The R&D, Best Practice and Future Prospect of SCADA Software for Oil and Gas Pipeline Network

Jan. , 2018
Presenter

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- Specialized in pipeline operation and management.
- Published Oil & Gas Pipeline SCADA System Technology and more than 20 related articles.
- Received three National Prize for Progress in Science and Technology, four Provincial-level Prize in pipeline technology and underground gas storage technology.
Background I: High Complexity of Natural Gas Pipeline Dispatching and Controlling

By 2017, under the transmission pattern of China’s natural gas pipeline network, Beijing Oil and Gas Pipeline Control Center remotely monitor and control nearly 40,000 kilometers of pipeline including around 300 compressor units, 450 stations, 1400 block valve stations and 1000 customers. Each dispatcher is responsible for controlling more than 3000 kilometers of natural gas pipeline.
In terms of resource allocation, with the increasing dependency of imported gas, PetroChina has completed the pipeline network of domestic produced natural gas, imported natural gas and imported LNG. Unbalance ratio of network transportation is ranged from 0.66 to 1.42. Gas resources from Underground Storage is less than 6% of natural gas consumption in 2017. BOGC is facing the big challenge of pipeline network operation.
Background II: Advanced technology for construction and operation of oil and gas pipeline network

1. Large-scale application of X80 Steel

Large-scale application of X80 Steel: PetroChina has successfully launched X80 spiral pipe fracture control technology, the manufacturing technology of thick wall pipeline for large diameter and fittings. PetroChina has also successfully accomplished the construction of the Second West-East gas pipeline by utilizing X80 steel, which is 12 MPa design pressure, and diameter 1219 mm (48 inches), making it one of the well-known pipeline in the natural gas industry. Also the blasting test of diameter 1422mm pipeline with the same specification was firstly completed in the world. It has been successfully applied on construction of the Eastern Route of Russia-China Gas Pipeline.
2. Domestication of key equipment

In the field of pipeline equipment manufacturing, PetroChina has organized the manufactures to develop 20 megawatts high speed electrical-drive compressor unit, 30 megawatt high speed gas turbine compressor unit, 2500 kilowatts pump unit and the 48-inch high pressure ball valve, with the main performance reaching the international advanced level.
3. Key technology of natural gas pipeline dispatching and controlling

The centralized remote control technology is integrated to optimize the control mode of natural gas pipeline network, so as to realize the centralized operation of the compressor unit and distribution. The research and development of automatic transmission technology realizes the automatic control of user's gas quantity, which in turns reduce the dispatcher amount of operation. By establishing innovation system of centralized control optimization management and online simulation system, PetroChina realizes real-time simulation and operation towards national advanced level.
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I. Introduction

SCADA (Supervisory Control and Data Acquisition) implements the operation processes by monitoring, adjusting and controlling systems remotely. Based on computer software, the SCADA fully take advantage of the computer technology, automatic control technology, communication and network technology, as well as the sensing instruments and actuators. SCADA system has been widely used in different fields, including oil and gas pipelines, power transmission, distribution and traffic control.
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II  Application Status of SCADA System
III  Independent R&D Process of SCADA Software
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1. Application Status of the Control Center

Beijing Oil & Gas Pipeline Control Center of PetroChina was established in 2006, with the main control center at Beijing and the backup control center in other locations, which are used to monitor and control the long distance oil and gas pipelines of CNPC. So far, it is capable of monitoring more than 60,000 km pipelines (over 40,000 km for gas, nearly 10,000 km for crude oil and about 10,000 km for product oil) and over 600,000 SCADA system data points.
2. Facing Situation

Pipeline transportation has become China’s fifth largest transportation industry following railway, highway, waterway and air transportation. Pipeline control has posed higher demand on operation safety, energy conservation and environmental protection. This, in turns, helped to upgrade requirement demand on the analysis and application of production data.

SCADA software is the core of oil and gas pipeline control and operation. The independent research and development satisfies the demand of developing SCADA system software in China.
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III. Independent R&D Process of SCADA Software

PetroChina Oil & Gas Pipeline Control Center had researched and developed the first SCADA system software for oil and gas pipelines with proprietary intellectual property rights – the Pipeline Control System (PCS), which cost three years as of 2011. In 2016, industrial test of the software had been conducted and acceptance was organized in 2017. PCS V1.0 released in May 2014. Software design completed in Dec. 2012. Commenced in Aug. 2011.
1. R&D of the PCS Software

During the research and development period, the technical standard system of the SCADA software for oil and gas pipelines had been established. With its core focusing on the object model of oil and gas pipeline equipments and basing on integrated service platform, this software, which features on service-orientation, distribution, standardization and extendibility, has been developed.

In May 2014, PCS V1.0 was duly released.
PCS V1.0 had passed the third-party comprehensive evaluation in the laboratory environment, which test in perspectives such as function, performance and communication protocol conformance. The evaluation was conducted by China Software Testing Center (CSTC).
2. Industrial Test of PCS Software

Industrial test of the PCS Software had been conducted at the Subei Section of Ji-Ning Gas Pipeline and Dagang-Zaozhuang Products Pipeline since June 2016. Host central control system was deployed in the facilities of Beijing Main Control Center and Langfang Backup Control Center. Two station control systems were deployed at the Yangzhou Station and Dezhou Station respectively.
Test contents

- Construction of the pilot systems: the host central control system realized 32,000 points of data acquisition and control, generalized more than 240 process flow displays.

- On-site test of the pilot system:
  
  1) Functional test: Complete the data acquisition, alarm processing and verification of other functions. Conduct remote monitor, control and adjustment, process switching and start/stop of pipeline transmission.

  2) Performance test: Complete the test of key performance indexes such as the time of command issuing and data refreshment, time of display switching and redundancy switching.
Outline

I Introduction

II Application Status of SCADA System

III Independent R&D Process of SCADA Software

IV Main Technical Features of PCS

V Practice and Prospect
1. PCS Software Introduction
The PCS Software could run in different operating systems such as Unix, Linux, Windows and supported application of Oracle and PostgreSQL database. It is capable of managing over one million datapoints in real time and refreshing data by 200,000 points per second. New technologies, such as integrative graphic model library (IGML) configuration, cross-system unified display interface, post disturbance review, and cross-platform support have been developed.
1.1 Software components

The PCS Software consists of modules such as integrated service platform (integrating service integration bus, system management, public service, real-time database, data processing, historical database and model management and so on), data acquisition, HMI & Web and pipeline process calculation subsystem.
1.2 Software Functions

Main functions of the PCS Software include:

- data processing and release with high concurrency and high real-time performance;
- flexible alarm and event management;
- historical database supporting massive data storage and query;
- user authority management based on “Role-Area of Responsibility”;
- data acquisition and management supporting equilibrium strategies, single-source multichannel, data caching and backfilling;
- supporting OPC, IEC 60870-5-104, Modbus TCP/RTU, CIP and DNP 3.0 protocols;
- scalable Vector Graphics (SVG) based HMI;
- supporting Web publishing and browsing;
- IGML configuration and maintenance based on pipeline equipment models;
- integrated with batch transportation analysis, hydraulic gradient analysis, linepack calculation etc.
2. Main technical features of PCS

2.1 Integrated service platform technology

By adopting the Service-oriented Architecture (SOA), the PCS Software had been developed an open integrated service platform and established the uniform “infrastructure platform” for data transmission, data storage and system administration. On the basis of the above, data acquisition and control, process calculation and other service functions had been realized. The separation of the infrastructure platform and service functions facilitates the future possibility of upgrades and expansion.
2.2 Oil and gas pipeline equipment oriented IGML configuration

By analyzing the service requirements of the SCADA system for oil and gas pipelines, the PCS Software realized the integrative configuration of equipment graphics, data models and database tables based on compressors, pumps, heating furnaces, valves and other typical equipments. When performing production process frame configuration, equipment database configuration and data point binding could be accomplished simultaneously when drawing the equipment icons, which greatly improved the efficiency of engineering compared to that of the traditional ways.
2.3 Standardized graphic storage and exchange

Based on Scalable Vector Graphics (SVG) technique, the PCS Software had formulated the standards for vector graphics for the SCADA system, normalized the description of the basic graphs and equipment models, realized the standardized storage of the typical equipment graphs and process frame of the oil and gas pipelines. The HMI could be directly converted into standardized SVG files and immediately used by the simulation, energy consumption analysis, training system and other third parties.
2.4 Data Backfilling Technology

In a scenario that communication link failure occurred between the control center and stations, field data would not be acquired by the SCADA system at the control center and would be buffered at the data acquisition subsystem of the PCS Software deployed at the station control layer. When communication link restored, the buffered data would be sent back to the control center to complete data backfilling as requested by the data acquisition subsystem at the central control layer, which could solve the problem of historical data missing due to communication interruption.
2.5 Post disturbance review technique

With the preset judging conditions for pipeline operation anomalies, the PCS Software could automatically triggered to record the scenario before and after the accident with the dynamic data storage and compression techniques, so as to accurately locate and record the data variation during pipeline operation anomalies. Afterwards, the accident process could be fully re-rendered through the review technique, which would make the operational analysis and troubleshooting more efficient and accurate.

Implementation methods (for example in industrial test):
- Configure the event developing record, storage time configured as 48h
- Configure data saving interval as 5min, storage time frame up to 48h
- Configure accident locking time as 5min before and after the accident
2.6 Pipeline process calculations

The PCS Software had integrated pipeline process calculation functions into the SCADA system software, including batch tracking, linepack analysis, hydraulic gradient analysis and pressure differential and flow analysis.
3. Laboratory testing performance indexes

China Software Testing Center conducted the main performance indexes test to PCS Software. The results are as follows:

<table>
<thead>
<tr>
<th>ID</th>
<th>Performance index</th>
<th>Test results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Data management capacity of single server for the real-time historical database</td>
<td>1,059,790 points</td>
</tr>
<tr>
<td>2</td>
<td>Update rate of the real-time database</td>
<td>Update time of the real-time database for 200,000 data is 86ms</td>
</tr>
<tr>
<td>3</td>
<td>Redundant server switchover time</td>
<td>910ms</td>
</tr>
<tr>
<td>4</td>
<td>Data refresh rate</td>
<td>867ms</td>
</tr>
<tr>
<td>5</td>
<td>Command response time</td>
<td>125ms</td>
</tr>
<tr>
<td>6</td>
<td>Response time for alarm generation to alarm prompt on HMI</td>
<td>934ms</td>
</tr>
<tr>
<td>7</td>
<td>Response time for image switching and accessing on the picture browser</td>
<td>452ms</td>
</tr>
<tr>
<td>8</td>
<td>Maximum, basic computation points</td>
<td>306,381 points</td>
</tr>
<tr>
<td>9</td>
<td>Mean computation points for 60,000 points</td>
<td>275.56m</td>
</tr>
<tr>
<td>10</td>
<td>Single protocol channel data acquisition capacity</td>
<td>3.98s</td>
</tr>
<tr>
<td>11</td>
<td>Web page data updating time within LAN</td>
<td>733ms</td>
</tr>
<tr>
<td>12</td>
<td>Typical oil and gas pipeline process data compression ratio</td>
<td>6.54%</td>
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### 4. Performance indexes for field industrial test

Indexes test for technical performance has been conducted to the PCS Software at the field. The results are as follows:

<table>
<thead>
<tr>
<th>System</th>
<th>PCS host Central Control System</th>
<th>PCS Load-Test System(backup control)</th>
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<tbody>
<tr>
<td></td>
<td>Dagang-Zaozhuang Pipeline</td>
<td>Ji-Ning Pipeline (Subei Section)</td>
</tr>
<tr>
<td>Data point scale</td>
<td>31,725 points</td>
<td>20 points</td>
</tr>
<tr>
<td>Response time for command issued at HMI to field equipment</td>
<td>0.064s</td>
<td>0.525s</td>
</tr>
<tr>
<td>Response time for alarm generated at the field equipment to HMI display</td>
<td>0.553s</td>
<td>1.557s</td>
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<tr>
<td>Picture switching time</td>
<td>0.731s</td>
<td>0.568s</td>
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<tr>
<td>Redundant switchover time</td>
<td>1.507s</td>
<td>1.038s</td>
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5. Summary

**Standard, scalable**
- All-in-one integrated service platform
- Standard data access interface
- Standard pipeline equipment model
- Supporting flexible application extension

**Efficient, safe, reliable**
- Single server supporting over one million points
- Real-time data update up to 200,000 points/s
- Application-based Single-Master Multi-slave Redundancy

**Flexible deployment strategies**
- Supporting cross-platform applications (UNIX/Linux/Windows)
- HMI supporting cross-system access
- Supporting distributed deployment

**Technical features**
- Integrative Graphic, Model Library Configuration
- Post Disturbance Review Technology
- Data Backfilling Technology
- Pipeline process calculation
Outline

I Introduction

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III Independent R&D Process of SCADA Software

IV Main Technical Features of PCS

V Practice and Prospect
V. Practice and Prospect

The PCS Software has fulfilled the technical gap of PetroChina in the field of SCADA software for oil & gas pipelines. Its functions and performance has been further improved by carrying out the industrial tests. Now, the PCS Software is applicable for industrial applications and will be firstly promoted and applied comprehensively in the Eastern Route of Russian-China Natural Gas Pipeline project.
Thank you!