Implementation Of Solid State Relays For Power System Protection

Nidhi Verma, Kartik Gupta, Sheila Mahapatra

ABSTRACT: This paper provides the implementation of solid state relays for enhancement of power system protection. Relays are an essential part of the power systems and are responsible for the control of any overload voltage or current and protection of the devices from these parameters. The main function of the relay is to constantly monitor the parameter to be controlled and if it exceeds the percentage range set by the controller then it sends a signal to the circuit breaker to break the connection and isolate the faulty part. Solid state relays are preferred over mechanical relays and in this paper relay functioning is done with the help of opto-coupler. Controlling of opto- coupler is done with the help of microcontroller. Circuit operates through Zero Voltage Switching leading to reduction in harmonics. The implementation of relay circuit offers minimal delay time which enables better time response for protection.

KEYWORDS: Load, Microcontroller, opto-isolator, Relay, Software, Solid State Relays, Zero voltage switching

INTRODUCTION

There are many applications of protection circuit as the need for energy to all has increased. With increasing population, the energy demand has increased and so the need to meet the need has increased. The major problem in transmission and distribution in country like India is losses and the faults that occur during the process. Faults sometimes can be very dangerous to the machines being used during generation, distribution and utilisation of electricity. Many protective devices are being used nowadays to avoid the consequences of faults.

RELAY

Relay is one such type of protective device. And circuit breaker is utilised to remove the faulty part from the healthy circuit. A relay is a switch that works on the principle of electromagnetic induction. The switching between the ON and OFF position is done with the help of an electromagnet thus removing the need of a person's presence. A relay can be operated with a small amount of power and can be used to control devices that draw much more power like circuit breakers and isolators. For example the air conditioner in your home is controlled with the help of relays. An AC unit requires roughly 220VAC at around 30A, that comes out to be around 6600 Watts however the coil used to control the relay may only need a few watts to pull the contacts together. A relay is like a remote control switch and has many applications because of its long life, high accuracy, relative simplicity and proven high reliability. These are very useful when we have a requirement to control huge amount of voltage or current with use of a small electrical signal.

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Throughout the industry a wide variety of application require the use of relays. Electrical power systems can be protected against trouble and power blackouts using sophisticated relays. These can also be utilised in the control and regulation of power generation and distribution. Relays are used in a lot of home appliances as well, such as dish washers, washing machines and refrigerators along with air condition or heating controls. Relays are commonly associated with electrical circuitry but there can be pneumatic and hydraulic relays as well.

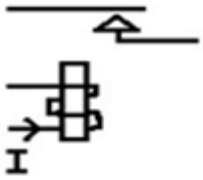


Figure 1: Schematic Representation Of Relay

Initially the contact is normally open which means not connected. The coil generates a magnetic field when current (I) is passed through it and closes the switch (i.e. top contact gets connected). A spring is used to again pull back the switch open, when power is removed from the coil.

HOW DO RELAYS WORK

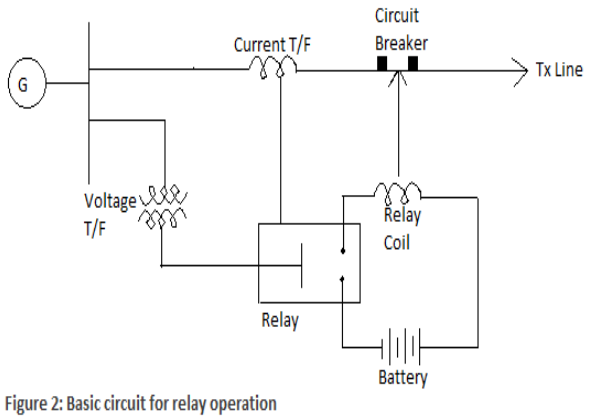


Figure 2: Basic circuit for relay operation

The main part of the relay is the sensing unit which basically is an electrical coil. AC or DC current can be used to power the coil. When applied current/ voltage increases from the threshold value, the armature of the relay gets activated by the coil, which is used to close the open contacts. The switch mechanism is actuated by a magnetic force that is generated when power is supplied to the coil. When coil is energised it sends information to the circuit breaker that breaks the circuit till the fault clearance or isolates the faulty part. The relay compares the current or voltage from the transformer connected before the relay and send information to the circuit breaker. The coil opens when the circuit breaker disconnects the faulty part.

The basic functions performed by the relay are:
On/Off Control- For example, in air conditioning control, relay is used to limit and control the compressor power which is a "high power" load. Limit Control - In this, relay is used to control a set of parameters and disconnect the device if the value of these parameters goes above or below the set value. For Example in Motor Speed Control, motor gets disconnected if the desired speed increases or decreases beyond the limit. Logic Operation – In this, the relay is connected to desired point only if a particular logic is getting fulfilled. For example, in Test Equipment control, the instrument under test is connected to a number of testing points.

TYPES OF RELAYS

Relay can be broadly classified on the basis of construction and application. There are three types of relay based on construction which are Electromechanical, Static and Numerical.

A.) Electromechanical Relays

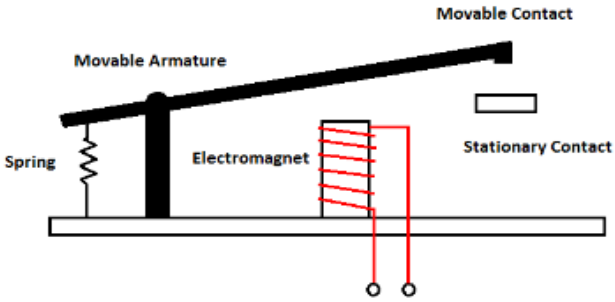


Figure 3: Electromechanical Relay

The above diagram shows the schematic of an electromechanical relay. The parts are as follows:

- Spring
- Electromagnet
- Moveable armature
- Stationary contact
- Moveable contact

The two contacts are kept separated with the help of a spring. When the electromagnet gets energized the two contacts are pulled together. With proper application, the integration between power circuits and control circuits can be done with the help of electromechanical relays. Advantages of Electromechanical relays are no requirement of heat sink, lower cost, availability of multiple poles and easy switching in both AC and DC.

B.) Static Relay (Solid State Relays)

In this type of relay, the comparison or measurement of electrical quantities is performed by a static circuit which gives an output signal for the tripping of a circuit breaker. These are known as static as they don't have any moving part. In this type of relay instead of magnetic coil or mechanical components we use analog electronic devices to create the relay characteristics and the incoming current or voltage waveforms are monitored by analog circuits, not digitized. In these, there is no effect of gravity or vibration or shock. Sometimes, these relays use microprocessor but they can't be called microprocessor relays as it lacks the attribute of digital/numeric relay. These relays use semiconductor devices like diodes, SCR, TRIAC, Power transistor etc. to conduct load current. Relatively low control circuit energy is required to perform switching of the output state from OFF to ON position since there is use of semiconductor devices. To protect the circuit under control for introduction of electrical noises we often use static relays. Static relays are highly reliable and have a long life. They do not have any moving parts or contact bounce and thus have a fast response. Only single pole switching can be accomplished using this relay. This acts as a major drawback. Secondly they are costly as compared to electromechanical relays.

Type of SSR:
It is convenient to classify the SSR by the nature of the input circuit and the classification is as follows:

1) Reed- Relay coupled SSR

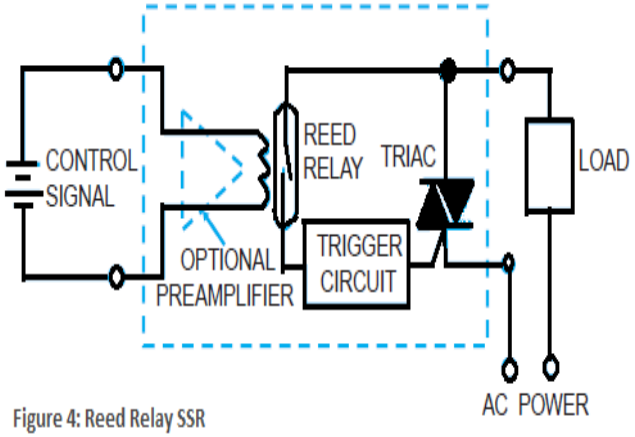


Figure 4: Reed Relay SSR

In this type of SSR application of control signal is done on the coil of the reed relay. Thyristor switch is triggered when the appropriate circuitry is activated upon closing of reed switch.

2) Transformer coupled SSR

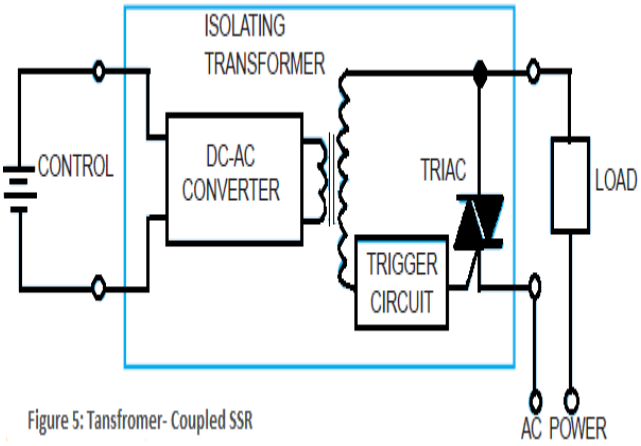


Figure 5: Tansfromer- Coupled SSR

In this type, primary of low-power transformer is provided with the control signal, the thyristor switch is triggered by the secondary that is generated by the primary excitation.

Photo- Coupled SSR

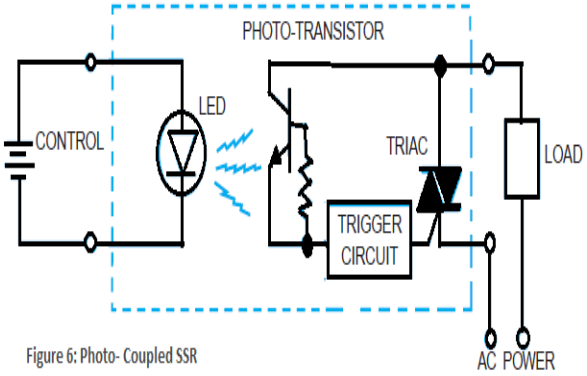


Figure 6: Photo- Coupled SSR

In this type of relay a light or infrared source (generally LED) is provided with a control signal. A photo- sensitive semi- conductor device (diode, transistor or thyristor) detects the radiation from that source and generates an output. The output triggers the TRIAC which is used to switch the load current. The electrical isolation is excellent as the input and output path are coupled only by a beam of light. This type of SSR is discussed in detail below.

C.) Numerical Relays

Numerical relays or digital relays are designed to carry out protection function of various electrical equipments such as generator, transformer, transmission lines, motor etc. with the use of digital technology. They use microcontroller with a software based protection algorithm for the electrical fault detection. These are based on digital technology and are more or less immune to variation or drift in parameters of individual components like OP-AMPS etc. due to changes in temperature, ageing etc. The reliability of the circuit increases with the use of digital signals. These may include protection functions, metering and self- test functions. These are programmable types of relays. In this type of relay the behaviour along with the characteristics can be programmed. It can be used to accomplish various protection functions with appropriate modifications in the software. This can be done either with the same hardware or small adjustment may be required to be done in the device.

SOLID STATE RELAYS

The block diagram of a solid state relay with opto-isolator made by us is given below:

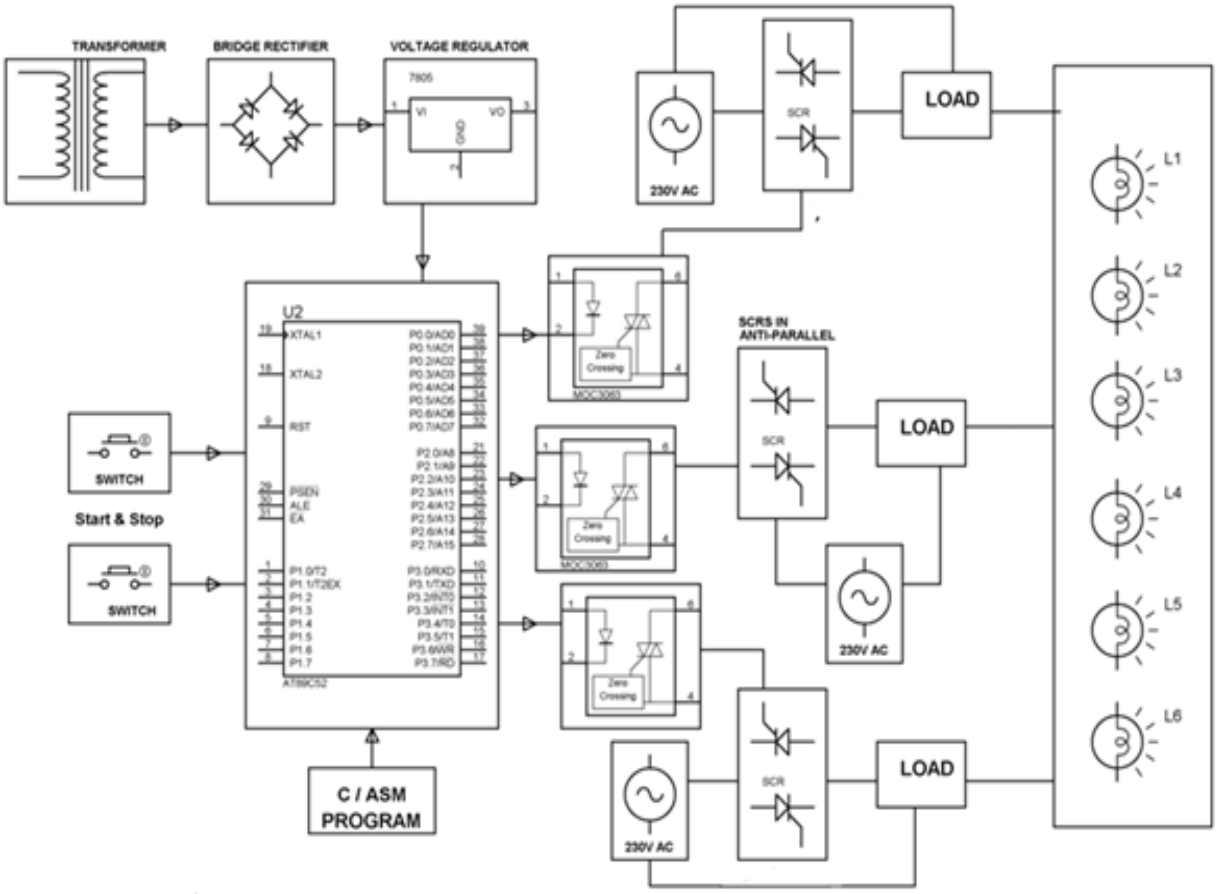
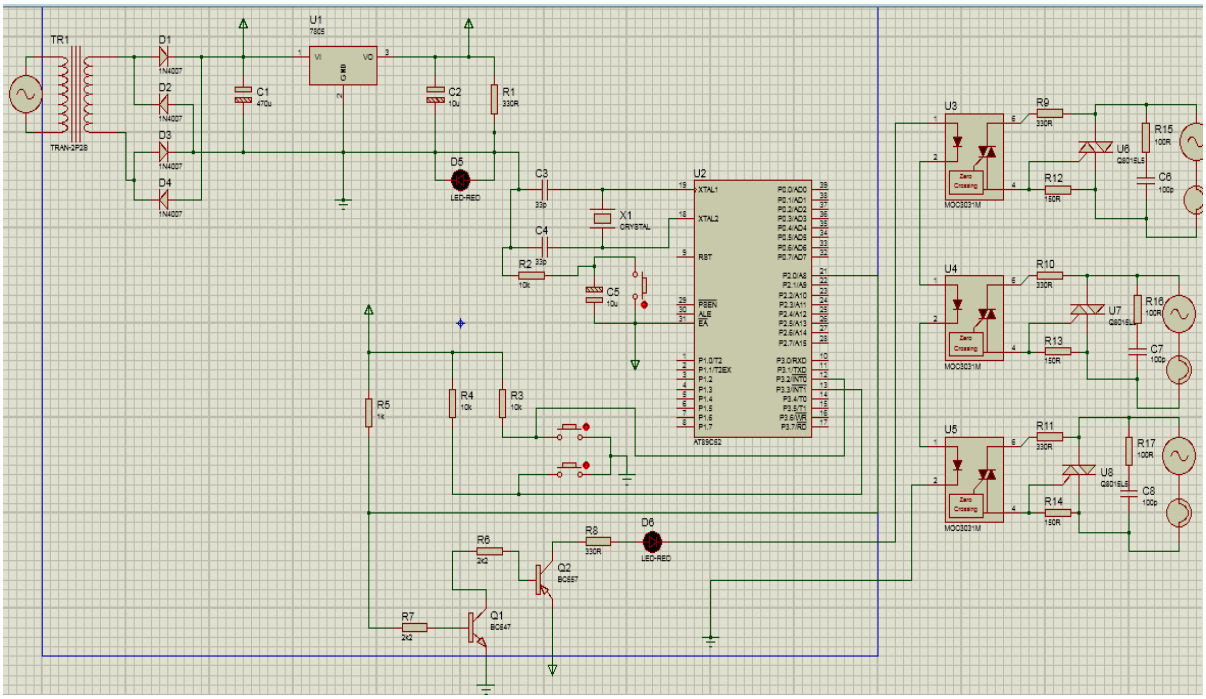


Figure 7: Block Diagram of SSR

The software implementation of the actual circuit is as follows:



In the above circuit a power block is made with the help of transformer, bridge rectifier and voltage regulator. This block is to provide a voltage at 5V. This voltage is given to the microcontroller for its further operation. The microcontroller is loaded with the code required for the circuit operation. The input to the microcontroller is given by start and stop push buttons which helps in generating random output pulses to pin 21 of the microcontroller. The

random pulses are amplified with the help of transistors. The output of the transistor drives 3 opto-isolators. The output of the opto-isolators drives respective TRIAC which are connected in series with load in each phase. Opto-isolator conducts only at zero- voltage crossing this implies even if switching is done at the peak of the supply then also load will get ON only after zero crossing voltage of supply voltage. In zero voltage switching (ZVS) the turn-on and turn-off occurs at zero current and voltage, resulting in an essentially lossless switch. This is very easy in ac circuits as the supply voltage itself gets zero 50-60 times a second. ZVS improves the life of controller as well as the load as it reduces the chances of arc formation in the relay. Without ZVS the power could get turned on when the voltage is, may be 120VAC which could result to an electrical arc (spark). Signal going to the opto- isolator is controlled with the help of pulse- width modulation technique. The output is observed by the ON and OFF of the three lamps which depicts the three phase supply in the normal power system.

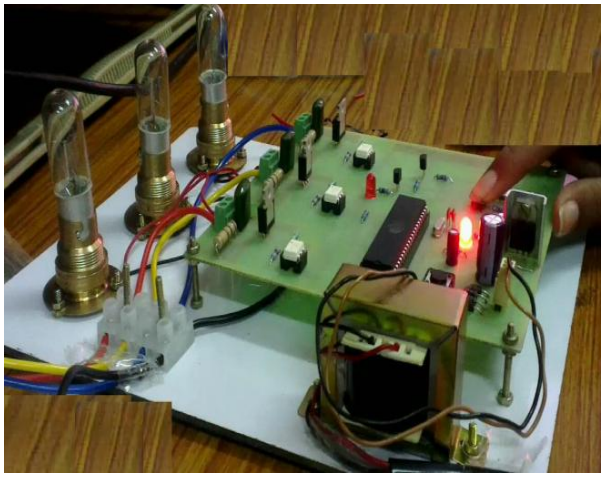


Figure 8: *Lamps are off*

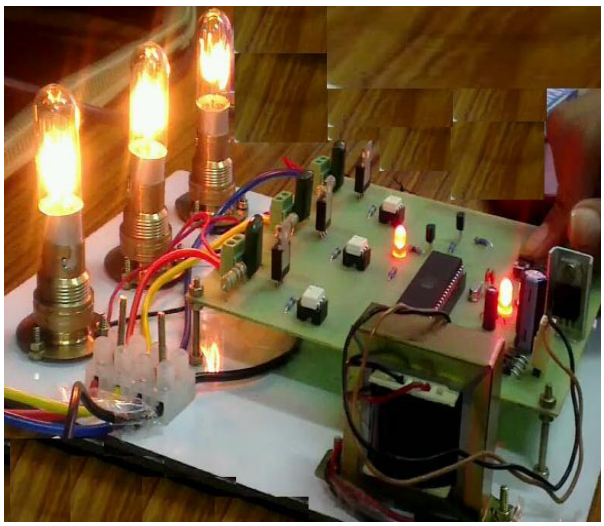
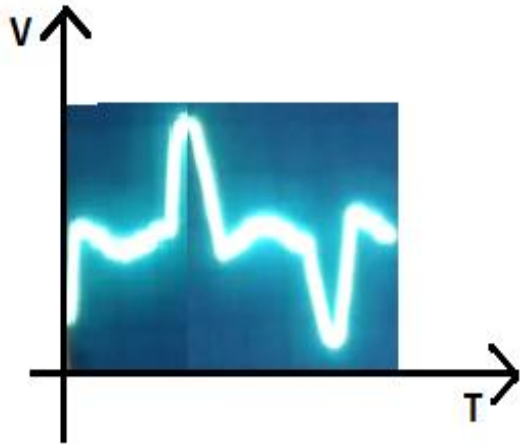
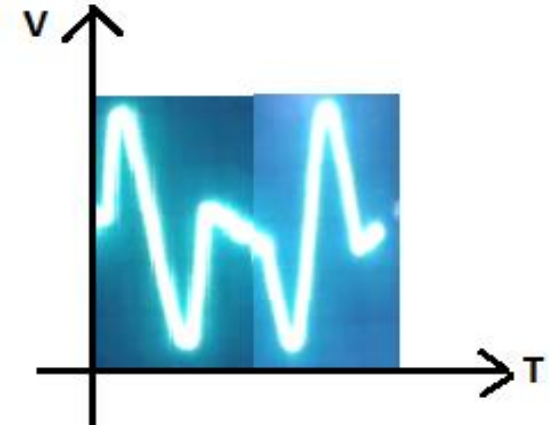


Figure 9: *Lamps are ON after pushing the push button*

RESULT





The load gets turn on or off only at zero voltage, the supply being A.C. gets zero 50 times in one second if the supply frequency is 50Hz. The above output is shown on the CRO across the load. Resistive path was needed to be provided between the CRO and the load so as to bring the voltage in range of CRO display. This could also be done by providing an isolated transformer across the load. By increasing the delay we can get different output with which the flickering of the lamp (load) changes and similarly the output on the CRO changes.

APPLICATION OF SOLID STATE RELAYS -

SSR has gained favour in various regions that was earlier the domain of electromechanical relay or contactor. These are increasingly used in transformers, lamps, temperature control, solenoids, motors and valves etc. Few applications include the following:

- Industrial automation, lighting and appliances
- Packaging and tooling machines
- Electronic appliances
- Manufacturing equipment
- Test and security systems
- Instrumentation system
- Production equipment
- On-board power control
- Traffic control
- Elevator control

- Vending machines
- Office machines
- Display and entertainment lighting

ADVANTAGES OF SOLID STATE RELAYS-

SSR has neither moving parts to wear out nor arcing contacts that are often the main cause of failure of EMR

- High degree of reliability
- Long life > 109 operations
- Zero-voltage turn-on, low electro- magnetic induction
- Shock and vibration resistant
- No contact bounce which leads to arcless switching
- Microprocessor compatible
- Fast response

APPLICATION OF RELAYS

Few applications of relay are as follows:

- General Purpose Relays can be used in Office Equipment, Pool and Spa, HVAC appliances and Security.
- Power Relays are used in Appliance Controls, Office and Vehicle Automation, Controlling of various processes in industries, Energy Management Systems, Motor Controls and HVAC.
- Low Signal Relays find their applications in Datacom, Telecommunications, CP/OA and Security devices.
- Solid State Relays are used for Motor Controls, Industrial Control and Timers.
- Signal Relays are used in Test Equipment, Instrumentation and Tele communications.

CONCLUSION

The paper provides implementation of solid state relays with zero voltage switching. Relay plays a pivotal role in modern power system protection to sense and isolate different types of fault in the power circuit. The selection of relays depends on power rating, voltage and current rating, effect of external factors etc. The software and hardware implementation of the solid state relay designed using microcontroller and opto-coupler is provided in the paper. Due to the use of semiconductor, arcless switching is possible with which the efficiency, reliability and life time of the protection unit increases. The output across the load on a CRO clearly depicts that the power losses during switching are reduced to a minimal value due to zero voltage switching. Isolation of faulty sections of power circuit during zero voltage switching leads to reduction in harmonics.

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