The Communication Method at the Auto-Startup System using TCP/IP and VXI and Expert System(G2)

Jung-Soo Kim and Joon Lyou

Abstract : This paper describes the communication method of an auto-startup system. The Auto-Startup system is designed to operate a nuclear power plant automatically during the startup operation. In general, the operations during startup in existing plant have only been manually controlled by the operator. The manual operation caused to the operator mistake. The Auto-Startup system consists of the Distributed Control System(DCS) and G2(Expert System). Also, Functional Test Facility(FTF) provides the plant's real-data for an Auto-Startup system. So, it is necessary to develop the communication method between these systems. We developed two methods: one is a network and the other is a hardwire line. To communicate between these systems(DCS-G2 and DCS-FTF), we developed the communication program. In case of DCS-FTF, we used the TCP/IP and VXI. But, in case of DCS-G2, we, what it called, developed the bridge program using the GSI(G2 Standard Interface). We test to check the function of the important parameter, on time, for analysis of the developed communication method. The results are a good performance when we check the communication time of important parameter. We conclude that Auto-startup system could save heat-up time about at least 5 hours and reduce the chance of the reactor operations and trip.

Keywords : Inter-Process Communication(IPC), Transmission Control Protocol / Internet Protocol(TCP/IP), G2, shared memory, Application Program Interface(API), Distributed Control System(DCS), VXI(Versa module eurocard eXtensions for Instrumentation) interface.

I. Introduction

Generally, the startup operation in a nuclear power plant consisted of four operational modes: the operation mode from cold shutdown to hot shutdown, the operation mode from hot shutdown to hot standby, the operation mode of a secondary system's heatup/startup and the operation mode from hot standby to 5%. Usually, the operations at these startup modes in existing nuclear power plants have only been manually controlled by the operator. The manual operation of this stage increases an operator's burden, thereby causing operator mistakes to occur[1]. In practical, when we installed the auto-startup system in nuclear power plant, the examination at the field trial test in Japan shown that the heatup & cooldown automation reduces the operator's manipulation frequency to approximately 40% and the operator's monitoring frequency to approximately 25%[2].

The Auto-Startup System is designed to operate a nuclear power plant automatically during the startup operation[3][4]. This system is designed to set a plant's parameters automatically in a manner similar to the method described in the General Operation Procedure (GOP). For the detailed contents of GOP, refer to the reference[1]. The Functional Test Facility(FTF) includes a software-code which simulates a Nuclear Power Plant. This facility will be utilized for testing or providing the real-data of a plant for the auto-startup system or advanced alarm system or accident identification system. The purpose of the test facilities is to test and validate the developed control algorithm, alarm reduction algorithm, and performance of the operator support system using artificial intelligence technology. This test facilities are increasingly being used to perform plant investigation and activities related to I&C systems such as integration testing, dynamic testing, engineering simulation, and verification and validation [5][6]. Also, the G2, a real time expert system developing tool, is used in the role of supervisory-control within the auto-startup system. The auto-startup system consists of the DCS and G2. The FTF provides the plant's real-data for an auto-startup system. These systems are connected to a network and hardwire. If we install a developed system in an existing nuclear power plant, it will be necessary to the hardwire because the existing power plant is not used in the network system. We have therefore developed two methods: one is a network and the other is a hardwire line. That is, the DCS-G2 is used in the network and DCS-FTF is used in the combined method(network and hardwire). In the case of the hardwire, most of the safety parameters are used. The non-safety parameters are used in the network. If we install this developed system in an

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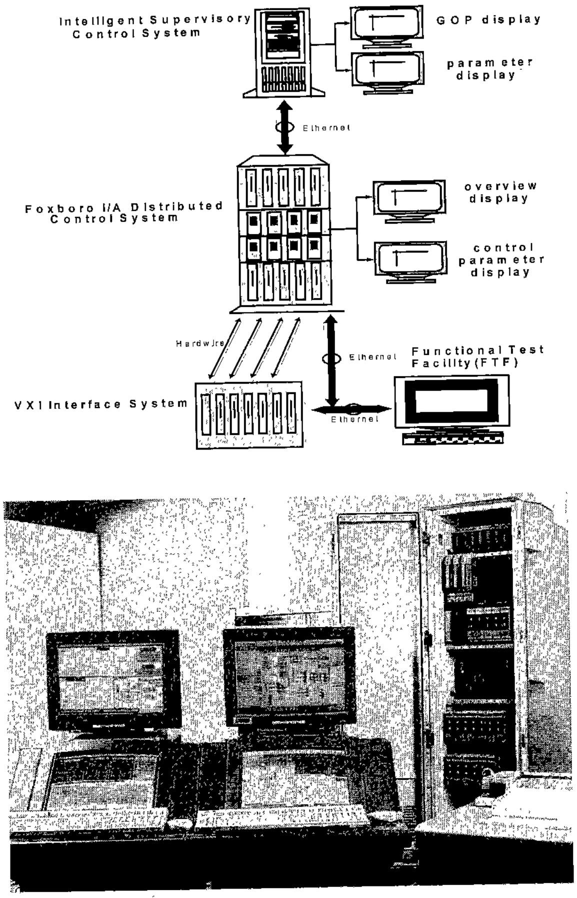

Fig. 1. The overall auto-startup system hardware configuration.

existing plant, the established hardwire line at the power plant will be directly linked to the DCS's field bus module. Fig. 1 shows the overall auto- startup system hardware configuration. To communicate between these systems(DCS-G2 and DCS-FTF), we developed a communication program. The communication method is divided into two parts: the DCS-G2 and the DCS-FTF. The DCS takes charge of controlling each mode's controller(mode I from cold shutdown to hot shutdown, mode II from hot shutdown to hot standby, the critical mode from hot standby to 5% and the secondary mode of the secondary system's heatup) and the G2 is in charge of controlling the DCS's controllers appropriately. The communication method developed in DCS-FTF is designed for the two-server process and two client program. The server in the function test facility includes two processes: the sending process and the receiving process. These two processes are generated by the fork function from the client signal. The client in the distributed control system includes two separate programs: a receiving and sending program. Also, the communication method developed in DCS-G2 is designed to receive the necessary data during the startup operation from the DCS, to process this data in the G2, and to send the G2's control data to the DCS's shared

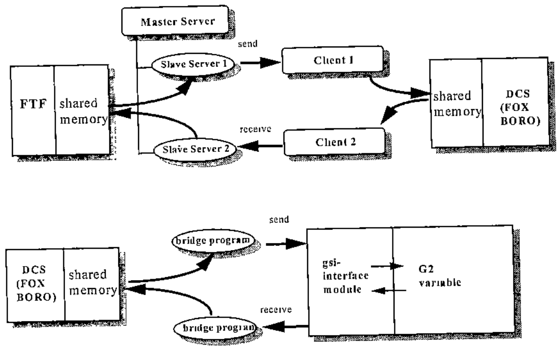

Fig. 2. Data flow between the auto-startup system and functional test facility.

memory. To develop the communication program, we used the shared memory((Interprocess communication: IPC) function) for receiving/sending the data between the two systems(DCS-FTF). In the case of the DCS, we utilized an API software tool[7]. The function of the API is similar to that of the IPC. In the case of DCS-G2, we used somewhat the same method as that of the DCS, but the G2 system used a different method. In the case of the G2, we utilized the GSI(G2 Standard Interface) interface module for receiving/sending the data within the G2[8]. Fig. 2 shows the data flow between the auto-startup system and functional test facility. In this paper, communication method at the auto-startup system and experimental of the developed system are described.

II. Development of communication method

1. The communication method of the functional test facility

Before the data exchange, we need to know how to access the shared memory and get the data to the shared memory. The reason we used the shared memory is because we wanted to separate the main program in the functional test facility from the communication program and easily extract the needed data from the database of the main program using IPC's function without going through the kernel. The merit of using the shared memory is to lessen the communication load on the inside of the workstation and increase the communication speed. The functions utilized for accessing

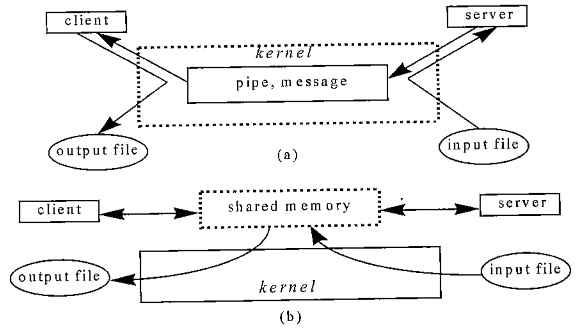

Fig. 3. The comparison of the communication method using the kernel with that using shared memory.

the shared memory are as follows: shmget(), shmat(), shmdt(), shmctl(). The detailed role of these functions are described in Reference [9]. Fig. 3 shows a comparison of the communication method using a kernel with that using a shared memory. After accessing the shared memory, we started the data-exchange. We designed a communication program having two slave servers below a master because we separated the sender process from the receiver process. Two processes are generated by a fork function. The fork function is executed when the signal is requested to connect by the client.

2. The communication method of DCS

In the case of the DCS, the method to access the shared memory is different. That is, we utilize the API (Application Program Interface) for accessing the shared memory at the DCS. The API S/W tool is linked between the shared memory and the DCS database. The database of the DCS is called the Object Manager(OM). The OM manages all the data of the DCS. To connect the communication program with the shared memory, we use the read/write function(readval(),wrtval()). This communication program is linked and compiled by the DCS's library function. After accessing the shared memory of the DCS, we start the data-exchange. We designed the two clients correspondent to two servers. The difference between client and server is that the client does not execute the fork but executes the two individual programs i.e., the receiving program and sending program, due to the characteristics of the client system. The read/write function of the DCS is not attached simultaneously to the DCS's shared memory. We therefore separated the read/write function into two individual programs. Also, the scan rate of the two systems is different(because the DCS's scan rate is fixed at 0.5 seconds while the functional test facility's scan rate is 0.25 seconds). We designed the scan rate of the auto-startup system to be fixed at 0.5 seconds.

3. The communication method of G2

In the case of the G2, we used the TCP/IP protocol to develop two bridge programs. The TCP/IP protocol is provided by the kernel of the G2. Although being used the same protocol(TCP/IP), some different method(bridge program) are developed for communication between DCS and G2 because G2 is of the characteristic communication method. To communicate with data between the DCS and the G2, we developed two parts in Fig. 2, one for the DCS and another for the G2. In the case of the DCS, we developed the bridge program for communicating with the G2. This bridge program is linked to the DCS's shared memory. To connect this communication program to the shared memory, we used the read/write function(readval(), wrtval()). This bridge program was installed within the DCS. Another part is the G2 standard interface module, GSI. The GSI module provides the external interface module within the G2. To utilize the GSI module, we set up the gsi-object and the gsi-object-definition. This gsi-object set up the connection configuration(for example, communication protocol, communication port, a point(for example, machine id number)) to send/receive data-exchanges from the DCS. Also, we defined the parameter variables from the DCS. We used the gsi-object-definition module which fixes the attributes of each variable(for example, float/integer, validity interval etc.). After setting up the gsi-object module's parameters, we started the data-exchange. We designed the operation to handle four programs separately because we disconnected the analog/digital and the send/receive data concerned with the two bridge programs receiving and the other programs sending. Two programs are involved in the receiving/sending of analog data. The others concern the receiving/sending of digital data. Of course, the scan time of the G2 setup is 0.5 seconds.

4. The communication method of VXI module

The VXI system is linked to the Functional Test Facility by Ethernet. Also the VXI system is linked to the DCS's Field bus module. VXI is the multivendor open architecture industry standard(IEEE-1155) for card-modular instrumentation. VXI was developed to meet the need of portable applications and provide a standard modular architecture for integrating into the general purpose interface bus(GPIB) test system and for stand-alone applications. In addition, the VXIbus specifies radiated and conducted electromagnetic compatibility(EMC) limits for both generation and susceptibility. EMC limits ensure that modules containing sensitive electronics circuits perform to expectations without interface from any other module operating in the system. The communication method moves in two ways: from FTF to DCS through VXI and from DCS to FTF through VXI. In the case of the FTF, the Functional Test Facility's signal is sent to the VXI module. This signal is changed to the electrical & contact signal(0-10Vdc or 4-20 mA) through the VXI interface module because the DCS is received only by the electrical signal(from 0-100 % to 4-20mA). The DCS field bus module is changed to the engineering unit from the electrical signal appropriately. In the case of the DCS, the DCS signal is sent to the VXI module through the hardwire line. The received signal is converted to an engineering unit from an electrical signal(from 4-20mA to 0-100%). The VXI module was used because if this developed system is installed in an existing plant, a hardwire system will be needed(because the existing power plant is not used to the network system until now).

III. Experiment of a developed communication method

Generally, there were two kinds of analysis of network system. First, we used the network protocol analyzer. The network analyzer was checked to the number of the data and the data arrival time, etc. Second, we checked the function of the important parameter, that is, this parameter was operated on time, etc. So, we choose the second method for analysis of the developed communication method. We analyzed the General Operating Procedure within the startup stage for developing an auto-startup system. As we analyzed the general operating procedure, the DCS-FTF received about 296 variables(the sum of the analog and digital parameters) from FTF(hardwire: 196, network: 100) and sent about 157 variables to FTF(hardwire: 137, network: 20). Of course, we classified the safety parameters from the GOP. Also, the DCS-G2 sent about 296 variables (the sum of the analog and digital parameters) from the DCS to the G2 and received about 60 variables(the sum of the analog and digital parameters) from the G2 to the DCS. This data was read by the communication program, one by one, put in the DCS's shared memory, one after another, and sent to the G2. In the reverse procedure, the G2 was sent to DCS's shared memory, this data was changed and the DCS's changed data was sent to FTF's shared memory through the VXI module and network. We developed the auto-startup system to four operational modes using the above-mentioned general operating procedure. Tables 1 and 2 show Mode I & II's control-configuration. In these Tables, Mode I's controller is the RCS temperature controller, pressure controller and Pressurizer level controller. To analyse the developed communication method, we chose the Mode I. Table 1 shows that Mode I starts after the coolant loops and the pressurizers are filled and vented. The RCS temperature controller incrases the RCS temperature from 60°C to 176.6°C and the RCS pressure controller maintains a pressure of 24Kg/㎠. So, we showed that each controller of the Mode I appropriately are operated to follow the Pressure-Temperature curve.

In this Figure, the SI bypass valves(KSIBPS) was On(1) and the S/G level(ZSGNOR) was full-level(100 %). From this data, all data was sent to the DCS's

Table 1. The control-configuration of Mode I.

	PID Gain		setpoint	control target	others
RCS temp controller	P	10	increase 0.45/min within 60~176.6℃	RHRS heat exchanger outlet control valve (HV-603)	change the heatup rate through RCP starting number
	I	0.2			
RCS pressure controller	P	2	maintain 24Kg/cm^2	letdown flow control valve (HV-142)	-
	I	0.4			
Pressurizer level controller	P	1	30%	charging flow control valve (FV-122)	start the pressurizer level control after pressurizer bubble generation
	I	4			

Table 2. The control-configuration of Mode II.

	PID Gain		setpoint	control target	others
RCS temp & pressure controller	P	2	176.6~292℃, 25~157Kg/cm^2	pressurizer spray valve (PV-444)	in case of Over heatup, operate PORV, in case of Over Pr. operate heater
	I	0.5			
Pressurizer level controller	P	1	30%	charging flow control valve (FV-122)	continue the Pressurizer level control at Mode I
	I	4			
Steam Generator level controller	P	10	50%	Auxiliary Feed Valve (HV-313/4/5)	start the level control below the 50%
	I	2			
	P	0.1	55%	Blowdown control valve (HV-304/5/6)	start the level control above S/G pressure 10Kg/cm^2
	I	0			

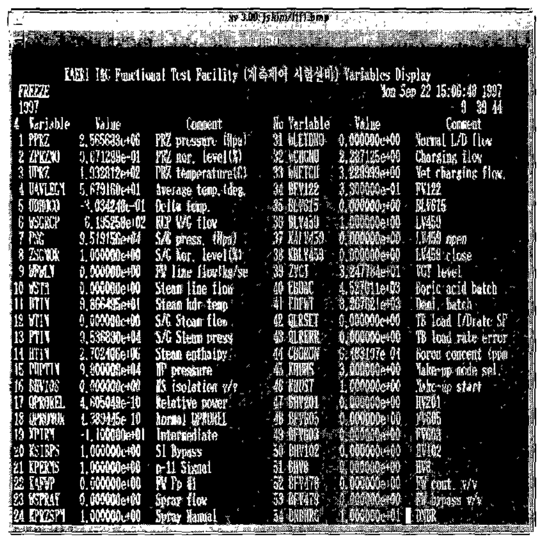

Fig. 4. The beginning data of the FTF at Mode I.

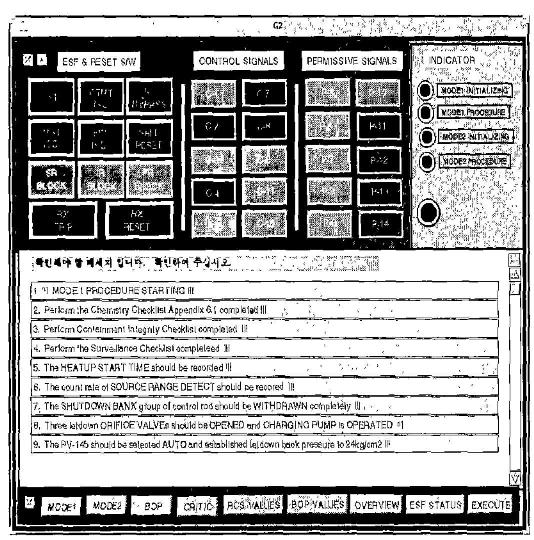

Fig. 5. The configuration of operating procedure of G2 control system.

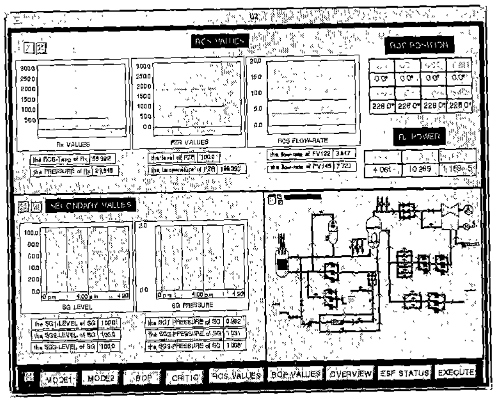

Fig. 6. The overview information constitution of G2 control system.

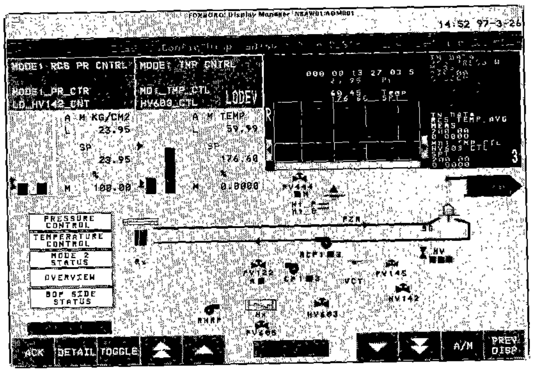

Fig. 7. The Mode I controller's constitution.

shared memory through VXI and network. This shared memory data was sent to the G2 through the network every 0.5 seconds. In this time, the G2 system is started. Fig. 5 shows the configuration of the operating procedure Fig. 4. The beginning display of FTF at Mode I. of the G2 at the beginning of Mode I. The operating procedure is shown at the bottom of this Figure. Also, the plant's important signal is indicated at the top of this Figure. The operator will be recognized at the present plant status.

Fig. 6 shows the overview information constitution of the G2. In this Figure, the operator is provided the overall plant parameters(primary & secondary parameters). Fig. 7. shows the Mode I control constitution. In this Figure, the pressure of mode I was controlled by the HV142 valve and we set up the setpoints to 24Kg/㎠. Also, the temperature of mode I was controlled by the HV603 valve and we fixed the setpoints to 176℃. The DCS PID(Proportional Integral and Derivative) controller constitutes that each controller follows the setpoint. That is, the G2 control's mode I signal is sent to each Mode I controller and the DCS's controller fixes the controller setpoint automatically and this controller's output is sent to the FTF. Fig. 8 shows the overlay display in each valve and pump. The operator knows each component's status(for example, valve and pump). This overlay display shows the RCP pump's status

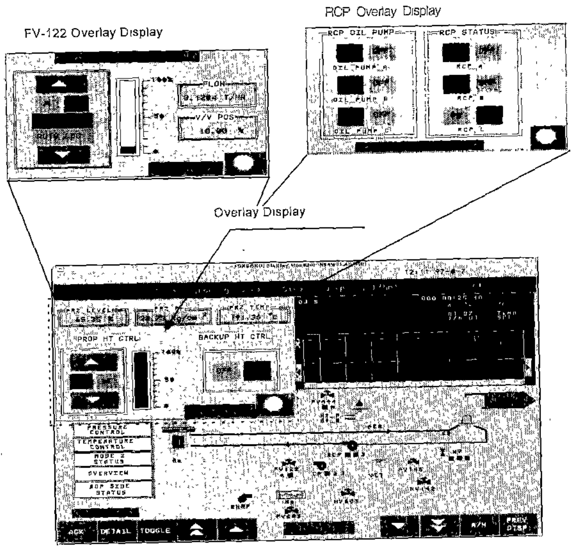

Fig. 8. The overlay display in each valve and pump at DCS.

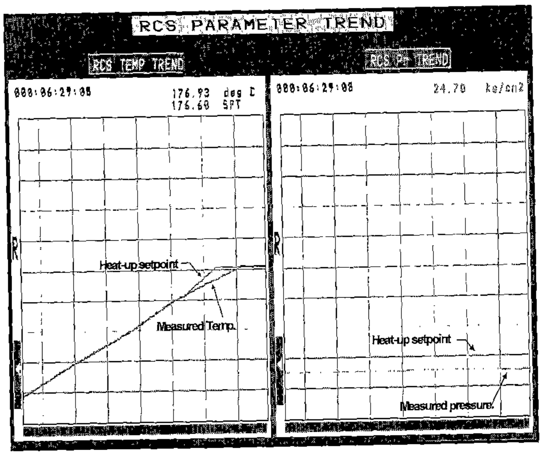

Fig. 9. The test result to control the RCS pressure and temperature at Mode I.

(On/Off) and FV-122 valve position. In each figure, the analog data display digit values and digital data shows the color; for example, the Pressurizer pressure is 23.73Kg/㎠, one RCP pump is red, two RCP pumps are blue(blue: off, red: on). Fig. 9 shows the RCS pressure and temperature from Mode I. Each controller follows the setpoint which we have already fixed. For the performance test of Mode I, the heat-up rate was set to 27℃/hr, the start temperature and the target temperature were 60℃ and 176.6℃ and the pressure setpoint was 24Kg/㎠ from Table 1. From the Mode I test, the heatup time to reach the target temperature was taken about 7 hours. The automatic temperature controller saved heat-up times about 2 hours than the skillful manual operation for heat-up operation. For the operation test of Mode II, the heatup rate was the same as that of Mode I in Table 2, that is, the target temperature was 292℃ and the pressure setpoint was 157Kg/㎠. From the Mode II test, the heatup time to reach the target temperature was taken about 8 hours. The automatic temperature controller saved heat-up times about 3 hours than the skillful manual operation. So, we concluded that Auto-startup system could save heat-up time about at least 5 hours and reduce the chance of the repeated operations and trips.

IV. Conclusion

In this paper, we developed a communication method using TCP/IP protocol and the shared memory between DCS and FTF. Also, we developed a bridge program using a GSI interface module. The methods of sending/receiving the plant data in a shared memory utilize the IPC function in FTF and API S/W tool in the DCS, respectively. The merit of the developed communication method is that it lessens the communication load at a workstation and increases the communication speed because a shared memory was used. Furthermore, the program easily accesses the database. Even if this method is applied to different systems, it can be easily used because of the general protocol and method of handling the shared memory. The proposed method has drawbacks regarding the testing of common-mode failure(including H/W and S/W) and software Verification and Validation, but it is possible to carry out a dynamic test using FTF, one step in the software Verification & Validation process. Also, if the next nuclear power plant is fully-digitalized or the auto-startup system is applied to the next generation Nuclear Power Plant, this system can be used to consider software Verification & Validation and common-mode failure. Futhermore, as we considered the existing plant, there will be no problem even if the developed system is installed to an existing plant.

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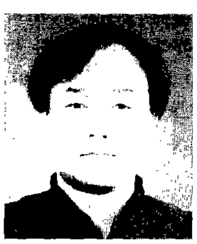

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