

## Design of Virtual Simulation System for Oil and Gas Gathering and Transportation

Wei Li <sup>a</sup>, Mingjiang Shi

Southwest Petroleum University, Chengdu, China

<sup>a</sup>leway@live.com

### Abstract

Oil and gas gathering and transportation is a complex system that concentrating oil, natural gas and other products produced by dispersed oil wells to oil and natural gas, to refiners and users. In order to produce qualified oil and gas, the level of oil and gas gathering and transportation's automation has a very high requirement. In the gathering and transportation process will inevitably encounter various problems need to be solved in time, technical personnel need to be familiar with the system operation and control principles, and can solve the problem in a limited time. Based on reliability, security and economy, this paper develops a set of simulated oil and gas gathering and transportation system based on virtual reality technology, OPC technology and mathematical modeling technology for high cost, high consumption and high risk environment of oil and gas gathering and transportation system. The System can be connected to a virtual PLC for simulation, you can visually see the simulation results. The system will reducing the material and time cost for debug PLC program, and can also be used for training needs.

### Keywords

Virtual Simulation, Virtual PLC, Oil and Gas Gathering and Transportation.

### 1. Introduction

Oil and gas gathering and transportation is an important subsystem in the huge and complex petroleum industry. It includes the collection, initial processing, separation, storage and transportation of oil and natural gas, not only the process is complicated and the process is complex, the oil and gas gathering level reflects the oil and gas field Development level, and the economic benefits of oil and gas fields are closely related. The joint station as a chain in the chain is a very important part of its monitoring system design level and staff familiarity with the system, and the joint station efficient, safe and stable operation is closely related. A virtual simulation system based on virtual reality technology, combined with virtual PLC and OPC technology was developed. In the joint station project to build hardware, the virtual simulation system is conducive to technical staff debugging PLC program code, identify the lack of control procedures, shorten the project on-line time. After the operation of the joint station, virtual reality system immersed in virtual reality, interactive features, is very suitable for training and teaching. The virtual simulation system of the joint station researched in this paper focuses on 3D visualization modeling, virtual roaming engine, OPC communication, the realization and configuration of virtual PLC. Virtual PLC through the OPC server communication control signal output to the virtual simulation system, after the mathematical model of the system, then the output signal Feedback to virtual PLC.

### 2. Design of virtual simulation system

#### 2.1 The software used

STEP7 is the Siemens PLC programming software, S7-300 and 400 series PLC programming software.

S7 PLCSIM is Siemens PLC simulation software, supports S7-300 and 400 series PLC simulation, S7 PLCSIM does not support through the CP communication.

Simatic net is Siemens communication software, this article used to fight OPC sever solve the host computer configuration software does not support Siemens communication protocol, can not directly access the s7-300 / 400 plc problem.

Nettoplcsim was developed by a personal developer to extend the communication interface of PLCSIM through a TCP / IP network interface.

Virtual simulation system of oil and gas gathering, virtual reality simulation software based on Open GL, including roaming engine, UI control interface and mathematical simulation background.

## 2.2 Overall design

In hardware side, there are two computers A and B in the same LAN. In the computer A, the preparation of STEP7 PLC program and the program to configure the project will be written to download PLCSIM simulation, and then open the Nettoplcsim software to configuration. In the computer B need to use Simatic net software to run an OPC Server, and then run the oil and gas gathering virtual simulation system, simulation. Virtual simulation platform block diagram shown in Figure 1.

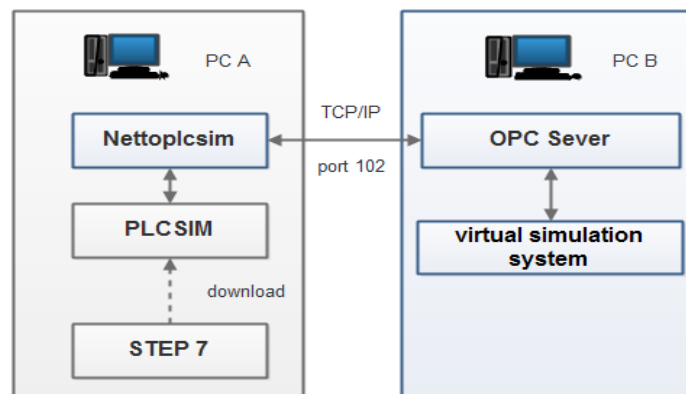


Fig.1 Virtual simulation system for oil and gas gathering and transportation

## 3. The achieve of virtual scene

Oil and gas gathering and transportation simulation system is the core of the entire virtual simulation platform. The virtual scene need to be as same as possible to the real scene, in order to meet the visual sense of reality, immersion and other visual requirements.

### 3.1 Three-dimensional modeling

In this paper, Rhino is used to draw the equipment model of the oil and gas gathering and transportation station, such as three phase separator, hydrothermal heating furnace, large oil storage tank, each of which can be used to build the relevant geometric model by computer 3D modeling method. Rhino uses NURBS (non-uniform rational B-spline curve) curve to describe the model, this creates the surface more smooth and not stiff, commonly used to achieve a complex surface of the three-dimensional model of modeling. In this paper, most of the models are composed of simple geometry, such as cubes, spheres, cylinders, capsules and so on, and then move, zoom, arrange, combine and so on. Small parts of the model such as rotating stairs and other complex surfaces by nurbs modeling method to complete. The different components in accordance with the different maps and state of the sub-group, and then were given the appropriate material, and finally the model exported to. 3ds format file. When exporting 3ds format file, nurbs surface is converted to polygon surface. At this time, you can set the precision of exporting the model, that is, how many triangles and nodes to describe the surface.

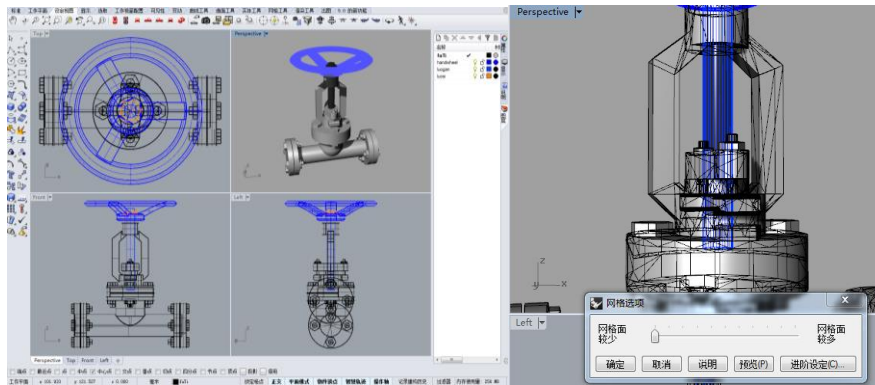


Fig. 2 Rhino for model building

### 3.2 Mapping technology

In order to make these models more real, you need to create the model and the real world to give the same material, so that it produces texture.

So that the model is filled with material texture is the essence of a two-dimensional map of the picture information through the adjustment of the relevant parameters of the projected three-dimensional model of the surface, and to form high light, reflection and other effects, resulting in metal, plastic texture.

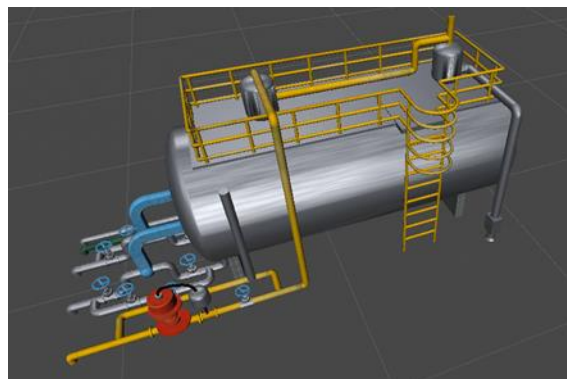


Fig. 3 Three-phase separation model after mapping

### 3.3 Three-dimensional coordinate system

All the built-up models need to be arranged together into the virtual world together, a series of coordinate transformation, the virtual scene will eventually be rendered to the screen.

#### 3.3.1 Geometric transformation

The processing and description of graphics in a roaming system require its coordinate system to provide functions such as pan, zoom and rotate. Translation transformation, scaling transformation, rotation transformation and other three-dimensional coordinate transformation algorithm is one of the more basic and important of the three.

(1) Translation transformation: the object from the original location  $P(x, y, z)$  displacement to a new location  $P(x', y', z')$ , is:

$$\begin{pmatrix} x' \\ y' \\ z' \\ 1 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & a \\ 0 & 1 & 0 & b \\ 0 & 0 & 1 & c \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix} \tag{1}$$

(2) Zoom transformation: change the direction of the object axis ratio, which determines the zoom factor zoom factor zoom transformation or scaling. When the zoom factor is greater than 1, the larger the value the more amplification, the scaling factor is less than 1 greater than 0, the smaller the

smaller the smaller the value. When the scale factor is 1, the model does not scale. When the origin remains unchanged, the matrix of the new scale point coordinates is:

$$S_{s_x, s_y, s_z} = \begin{pmatrix} s_x & 0 & 0 \\ 0 & s_y & 0 \\ 0 & 0 & s_z \end{pmatrix} \quad (2)$$

(3) Rotation transformation: three-dimensional rotation transformation There are three axes can be rotated around, respectively, x, y, z positive direction of the axis, which corresponds to the axis of rotation of the right axis rotation law, the corresponding matrix transformation:

Rotate around the z axis:

$$R_{\theta, I} = \begin{pmatrix} \cos \theta & -\sin \theta & 0 \\ \sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (3)$$

Rotate around the y axis:

$$R_{\theta, J} = \begin{pmatrix} \cos \theta & 0 & \sin \theta \\ 0 & 1 & 0 \\ -\sin \theta & 0 & \cos \theta \end{pmatrix} \quad (4)$$

Rotate around the x axis:

$$R_{\theta, k} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos \theta & -\sin \theta \\ 0 & \sin \theta & \cos \theta \end{pmatrix} \quad (5)$$

### 3.3.2 Spatial transformation

Dimensional model in the modeling of all the points and surface position, that is, the size of the model, the rotation is based on the establishment of three-dimensional model of the software coordinate system, that is, model space. Objects in space require a new three-dimensional coordinate system for graphical description, and the final presentation in front of the user is a two-dimensional picture. So in this presentation process, need to go through many steps of coordinate transformation, in order to achieve the final picture effect. Transformation of the process, as shown in Figure 4.

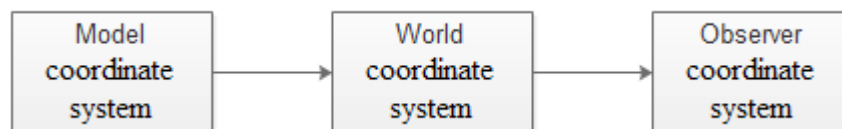


Fig. 4 Coordinate system Transformation

## 4. Realization of Communication System Based on OPC Technology

OPC is the interoperability standard for the secure and reliable exchange of data in the industrial automation space and in other industries.

An OPC server is comprised of several objects: the server, the group, and the item. The OPC server object maintains information about the server and serves as a container for OPC group objects. The OPC group object maintains information about itself and provides the mechanism for containing and logically organizing OPC items.

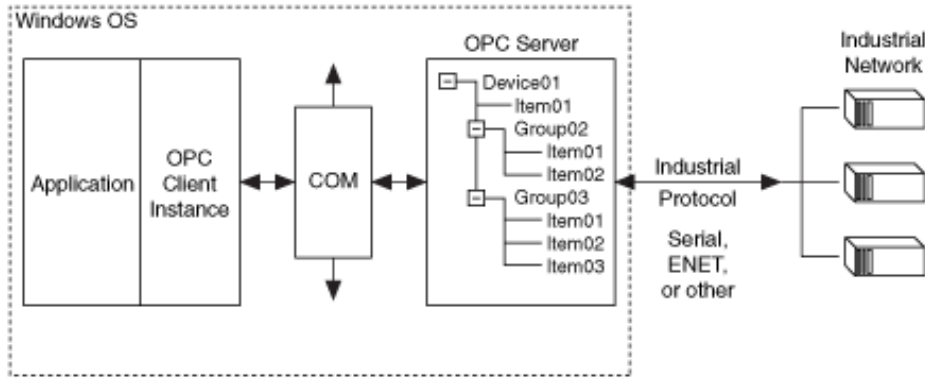


Fig. 5 OPC sever main framework

**4.1 OPC objects and interfaces**

The OPC Server object provides a way to access (read/write) or communicate to a set of data sources. The types of sources available are a function of the server implementation.

An OPC client connects to an OPC server and communicates to the OPC server through the interfaces. The OPC server object provides functionality to an OPC client to create and manipulate OPC group objects. These groups allow clients to organize the data they want to access. A group can be activated and deactivated as a unit. A group also provides a way for the client to 'subscribe' to the list of items so that it can be notified when they change.

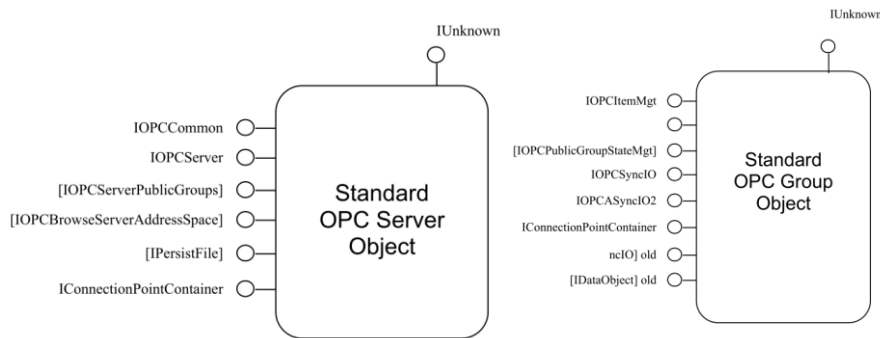


Fig. 6 Standard OPC server object and OPC Group object

**4.2 OPC client core programming and implementation**

Instantiate the OPC server.OPCServer to connect only need to know their PC site name and the corresponding IP address, the official package GetTypeFromProgID interface will automatically through the encapsulated protocol to remotely access the PC site. The implementation of the program shown in Figure 7.

```

public bool CreateServer(out string err)
{
    err = "";
    Type svrComponentTyp = Type.GetTypeFromProgID(m_strProgID, m_strServer);
    try
    {
        m_opcServer = (IOPCServer)Activator.CreateInstance(svrComponentTyp);
        return true;
    }
    catch (Exception e)
    {
        err = e.Message;
        return false;
    }
}

```

Fig. 7 Instantiates the OPC server

## 5. Virtual PLC communication methods and configuration

### 5.1 Function of Nettoplcsim

NetToPLCsim allows us to use network communication together with the PLC-Simulation S7-Plcsim, using the network interface of the PC on which the simulation is running. For example, NetToPLCsim allows to test client application (SCADA system, etc.) together with S7-Plcsim, without a real PLC.

The S7-communication uses TCP port 102. If a Step 7 installed on the system, there is a service called "SIMATIC S7DOS Help Service" (old name was "SIMATIC IEPG Helper"). This service listens on all available network interfaces for incoming connections on TCP port 102. Thus as long this service is running, it's not possible to start an server from another application like NetToPLCsim using this port.

NetToPLCsim supports most of the functions which are supported by S7-Plcsim, such as:

- 1.Tag services: reading and writing data areas.
- 2.Block services: Program upload, program block online view...
- 3.Block specific messages with Alarm\_S, Alarm\_D.
- 4.Support of multiple Plcsim instances on a single computer.

### 5.2 Configuration of Nettoplcsim and PLCSIM

First step, configure the hardware and NetPro in STEP 7.

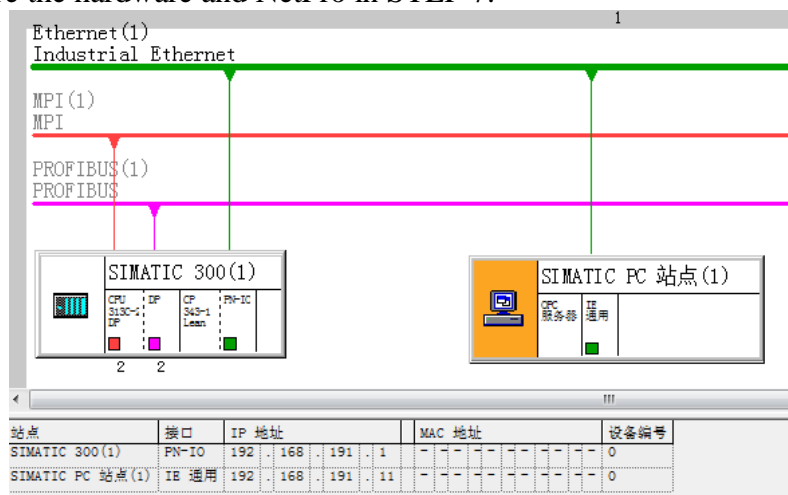


Fig. 8 Configuration of NetPro

Then, in step 7 PG add a new IP address to the network card, through the ip address to achieve the S7-400 Ethernet CPs function.

1. Open the properties of the local connection.
2. Select Internet Protocol version 4 of the fourth version.
3. Open the properties
4. Open the Advanced Settings.
5. Select the IP address and click Add.
6. In the pop-up dialog box, enter 192.168.1.20 and click Add.

The third step is to load the SIMATIC PC station from the SIMATIC Manager.

1. Open PLCSIM from step 7 and set the PG / PC interface to TCP / IP in PLCSIM.
2. Open Nettoplcsim and go to the Windows Task Manager to close the Simatic IEPG Helper service.
3. In Nettoplcsim add a station configuration network ip address and plcsim ip address, click start server.

## 6. Conclusion

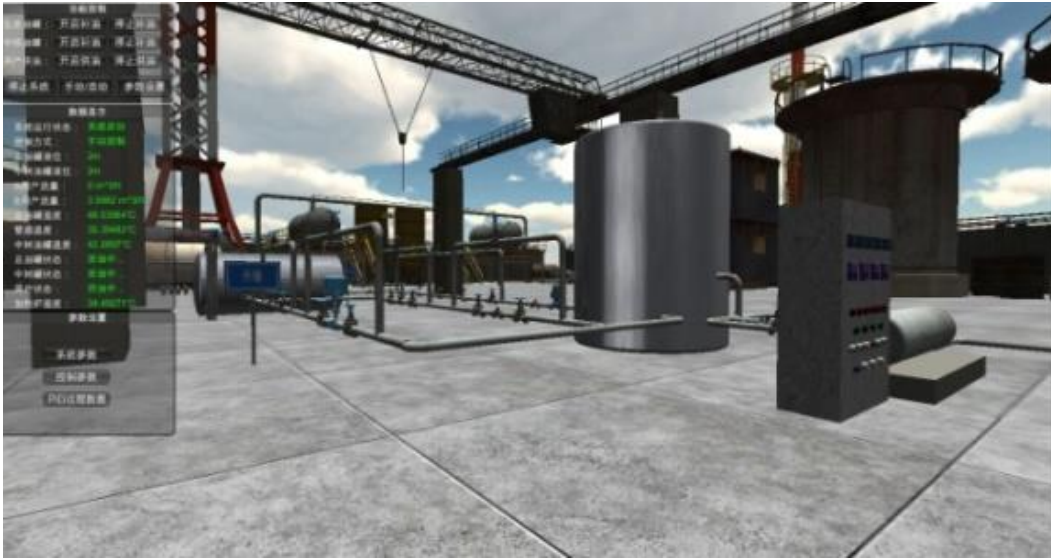


Fig. 9 Oil and gas gathering transmission virtual simulation interface

The system successfully uses the OPC technology to make the virtual reality system communicate with the virtual PLC effectively and realize the control simulation of the oil and gas gathering and transportation, so that the PLC control program can be debugged when the technician is not in the field or in production. Optimize the control code, help to improve the automation of oil and gas gathering and transportation, improve production efficiency.

## References

- [1] Zhao Qing. Oilfield joint station simulation training system development [D]. China University of Petroleum (East China), 2013.
- [2] Yang Lu. OPC-based virtual monitoring system design and design [D]. Shanghai University of Engineering, 2015.
- [3] Zhang Rui. Virtual PLC experimental platform for the study and design [D]. Beijing University of Chemical Technology, 2014.