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SIMULATION OF D-STATCOM IN POWER SYSTEM

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***ABSTRACT* :** *A Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure or a mis-operation of end user equipments. Utility distribution networks, sensitive industrial loads and critical commercial operations suffer from various types of outages and service interruptions which can cost significant financial losses. With the restructuring of power systems and with shifting trend towards distributed and dispersed generation, the issue of power quality is going to take newer dimensions. In developing countries like India, where the variation of power frequency and many such other determinants of power quality are themselves a serious question, it is very vital to take positive steps in this direction .The present work is to identify the prominent concerns in this area and hence the measures that can enhance the quality of the power are recommended.*
This work describes the techniques of correcting the supply voltage sag interruption in a distributed system. At present, a wide range of very flexible controllers, which capitalize on newly available power electronics components, are emerging for custom power applications A D-STATCOM injects a current into the system to correct the voltage sag, interruption. Results are presented to assess the performance of device as a potential custom power solution. The validity of proposed method and achievement of desired compensation are confirmed by the results of the simulation in MATLAB/ Simulink.

***Keywords*:** *D-Statcom,, voltage dips, interruption, power quality, VSC.*

I. INTRODUCTION

The name power quality has become one of the most productive concepts in the power industry since late 1980s. Power Quality concept mainly deals with three factors namely Reliability, Quality of Supply and Customer service. Power quality may be defined as the ***"Degree to which both the utilization and delivery of electric power affects the performance of electrical equipment."***

Power quality in electric networks is one of today's most concerned areas of electric power system. The power quality has serious economic implications for consumers, utilities and electrical equipment manufactures. Modernization and automation of industry and increasing use of computers, microprocessor and power electronics system such as adjustable speed drive. Integration of non-conventional generation technologies such as fuel cells, wind turbines and photo-voltaic with utility grids often requires power electronic interfaces. The power electronic system also contributes to power quality problem. Under the deregulated environment, in which electric utilities are expected to compete with each other, the customer satisfaction becomes very important. The impact of power quality problems is increasingly felt by customers industrial, commercial and even residential.

The power quality problems can be solving by considering two approaches. According to first approach the solution to the power quality problems can be done from the utility side. This approach is called as load conditioning, in which the equipment is considered less sensitive to power disturbances, allowing the operation even under significant variation distortion.

In second approach, install line conditioning system that suppresses the power system disturbances. In this approach the compensating devices is connect to low and medium voltage distribution system in shunt. Shunt power filters operate as a controllable current source. The scheme is implemented with voltage source PWM inverters, with a dc source having a reactive element such as a capacitor. Apart from this there are many approaches to nullify the problems, but in this paper we are solving the problem using shunt controller only.

To solve the power quality problem, custom power devices used here is D-STATCOM. D-STACOM is the most efficient and effective modern customs power device used in power distribution networks.

In a three-phase system, unbalanced voltages also are a power quality problem. Among them, two power quality problems have been identified to be of major concern to the customers are voltage sags and harmonics, but this paper will be focusing on voltage sag.

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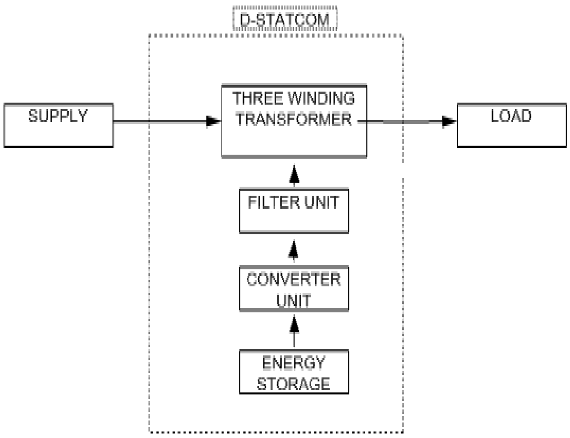
1. D-STATCOM:

The D-STATCOM is basically one of the custom power devices. It is nothing but a STATCOM but used at the Distribution level. The key component of the D-STATCOM is a power VSC that is based on high power electronics technologies.

Basically, the DSTATCOM system is comprised of three main parts: a VSC, a set of coupling reactors and a controller. The basic principle of a D-STATCOM installed in a power system is the generation of a controllable ac voltage source by a voltage source converter (VSC) connected to a dc capacitor (energy storage device). The ac voltage source, in general, appears behind a transformer leakage reactance. The active and reactive power transfer between the power system and the D-STATCOM is caused by the voltage difference across this reactance. The D-STATCOM is connected in shunt with the power networks at customer side, where the voltage-quality problem is a concern. All required voltages and currents are measured and are fed into the controller to be compared with the commands. The controller then performs feedback control and outputs a set of switching signals to drive the main semiconductor switches (IGBT's, which are used at the distribution level) of the power converter accordingly. The basic diagram of the D-STATCOM is illustrated in Fig 1.& in Fig.1.1. The ac voltage control is achieved by firing angle control. Ideally the output voltage of the VSC is in phase with the bus voltage. In steady state, the dc side capacitance is maintained at a fixed voltage and there is no real power exchange, except for losses.



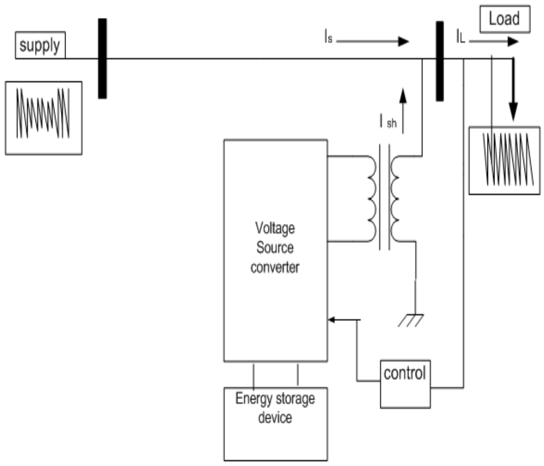
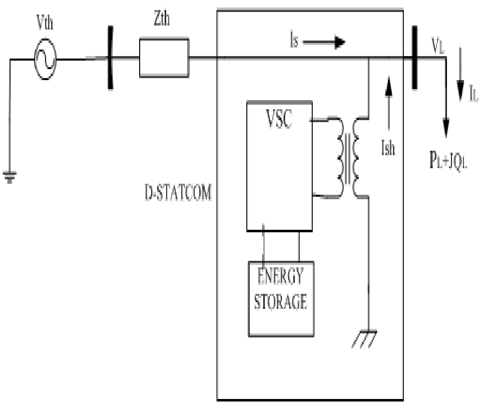


Fig. 1Block diagram of D-Statcom. **Fig. 1.1 Principal of D-Statcom.**



1.2 PRINCIPLE OF VOLTAGE REGULATION

1.2.1 Voltage regulation without D-Statcom

Consider a simple circuit as shown in fig. 1.2. It consists of a source voltage V_{th}, V_L is the load voltage and load current I_L. Without a voltage compensator the load voltage drop caused by the load current I_L. The change in load voltage is ΔV.

$\Delta V = V_{th} - V_L = Z_{th} * I_L$

$I_L = \frac{(PL - jQL)}{VL}$

$\Delta V = (Rth + jXth) * (\frac{(PL - jQL)}{VL})$

$\Delta V = \Delta Vr + \Delta Vx$

So, the voltage change has a component ΔVr in phase with Vth and component ΔVx having lagging phase difference.

Fig. 1.2 Schematic diagram of D-Statcom

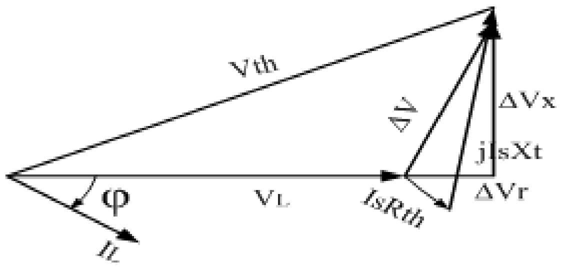


Fig.1.2.1 Phasor diagram of uncompensated.

1.2.2 Voltage regulation with DSTATCOM

Now consider a compensator connected to the system. It is as shown in Fig 1.2.1 shows vector diagram with voltage compensation. By adding a compensator in parallel with the load, it is possible to supply voltage =Load voltage by controlling the current of the compensator.

$$Is = Ish + I_L$$

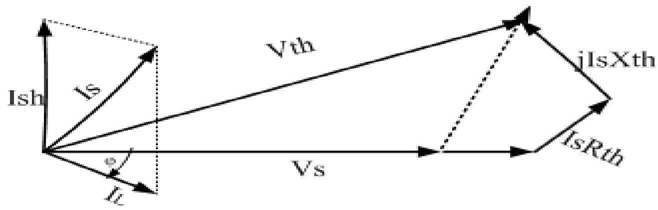


Fig.1.2.1 Phasor diagram of compensated.

II. CONTROLLER

A controller is required to control or to operate both D-Statcom a during the fault condition only. Load voltage is sensed and passed through a sequence analyzer. The magnitude of the actual voltage is compared with reference voltage i.e Vref. Pulse width modulated(PWM) control system is applied for inverter switching so as to generate a three phase 50Hz sinusoidal voltage at the load terminals. Switching frequency in the range of few KHz. The IGBT Inverter is controlled with PI controller in order to maintain 1p.u voltage at the load side. An advantage of proportional pulse integral controller is an actuating signal which is the difference between the reference voltage and feedback load voltage. Output of the controller is in the form of an angle δ, which introduces additional phase-lag/lead in the three-phase voltage. The output of error detector is the missing voltage. The controller output when compared at PWM signal generator hence, the result in the desired firing sequence.

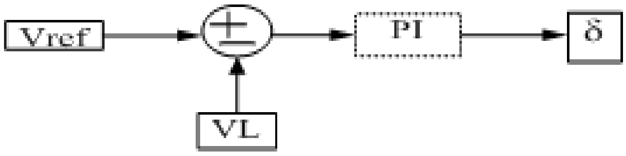


Fig.2.1 Schematic of PI controller

The sinusoidal signal $V_{control}$ phases modulated by means of the angle δ are,

V_A=Sin (ωt + δ) V_B=sin (ωt + δ -2π/3) V_C =sin (ωt + δ+2π/3)

This modulated signal is compaired with triangular signal and generates the switching signals for the converter valves. The main parameters of the sinusoidal PWM scheme are the amplitude modulation index of signal, and the frequency modulation index of the triangular signal. The modulating angle is applied to the PWM generator in phase A. the angles for Phase B and phase C are shifted by 120º and 240º lagging respectively. The speed of response is clearly shown in the simulation result shown.

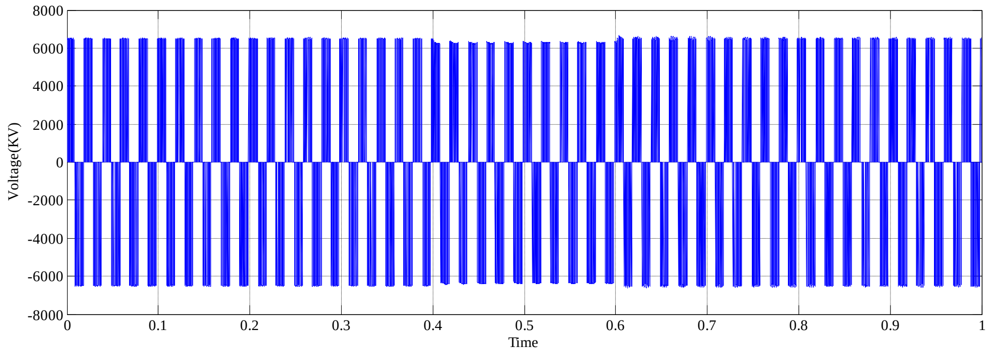


Fig. 2.2 output of proposed two level voltage source converters.

III. PARAMETERS OF D-STATCOM TEST SYSTEM

The test system consists of 230KV, 50Hz transmission line (considered to be source). This source, feeding two transmission lines feed two distribution network through a three winding transformer connected in Y/Δ/Δ 230/11/11 KV.

TABLE system parameters

Sr. No.	System Quantities	Standards
1	Source	230KV, 50Hz 100MVA
2	Three winding transformer	100MVA,Y/Y/Y 230/11/11 KV
3	Load on bus1	P=1.776MW, Q= 65.26MVAR(highly inductive)
4	Load on bus2	P=385.124KW Q=2MVAR(highly inductive)
5	Injection transformer	100MVA, 50Hz,Δ/Y 11/11KV
6	Inverter parameters	IGBT based, 3 arms, 6 pulse, carrier Frequency=1080Hz

SINGLE LINE DIAGRAM OF THE D-STATCOM TEST SYSTEM:

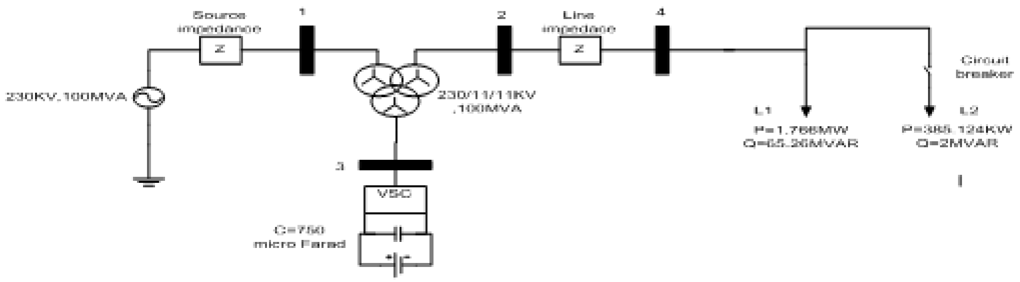


Fig. 3 single line diagram of test system for D-statcom.

IV. SIMULINK MODEL OF TEST SYSTEM AND RESULTS

4.1 Simulation of test system without fault and without D-STATCOM

This simulink model present the test system without any fault and no connecting custom device like D-STATCOM .

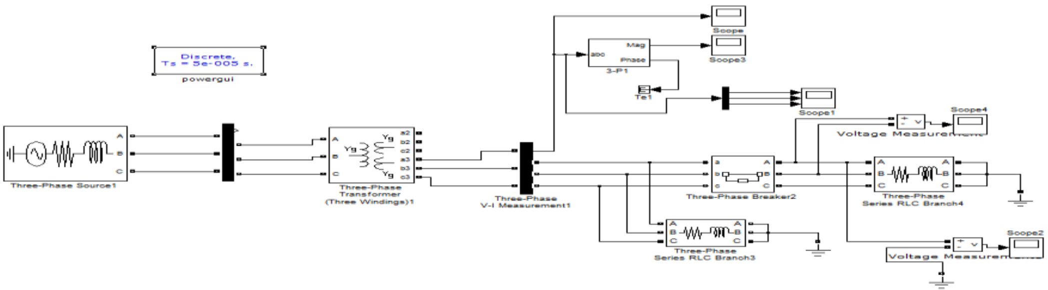


Fig.4.1. simulink mode without fault and without D-STATCOM.

4.2 Simulation Results without fault and without D-STATCOM

The following results shows the system when considering no fault and no connection of D-STATCOM rms value of Voltage in p.u, instantaneous voltages and line to line voltage of the simulation result shown in the following fig.4.2.1 and 4.2.2 respectively. The line to line voltage is 11KV is measured.

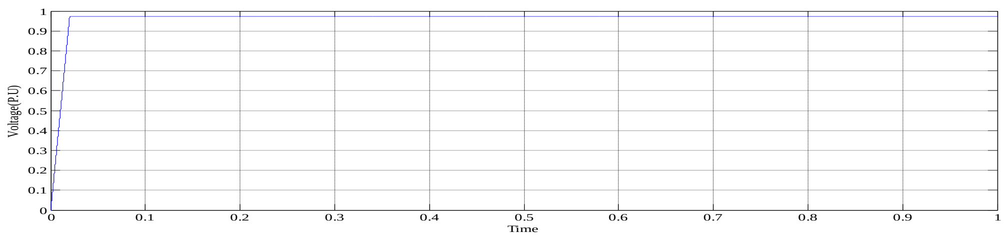


Figure 4.2.1 Voltage Vrms(p.u) at load side.

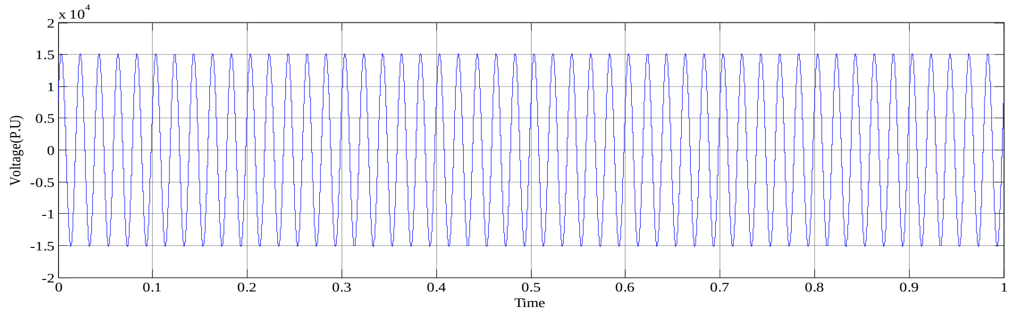


Figure 4.2.2 line to line voltage (KV) at load side.

4.3 Simulation of test system with fault but without D-STATCOM

In this simulink model we have system in which source is connect to primary side of tertiary transformer as shown. The load is connected to the secondary sides of 11KV.the sag is create here by providing the switching for the interval of 0.4-0.6 sec.

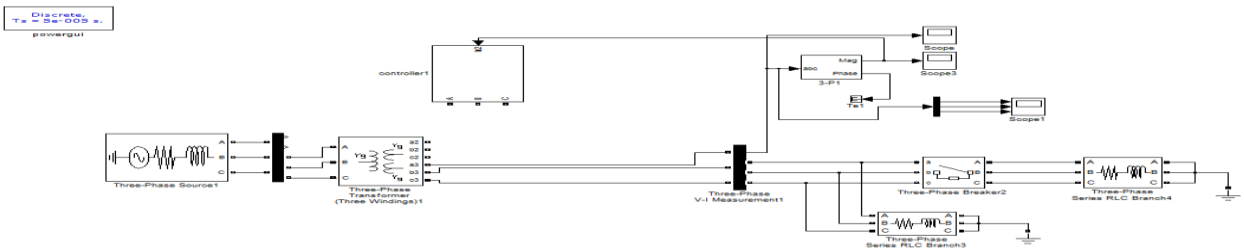


Fig. 4.3 simulation test system without D-STATCOM

4.4 Simulation Results with fault but without D-STATCOM

From the following results it is observed that during the fault time i.e 0.4-0.6 sec, the voltage sag to some finite value. The sag during the fault at the load side is nearly 10-15% , and measured the line to line voltage value during fault time is 10.25KV. Such observation can be found on the following fig.4.4

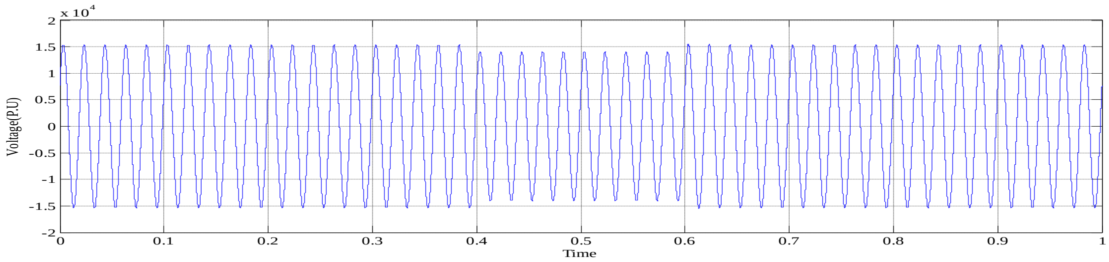


Fig. 4.4 line to line voltage (KV) at load side.

4.5 Simulation of test system with D-STATCOM

In this simulink model we have system which fed the load through secondary winding of tertiary transformer as shown. Out of two parallel loads, sag is created by providing the switching on one of load. The D-STATCOM is connected to one of the secondary winding of tertiary transformer .The system is shown in following fig.4.5.

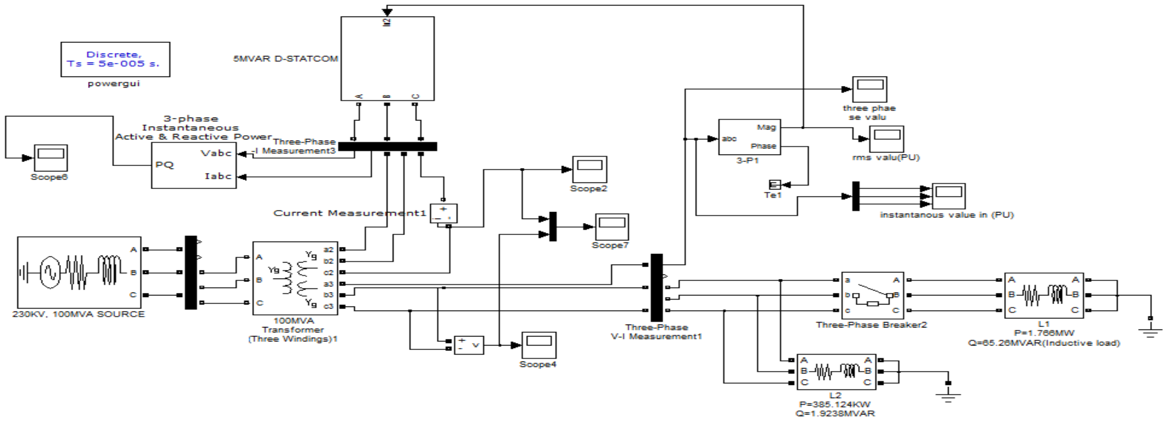


Fig.4.5 simulation test system with D-STATCOM

4.6 Simulation Results with fault and with D-STATCOM

From the following results it is clear that the D-STATCOM compensate the voltage sag during the fault time 0.4-0.6 sec. the compensated results of sag with respective line to line voltage is shown in fig.4.6. The battery voltage is found to be 28KV.

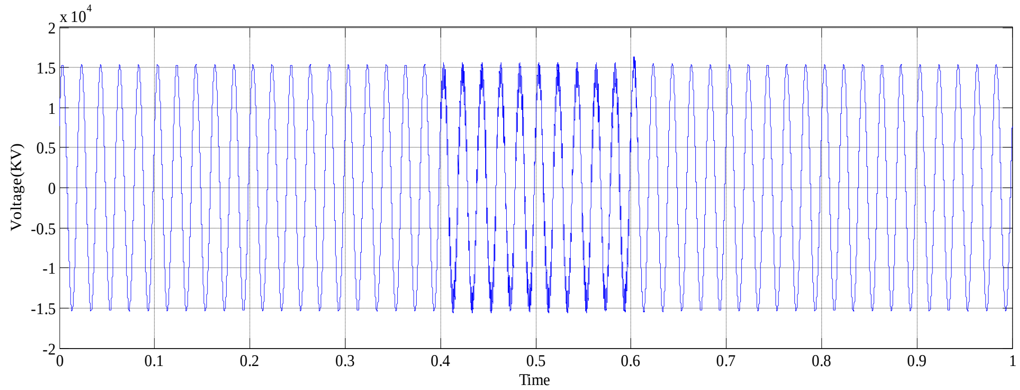


Figure 4.6 line to line voltages (KV) at load side. with fault and with D-STATCOM

V. FUTURE SCOPE

The following point can be consider for future extension of work

- The control circuit can be change. The other controller like fuzzy, PQ technique and adaptive PI fuzzy controller may employ in the compensation scheme.
- Result can be improve by considering the operation with multi-level inverter
- Both custom devices can be established for active loads like wind turbine and solar source.

VI. CONCLUSION

The paper presented the study and simulation model of custom power equipment, namely D-STATCOM. and applied them for power quality problem such as voltage sag. The highly develop graphic facilities available in MATLAB is used to conduct all the aspect of model implementation and to carry out extensive simulation studies. A controller which is based on closed loop technique is used which generate error signals and this signals are used to trigger the switches of inverter using pulse width modulation (PWM) scheme in the D-STATCOM. This PWM control scheme only requires voltage measurements. The simulations are carried out for both sag on 11KV feeder using both D-Statcom. as custom power devices and it has been found that D-Statcom provide excellent voltage regulation capabilities.

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