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METHODS OF TRANSMISSION LINE COMPENSATIONS USING FACTS DEVICES

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1.1 Introduction about FACTS:

The world revolves around energy and the energy sector is continually transforming and evolving. The demand for energy efficiency continually rises for multiple reasons. Technology has improved for all sectors of the power grid, including renewable energy sources, fault protection, and SMART grid technology. The implementation of new technology and power load on a large scale, coupled with the removal of grid stabilizers has posted different challenges which has been overcome using FACTS.

FACTS is an acronym which stands for Flexible AC Transmission System.FACTS defines Alternating current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability.

With the invention of thyristor devices, power electronic converters are developed that led to implement FACTS controllers. These power electronic based controllers can provide smooth, continuous, rapid and repeatable operations for power system control.

The usage of power has been increasing day-by-day because of increasing the technology so it is very important to increase the transmission capacity at minimum cost,so this can be achieved by using the FACTS techniques. Some of the FACTS devices are turn-on and turn-off semi-conductors like GTO's and MCT's.

1.2 Different FACTS devices:

There are different types of devices which are used for obtaining the Flexibility in AC Transmission System.

1) Shunt devices
    a) Static var Compensator (SVC)
    b) Static synchronous compensator (STATCOM)
2) Series devices
    a) Thyristor controlled series control (TCSC)
    b) Thyristor Controlled Series Reactor (TCSR)

1.3 Need of FACTS devices

Today the power system is very complex and interconnected; we need to improve power utilization to maintain security and reliability. Some transmission lines are overloaded, and some are loaded below the limit by which voltage profile deteriorates and system stability decreases so we need to control the power flow in the transmission line for power transfer. Hence the development of power electronic technology has introduced Flexible AC transmission system (FACTS) devices.

The possibilities offered by the FACTS technology include

- Power can be controlled for desired amount such that it flows through prescribed transmission routes
- Loading of the transmission lines near their thermal, steady-state and dynamic limits

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- Enhancing the power transfer capability between interconnected transmission lines
- Increasing the quality of supply for sensitive industries
- Enhancing transmission system reliability and availability by limiting the impact of multiple faults .

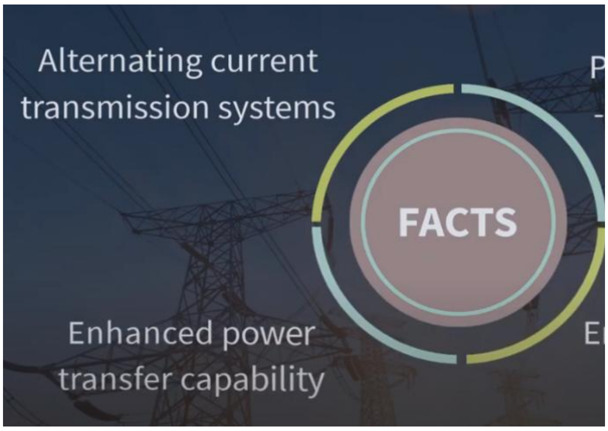

Fig 1.The possibilities offered by the FACTS technology include

1.4 Advantages and Disadvantages of FACTS

a) Advantages

-
- FACTS increase the reliability of AC grids.
- They reduce power delivery costs.
- They supply inductive and reactive power to the grid and improve transmission quality and efficiency of power transmission.
- There is a fast voltage regulation
- Increases power transfer over a long AC lines

b)Disadvantages

- A limited amount of power can be sent over a transmission line.
- Conductors and equipment can be damaged by overheating if too much power is drawn.
- The power flowing over an AC line is proportional to the sin of the phase angel of the voltage at the receiving and transmitting ends. This angle varies depending on the system loading and generation and an angle of 90degree is not suitable.

S.no	Title of the Paper	Description
1.	Proposed Terms and Definitions for Flexible AC Transmission System (FACTS)	This paper defines the different parameters like FACTS, FACTS controllers and converters.
2.	Flexible AC transmission systems, Methods of transmission line compensation	This paper gives the detailed information about different compensation methods in transmission lines like shunt compensator, series compensators, series capacitance compensators and phase angle controls
3.	Flexible AC Transmission Systems and Resilient AC Distribution	This report mainly discusses about FACTS and state the key roles of

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	Systems in Smart Grid	FACTS in a smart grid like how to increase penetration of renewable energy, improve power capability and hoe to improve stability of existing grid. About some different compensation techniques etc.,
4.	Flexible AC transmission systems, Advanced FACTS controllers.	In this we can learn advanced FACTS controllers based on the use of turn-on turn-off power semiconductors such as GTO's and MCT's. GTOs are the only available power semiconductors suitable for large, advanced FACTS controllers applicable to electrical power transmission
5.	Flexible AC transmission systems Conventional FACTS controllers	Different conventional FACTS controllers and compared with advanced controllers.

6.	Flexible AC Transmission Systems	This tutorial gives an overview of the area and explains why FACTS devices are needed. Future tutorials will describe methods of controlling and compensating AC transmission lines, FACTS based on thyristors and FACTS devices based on GTOs
7.	Intelligent Application of Flexible AC Transmission System Components in an Evolving Power Grid	This paper discusses about the FACTS and need of FACTS and different types of FACTS control techniques. They also discussed the MATLAB /SIMULINK simulate designed power systems accurately with the additional functionality to model FACTS.
8.	Flexible converters for meshed HVDC grids: From Flexible AC transmission systems (FACTS) to Flexible DC grids	In this we can see how FACTS are useful for making smart grids. How we can make the HVDC system flexible with the help of FACTS.
9.	Optimal Power Flow with the Consideration of Flexible Transmission Line Impedance	In this we can see how FACTS are useful for making smart grids. How we can make the HVDC system flexible

		with the help of FACTS
10.	Flexible AC Transmission Systems	This paper gives the total review on FACTS

Compensation or controlled techniques in facts

The compensation techniques of the power system supply the inductive or capacitive reactive power (to its particular limits) in order to improve the quality and efficiency of the power transmission system. The following are the two popular compensation techniques used in power system.

a. Shunt Compensators
b. Series compensators

3.1.1 Shunt compensator

In this type of reactive power compensation, various compensation, or FACTS devices (which can be either switched or controlled) are connected in parallel to the transmission lines at particular nodes.

These devices inject the current into the lines so that the reactive component of the load current is compensated thereby the losses are reduced and voltage regulation is improved.

The types of shunt compensation devices include static synchronous compensator (STATCOM) and static VAR compensator (SVC).

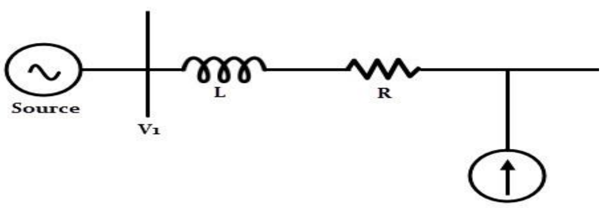

Fig: 2 circuit diagram of shunt compensator

3.1.2 Series Compensator

In this, various compensation or FACTS devices (which can be either switched or controlled) are connected in series with the transmission lines at particular nodes. This compensation will give more control of power flow through the line and also improves the dynamic stability limit of the power system.

Mostly, capacitors are installed in series with the lines. The amount of compensation is varied by installing several capacitor banks in series with the lines. This is achieved by thyristors-controlled series capacitors.

Thyristor controlled switched capacitors (TCSC) and fixed series capacitor (FSC) techniques are widely used for series compensation.

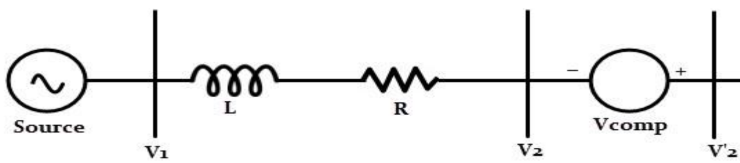

Fig :3 circuit diagram of series compensator

3.2 FACTS Controllers

FACTS controllers can help to solve technical problems in interconnected power systems and can also improve the synchronous operation of the inter connection and influence the load flow conditions.

These are also defined as a power electronic based system and other static

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equipment that provide control of one or more AC transmission system parameters.

3.2.1 Types of FACTS Controllers

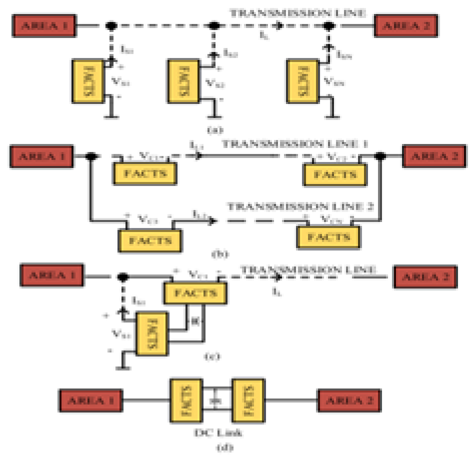
FACTS controllers are classified as

Shunt connected controllers

Series connected controllers

3.2.1.1 Shunt connected controllersfig :4 different FACTS controller configuration

These controllers inject a current into the system at the point of connection. If this current is in phase quadrature with the line voltage, a shunt controller consumes or supplies variable reactive power to the network.



Different FACTS controller configurations

Similar to the series connected controllers, these controllers could be a variable reactor or capacitor or a power electronic based variable source. Examples of the shunt controllers include TCR, STATCOM, TSR, TCSC and TSC.

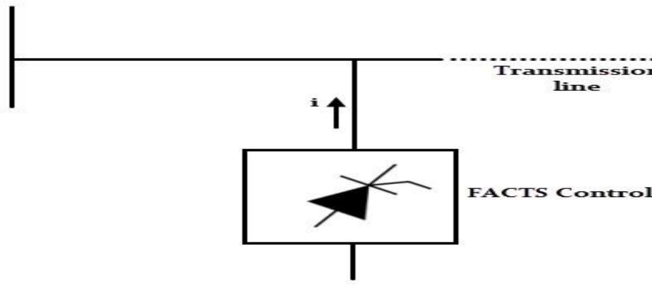


Fig :5 Circuit representation of Shunt connected controllers

3.2.1.2 Series connected controllers

These controllers inject a voltage in series with the line. If this voltage is in phase quadrature with the current, the controller consumes or supplies variable reactive power to the network. These controllers could be variable impedance such as a reactor or capacitor or a power electronic based variable source. Examples of the series controllers include SSSC, TCSR, IPFC, TSSC, TCSC, and TCS

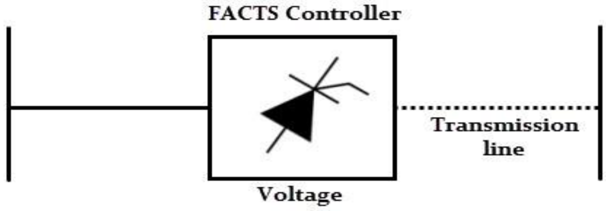


Fig :6 Circuit representation ofSeries connected controller

Facts devices or controllers

FACTS devices are static power-electronic devices installed in AC transmission networks to increase power transfer capability, stability, and controllability of the networks through series and/or shunt compensation. These devices are also employed for congestion management and loss optimization.

The FACTS devices have been used during the last 3 decades and provide better utilization of existing systems.

FACTS are used to control the transmission line power flow, voltage control, transient stability improvement, and oscillation damping

The static synchronous series compensator (SSSC) and thyristor-controlled series capacitor (TCSC) are some of the FACTS control devices which provide series compensation to reactance of the lines to which they are connected, while the static synchronous compensator (STATCOM) and static VAR compensator (SVC) (where VAR stands for volt–ampere reactive) are FACTS devices which provide shunt compensation to transmission lines. FACTS control devices also provide adequate damping of interarea oscillations by acting as actuators in robust control schemes and PMU-based wide-area control schemes.

4.1 Static Var Compensator

It is a shunt type controller which controls the power flow by generating or absorbing whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific parameters of the electrical power system (typically bus voltage) in transmission system and improves the transient stability of power grids. This controller regulates the voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system.

SVC is based on thyristors without gate turn-off capability. The operating principal and characteristics of thyristors realize SVC variable reactive impedance. SVC includes two main components and their combination: Thyristor-controlled and Thyristor-switched Reactor (TCR and TSR); and Thyristor-switched capacitor (TSC).

TCR and TSR are both composed of a shunt-connected reactor controlled by two parallel, reverse-connected thyristors. TCR is controlled with proper firing angle input to operate in a continuous manner, while TSR is controlled without firing angle control which results in a step change in reactance.

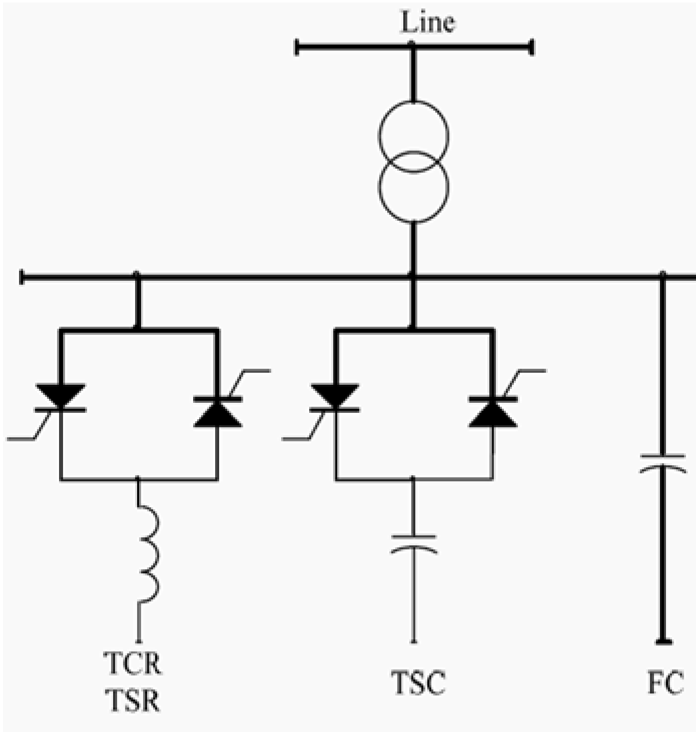


Fig :7 Static VAR Compensators (SVC)

TSC shares similar composition and same operational mode as TSR, but the reactor is replaced by a capacitor. The reactance can only be either fully connected or fully disconnected zero due to the characteristic of capacitor.

With different combinations of TCR/TSR, TSC and fixed capacitors, a SVC can meet various requirements to absorb/supply reactive power from/to the transmission line

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4.1.1: Thyristor controlled Reactor (TCR)

Thyristor-controlled reactor (TCR) is a reactance connected in series with a bidirectional thyristor valve. The thyristor valve is phase-controlled, which allows the value of delivered reactive power to be adjusted to meet varying system conditions. Thyristor-controlled reactors can be used for limiting voltage rises on lightly loaded transmission lines. Another device which used to be used for this purpose is a magnetically controlled reactor (MCR), a type of magnetic amplifier otherwise known as a transductor

In parallel with series connected reactance and thyristor valve, there may also be a capacitor bank, which may be permanently connected or which may use mechanical or thyristor switching. The combination is called a static VAR compensator.

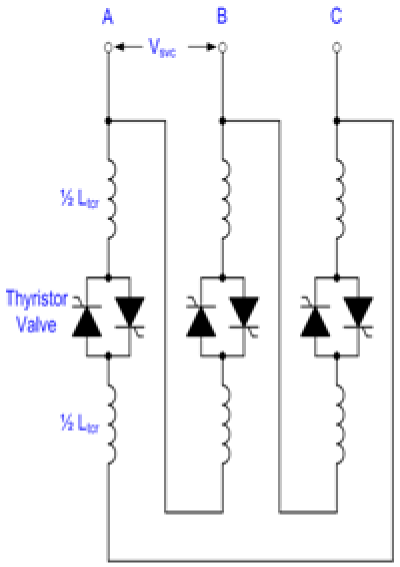

Fig :8 phase thyristor-controlled reactor
fig :9 circuit of thyristor controlled reactor

Thyristor controlled reactor consist of reactor L placed in series with the thyristor valve. This reactor is the controlled element of the TCR, and it controls the thyristor valve. TCR consists of two opposite poled thyristor which conducts every alternate half cycle of the supply.

4.1.2 Thyristor Switched Reactor (TSR)

It is a special case of a TCR where phase control of the current is not exercised, instead the reactor is switched such that thyristors are either fully ON or OFF as in case of TSC. The advantage of TSR over TCR is that no harmonics current generation. Also, this controller uses thyristors without firing control and hence lower cost and losses.

The reactive compensation control in electric power system uses the above stated SVC types in different configuration, such as combination of TCR and TSC, combination of TCR and TSC with filter circuit and TCR with filter circuit as shown in figure.

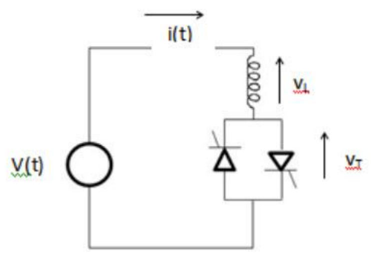

Fig :10 circuit diagram of TSR

4.2 STATCOM

STATCOM or Static Synchronous Compensator is a power electronic device using force commutated devices like IGBT, GTO etc. to control the reactive power flow through a power network and thereby increasing the stability of power network. STATCOM is a shunt device i.e.,

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it is connected in shunt with the line. A Static Synchronous Compensator (STATCOM) is also known as a Static Synchronous Condenser (STATCON). It is a member of the Flexible AC Transmission System (FACTS) family of devices.

The terms Synchronous in STATCOM mean that it can either absorb or generate reactive power in synchronization with the demand to stabilize the voltage of the power network.

Basic Principle of Operation

In the case of two AC sources, which have the same frequency and are connected through a series reactance, the power flows will be:

- Active or Real Power flows from the leading source to the lagging source.
- Reactive Power flows from the higher to the lower voltage magnitude source.

Consequently, the phase angle difference between the sources decides the active power flow, while the voltage magnitude difference between the sources determines the reactive power flow. Based on this principle, a STATCOM can be used to regulate the reactive power flow by changing the output voltage of the voltage-source converter with respect to the system voltage

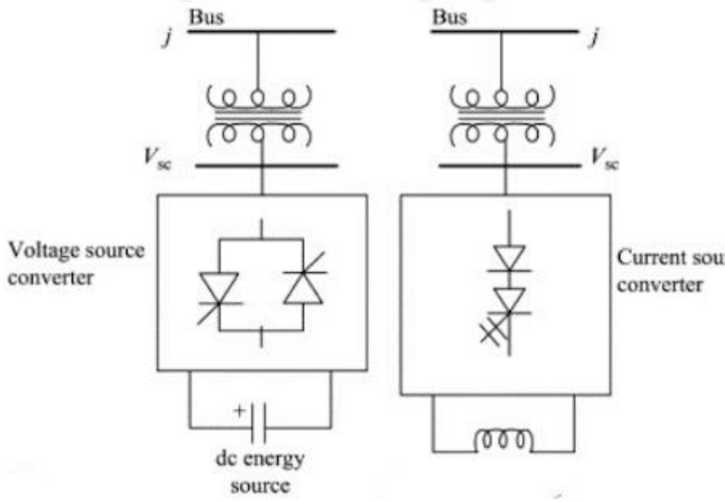

Fig:11 circuit diagram of STATOM

4.3 Thyristor Controlled Series Capacitor (TCSC)

Thyristor controlled series compensator (TCSC) controller, the first generation of flexible AC transmission system (FACTs), can control the line impedance through the introduction of aL thyristor-controlled capacitor in series with the transmission line. TCSC is used as series compensator in transmission system. The TCSC controller can be designed to control the power flow, to increase the transfer limits or to improve the transient stability. The TCSC controller can provide a very fast action to increase the synchronization power through quick changing of the equivalent capacitive reactance to the full compensation in the first few cycles after a fault, hence subsequent oscillations are damped. TCSC controller provides variable impedance, which is required for the compensation. The presented controller is suitable only in capacitive zone. For the transition from a capacitive vernier mode

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to bypass mode the TCSC controller can be modeled with detailed dynamics.

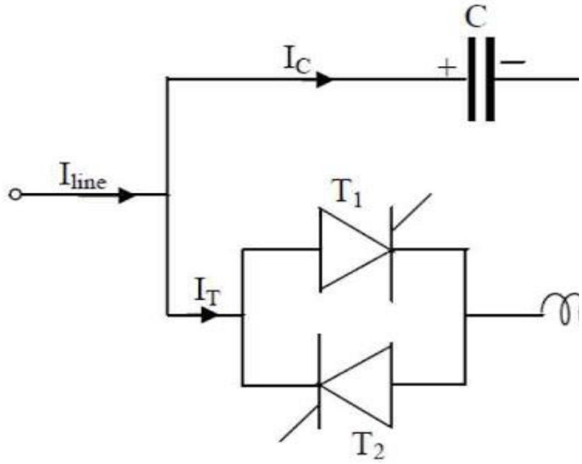

Fig :12 circuit diagram of TCSC

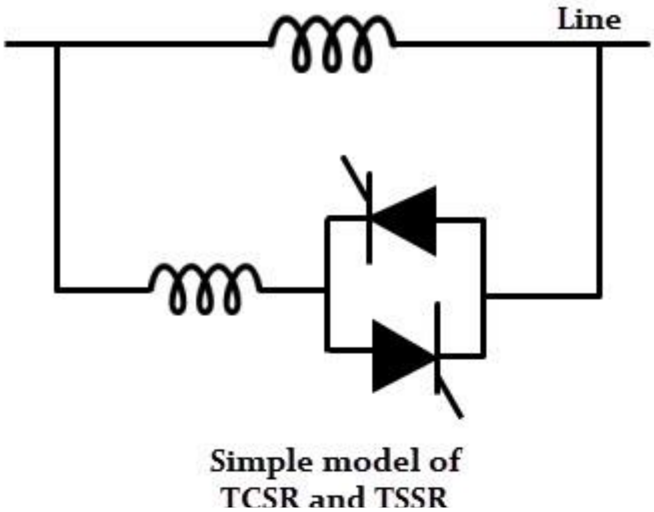

Fig :13 circuit diagram of TSSR

4.4 Thyristor Controlled Series Reactor (TCSR)

It is an inductive reactance compensator which consists of a series reactor in parallel with thyristor switched reactor. This controller provides a smooth variable inductive reactance.

When the thyristor's firing angle is 1800, the reactor stops conducting and hence the uncontrolled reactor only is in series with the line that acts as a fault current limiter. If the firing angle is below 1800, the net (or overall) inductance decreases, thereby voltage is controlled in the network.

CONCLUSION

Tomorrow's market forces, Giving the status quo, the power transmission and power quality markets are likely to be shaped by a host of factors in the years ahead, such as:

- Rising demand for clean energy
- Expanding and interconnecting of grid infrastructures
- Gradually replacing and upgrading of aging grid infrastructure
- Making AC grids more efficient to fulfill future demands

Achieving all this – a pre-requisite for meeting the world's skyrocketing energy demands – requires new approaches and new technologies.

So, by this we can say in our modern society, lives revolve around power. Emerging technologies increase power consumption and energy dependence. The development of everything from electric vehicles to smart homes to massive data centers widens the spectrum of energy use.

The urbanization of large cities and manufacturing demands have increased centralized load centers

With the high monetary and customer demand in mind, it is crucial to identify solutions to maintain high reliability in the specific power system. Among many other solutions, one method to ensure grid reliability is through the planned installation of flexible alternating current transmission systems or FACTS

They provide greater system reliability through quick voltage regulation and provide load flow control of network surrounding the devices.

FACTS devices need to be optimally installed and coordinated in a power system to deliver reliable, quality and economical power to all, by satisfying all the requirements of the consumers mentioned.

There are different types of FACTS devices which are discussed above helps to achieve controller over transmission system, so that we can control the different parameters and increase the efficiency of the system

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