their mark.

II. CLASSIFICATION OF ELECTRIC MACHINES

There are several methods of classifying electric machine:

- Electric power supply - Electric machines are classified as D.C. and A.C. machines as well as according to their stator and rotor constructions as shown in Figure 1.

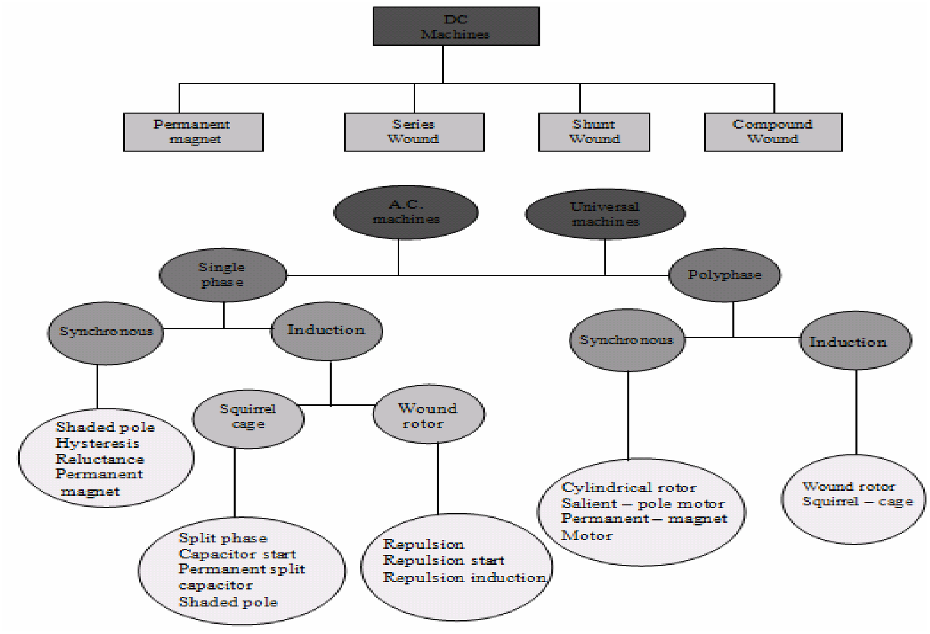


Figure 1: Classification of Electric Machines.

III. BASIC FEATURES OF ELECTRIC MACHINES

The basic structural features of a D.C. machine:

- Stator - The stator carries the field winding. The stator together with the rotor constitutes the magnetic circuit or core of the machine. It is a hollow cylinder.
- Rotor - It carries the armature winding. The
Armature is the load carrying member. The rotor is cylindrical in shape.
- Armature Winding - This winding rotates in the \magnetic field set up at the stationary winding.
It is the load carrying member mounted on the rotor. An armature winding is a continuous winding; that is, it has no beginning or end. It is composed of a number of coils in series as is shown in Fig 2. Depending on the manner in which the coil ends are connected to the commutator bars, armature windings can be grouped into two: lap windings and wave windings. Wave winding gives greater voltage and smaller current ratings while the lap winding supplies greater current and smaller voltage ratings.
- Field Winding - This is an exciting system which may be an electrical winding or a permanent magnet and which is located on the stator.
- Commutator - The coils on the armature are terminated and interconnected through the commutator which comprised of a number of bars or commutator segments which are insulated from each other. The commutator rotates with the rotor and serves to rectify the induced voltage and the current in the armature both of which are A.C.
- Brushes - These are conducting carbon graphite spring loaded to ride on the commutator and act as interface between the external circuit and the armature winding.
- Poles - The field winding is placed in poles, the number of which is determined by the voltage and current ratings of the machine.
- Slot/Teeth - For mechanical support, protection from abrasion, and further electrical insulation, non-conducting slot liners are often wedged between the coils and the slot walls. The magnetic material between the slots is called teeth. Figure 3 shows a cross-sectional view of slot/Teeth geometry

On the other hand, the basic constructional features of an A.C. machine (e.g induction machine) are: • Rigid Frame - The whole construction ensures compact and adaptable design at low weight and low vibration level in all operating conditions and throughout the whole speed range . Figure 2 shows a basic Rigid Frame Design.

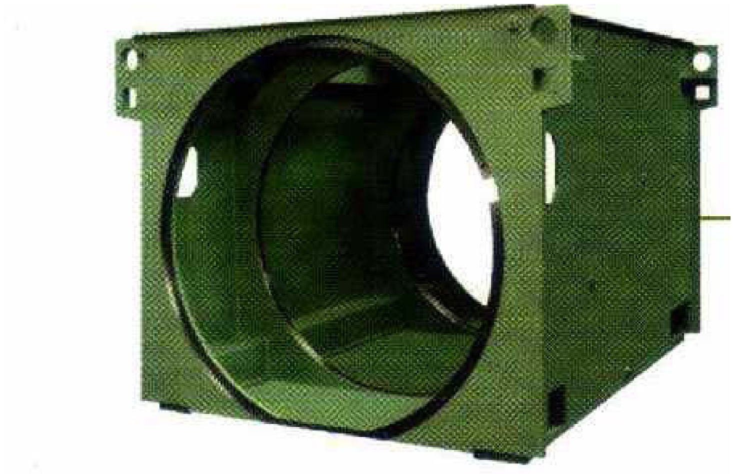


Fig2: Rigid Frame

Stator Package- The Stator core is a stack of thin electrical sheet steel laminations insulated by a heat resistant inorganic resin. The radial cooling ducts ensure uniform and efficient cooling. The stator package, shown in Figure 3 forms a solid block which retains its rigidity throughout the long life time of the machine.

Fig:3 Stator Package

Rotor Construction - The rotor of A.C. machines can be of wound type or squirrel cage type. A typical squirrel cage rotor is shown in Figure 4. Depending on the number of poles and whether the shaft is of the spider or cylindrical type, the rotor core is shrunk onto the shaft and the conductor bars tightly caulked into the slots to prevent bar vibration.

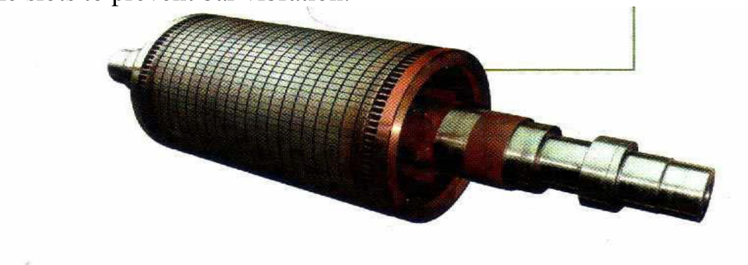


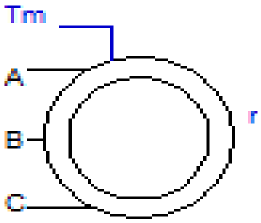
Fig:4 Rotor Construction

Rugged Bearing Assemblies - The bearings are designed for reliable continuous operation and ease of maintenance. Depending on the Rated power, anti-friction bearings with a life time of over 100,000 hours are available Figure 5.

Fig:5 Rugged Bearing Assemblies

IV. BASIC PARAMETER OF SIMLINK FOR ASM MODELING

The machine which we have simulated is a three phase induction machine having the following details



The Asynchronous Machine block operates in either generator or motor mode. The mode of operation is dictated by the sign of the mechanical torque: If Tm is positive, the machine acts as a motor. If Tm is negative, the machine acts as a generator.

a. Inputs and Outputs of the machine

Tm

The Simulink input of the block is the mechanical torque at the machine's shaft. When the input is a positive Simulink signal, the asynchronous machine behaves as a motor. When the input is a negative signal, the asynchronous machine behaves as a generator.

m

The Simulink output of the block is a vector containing 21 signals. We can demultiplex these signals by using the Bus Selector block provided in the Simulink library. The stator terminals of the Asynchronous Machine block are identified by the A, B, and C letters. The rotor terminals are identified by the r. Note that the neutral connections of the stator and rotor windings are not available; three-wire Y connections are assumed

Parameter	Definition
Rs, Lls	Stator resistance and leakage inductance
R'r, L'lr	Rotor resistance and leakage inductance

Lm	Magnetizing inductance
Ls, L'r	Total stator and rotor inductances
Vqs, iqs	q axis stator voltage and current
V'qr, i'qr	q axis rotor voltage and current
p	Number of pole pairs
Te	Electromagnetic torque
Tm	Shaft mechanical torque
J	Combined rotor and load inertia coefficient.
H	Combined rotor and load inertia constant.
F	Combined rotor and load viscous friction coefficient

V. PROPOSED ASYNCHRONOUS MACHINE FOR SIMULINK MODELING

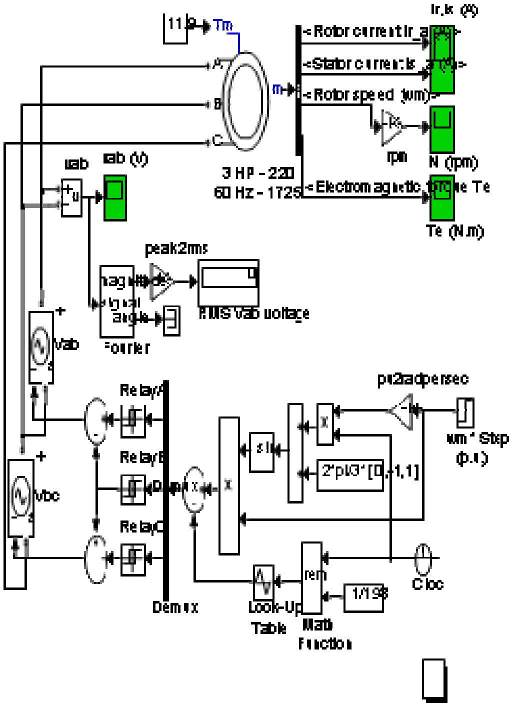


Fig:6 Simulink model of asynchronousMachine with PWM Inverter

Description Table:

Rotor Type	Squirrel cage
Reference frame	Stationary
Nominal power	3.746V/A
Node voltage vrms	220volt
Frequency	60Hz
Resistance	0.435ohm
Inductor	2*2.0e-3H
Rotor Resistance	0.816ohm
Rotor Inductance	2.0e-3H
Mutual inductance	69.31e-3
Inertia	0.089
Friction factor	0
Pairs of poles	2

VI. LIMITATIONS OF ASYNCHRONOUS MACHINE BLOCK:

- The Asynchronous Machine block does not include a representation of iron losses and saturation. You must be careful when you connect ideal sources to the machine's stator. If you choose to supply the stator via a three-phase Y-connected infinite voltage source, you must use three sources connected in Y. However, if you choose to simulate a delta source connection, you must use only two sources connected in series
- When you use Asynchronous Machine blocks in discrete systems, you might have to use a small parasitic resistive load, connected at the machine terminals, in order to avoid numerical oscillations. Large sample times require larger loads. The minimum resistive load is proportional to the sample time. As a rule of thumb, remember that with a 25 ms time step on a 60 Hz system, the minimum load is approximately 2.5% of the machine nominal power. For example, a 200 MVA asynchronous machine in a power system discretized with a 50 ms sample time requires approximately 5% of resistive load or 10 MW. If the sample time is reduced to 20 ms, a resistive load of 4 MW should be sufficient.

VII. RESULTS:

Asynchronous machine with PWM:

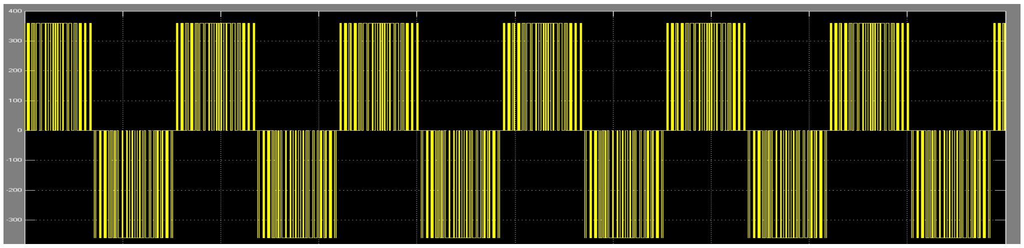


Fig7: 0utput of pulse width modulator

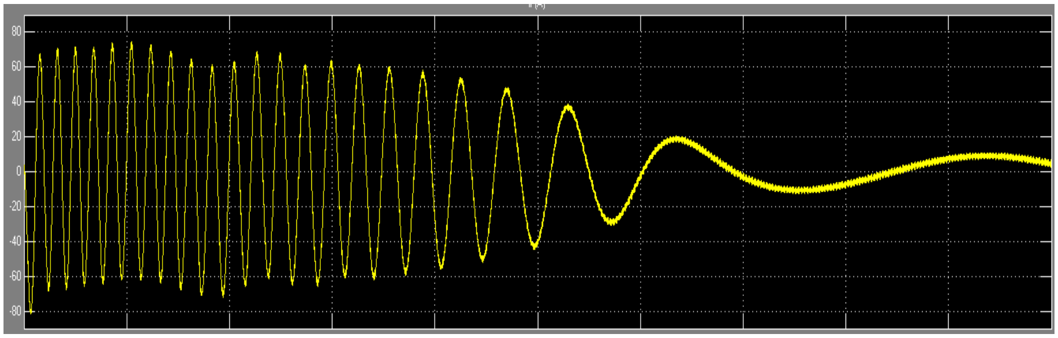


Fig8: Waveform of time vs armature current

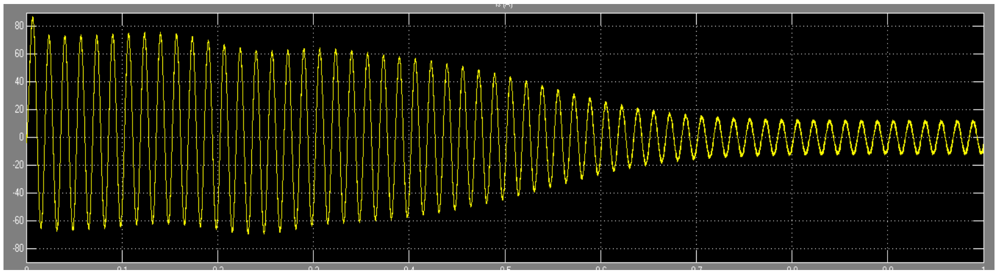


Fig 9: Waveform of time vs rotor current

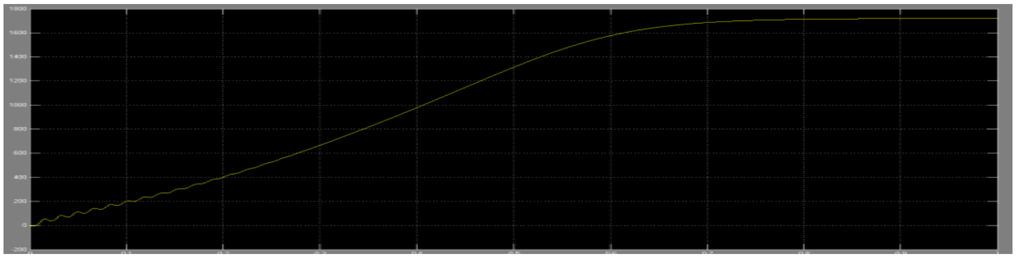


Fig 10: Waveform of time vs Speed

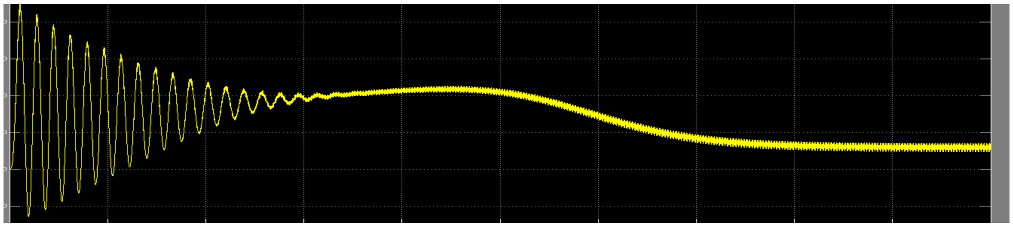


Fig 11: waveform of time vs torque

Here Asynchronous Machine block is used in motor mode. It consists of an asynchronous machine in an open-loop speed control system.

The machine's rotor is short-circuited, and the stator is fed by a PWM inverter, built with Simulink blocks and interfaced to the Asynchronous Machine block through the Controlled Voltage Source block. The inverter uses sinusoidal pulse-width modulation. The base frequency of the sinusoidal reference wave is set at 60 Hz and the triangular carrier wave's frequency is set at 1980 Hz. This

corresponds to a frequency modulation factor mf of 33 (60 Hz x 33 = 1980). It is recommended that mf be an odd multiple of three and that the value be as high as possible.
The 3 HP machine is connected to a constant load of nominal value (11.9 N.m).
The stationary reference frame was used to obtain the results shown above.

VIII. GRAPH ANALYSIS:

Fig 15 shows the machine's speed going from 0 to 1725 rpm (1.0 p.u.). Fig 16 shows the electromagnetic torque developed by the machine. Because the stator is fed by a PWM inverter, a noisy torque is observed. However, this noise can be seen in stator and rotor currents But not visible in the speed because it is filtered out by the machine's inertia.

Asynchronous machine without PWM:

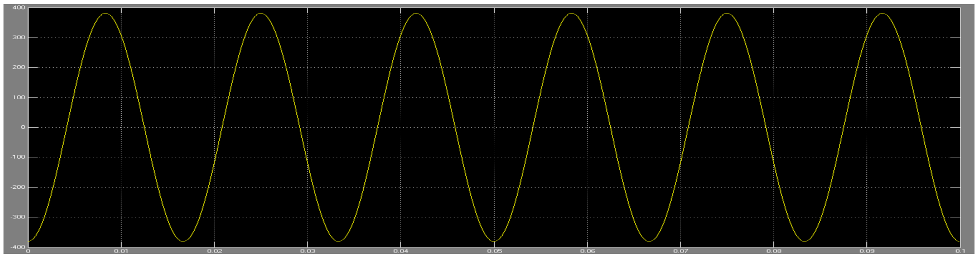


Fig12: Input supply given to stator of machine

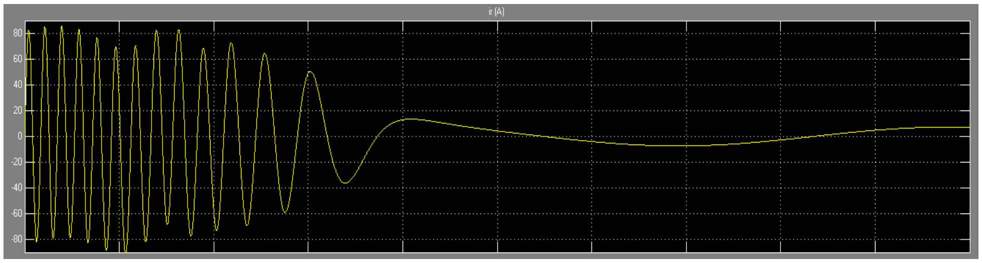


Fig13: Waveform of time vs armature current

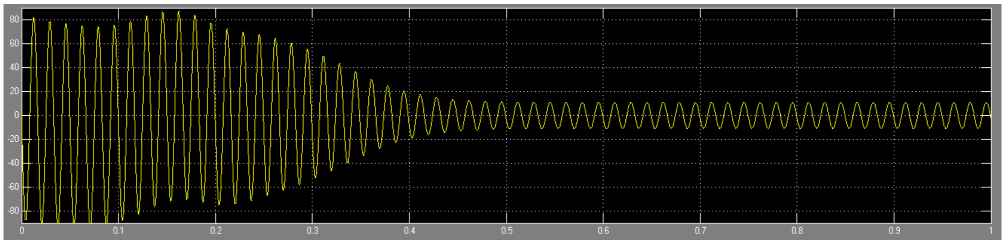


Fig14: Waveform of time vs rotor current

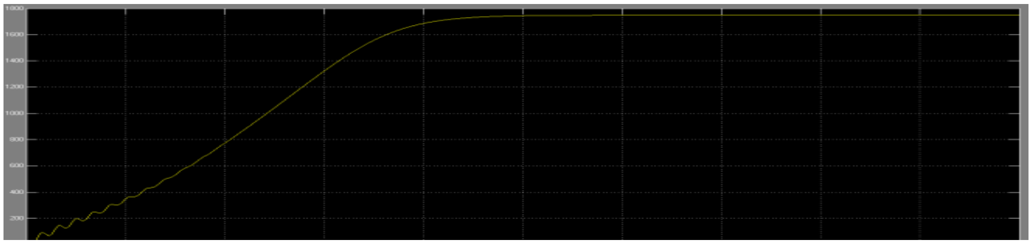


Fig15: Waveform of time vs speed

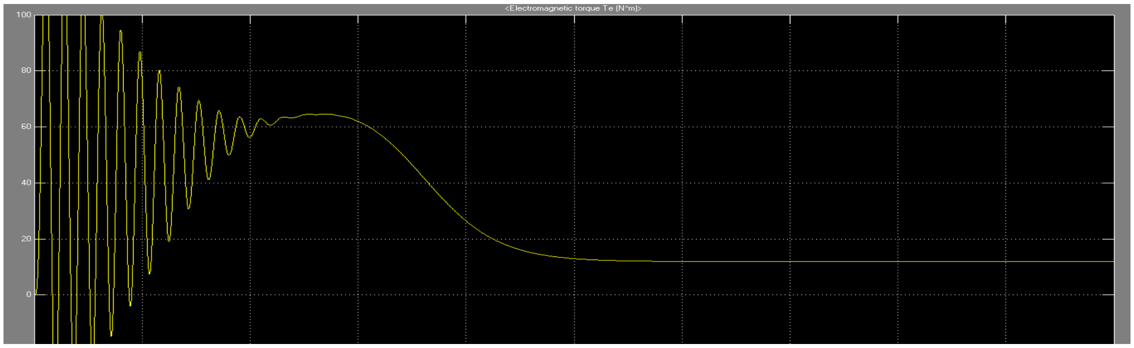


Fig16: Waveform of time vs torque

IX. CONCLUSION

The rapid advance of the power electronics have allowed induction motors, the conventional solution for constant speed rotating power applications, to be used efficiently also in variable speed drive systems. In such cases, though, the motor must be fed by means of a static frequency inverter, rather than directly by the (sinusoidal) power line. The utilization of squirrel cage induction motors with electronic inverters presents great advantages on costs and energy efficiency, compared with other industrial solutions for varying speed applications. Nevertheless, the inverter affects the motor performance and might introduce disturbs into the mains power line.

The increasing number of applications with induction motors fed by PWM inverters operating in variable speed duty thus requires a good understanding of the whole power system as well as the interactions among its parts one another (power line – frequency inverter – induction motor – load).

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