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Intelligent Improvement of Pipeline Centralized Dispatch and Control

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Abstract. Under the requirement of CNPC in the construction of intelligent oil and gas pipeline, PetroChina Oil & Gas Pipeline Control Center has focused its work on the intelligent improvement of pipeline centralized dispatch and control system. The concept of Pipeline Intelligent Dispatch and Control is put forward, of which the framework, service objects, platforms and targets are established as well. Besides, the development strategy with 2 technical directions are proposed for the intelligent improvement of pipeline centralized dispatch and control, on the basis of learning from practices of power grid intelligent dispatch and petrochemical intelligent factory. In the first direction of informatization construction, there are 5 routes including central database, office automation, state/trend demo, professional simulation and industrial automation. In the second direction of intelligence promotion, there are 3 routes including optimization problem, prediction problem and recognition/judgment problem. In addition, the intelligent development is not a pronoun of staff reduction, but a personnel structural optimization. The cultivation and reserve of high-skilled talents should be emphasized as well as persistent technical innovations.

1. Introduction
With the rapid development of big data and artificial intelligence techniques, a new round of worldwide industrial transformation competition has been launched. By the grand strategic plans of Germany “Industry 4.0”, American “National Strategic Plan for Advanced Manufacturing” and the domestic “Made in China 2025”, a deep integration of traditional industrial manufacturing technology and electronic information is promoted, and the goal of advance towards automation, informatization and artificial intelligence is proposed.

Through decades of hard work, the transformation of domestic pipeline industry from traditional pipeline to digital pipeline has been accomplished, with the achievements such as digital design, mechanical construction, informational management, and electronic supplies purchase. Under the new requirement of China National Petroleum Corporation(CNPC) in the construction of intelligent oil and gas pipeline, PetroChina Oil & Gas Pipeline Control Center has focused its work on the intelligent improvement of pipeline centralized dispatch and control system, to upgrade the pipeline remote monitoring, enhance the decision support ability, and level up the operation and management.

2. Pipeline Intelligent Dispatch and Control
The intelligent development, as a new engine of industrial innovation, is carried out with various routes and targets in research and application for different industries. Through an investigation on the demand and technical characteristics of pipeline industry, the concept of Pipeline Intelligent Dispatch and Control is put forward as follows, based on the successful practices and experiences from the intelligent manufacturing, smart power grid, and intelligent petrochemical plant. While, the framework of pipeline intelligent dispatch and control system is obtained, and the service objects, working procedure, platforms and upgrading goals are shown in figure 1.

Figure 1. Framework of Pipeline Intelligent Dispatch and Control

Pipeline Intelligent Dispatch and Control, which is based on the pipeline automation and informatization by a comprehensive use of advanced techniques such as IoT, modern communication, sensor measurement, industrial control, simulation, optimization, big data and machine learning, is aimed to promote the visualization of working state, optimization of operation, automation of control and early warning of emergency, enhance the ability of self-learning, self-adaption and decision support of the whole system, improve the performance and efficiency of scheduler, dispatcher and supervisor, and further ensure the safe, economical and environment friendly operation of pipeline network.

In the stage of data acquisition, an enterprise-level central database is expected by the combination of meteorological data with the existing database from SCADA System, Plant Information System, Pipeline Production System and Pipeline Integrity Management System, to supply more comprehensive information for decision support[1].

In the stage of decision support, a virtual brain for intelligent dispatch and control is necessary to assist the working staffs with timely and optimal guide. The development of the virtual brain could be carried out in three aspects: firstly, enhance and improve the application of pipeline simulation to promote the transformation of empirical decision to scientific decision; secondly, explore the application of cutting-edge machine learning algorithms to discover knowledge and open mind by deeply mined information; thirdly, upgrade the pipeline simulation system to serve as a reliable and authoritative platform for various dispatch and control tests, by joint development of hydraulic thermal
simulation and automatic control simulation, following the example of flight simulator in the aerospace industry.

In the stage of decision making, the work ability and efficiency of scheduler, dispatcher and supervisor will be promoted by the supports from the professional analysis, discovered knowledge and accurate simulation. It is beneficial to accelerate the progress in digitalization, promptness, automation, informatization and optimization of the pipeline centralized dispatch and control, through the interaction of the three stages mentioned above [2].

3. Development Strategy
Under the overall guideline of the strategy “Made in China 2025”, the main work of PetroChina Oil & Gas Pipeline Control Center has been focused on energetically improving the intelligent level of transportation and operation control to fulfill and promote the construction of intelligent oil and gas pipeline. On the basis of learning from successful practices of power grid intelligent dispatch and petrochemical intelligent factory, combined with the features of pipeline operation, the following advices (shown in Figure 2) are put forward for the intelligent improvement of pipeline centralized dispatch and control.

**Figure 2. Development Strategy and Key Points of Pipeline Intelligent Dispatch and Control**

3.1. Promoting the construction of pipeline informatization
Informatization construction is an important way of intelligent development. The key point is to open up information barriers to share resources, strengthen professional analysis to improve cognitive level, improve the visual effects to promote information presentation, and advance the automatic level to reduce labour intensity. The specific improvements could be carried out according to the following five aspects.
1) Promote the enterprise central database management.
   On the one hand, based on the existing databases from SCADA, PI, PPS and PIS, some necessary meteorological data should be complemented to improve the comprehensiveness of basic data information; on the other hand, the interworking and resource sharing of basic database, simulation test database and accident database should be promoted, in order to provide comprehensive information guarantee for making overall plan and optimized decision.

2) Improve the level of office automation.
   First, develop the electronic operation ticket system, to replace the current paper operation ticket and realize informatization management of operation examination and approval. Second, develop the quick recording function, to make a flexible log and classified memory for important events such as shutdown or abnormal production process. Third, develop the auto message function for production information, to simplify the tedious daily office work and better play the role of mobile terminal to operation management.

3) Strengthen the power equipment state monitoring and key parameters trend tracking.
   First, improve the precision of the characteristic curve of power equipment, to improve the display of operating point for gas compressor and oil pump. Second, the trend of operating efficiency for compressor, pump and heating furnace should be presented in real time, to timely check their operating conditions and health. Third, strengthen the dynamic trend tracking of oil pipeline flow ability indicators such as oil gel point, pipeline friction resistance, wax deposition and heat transfer coefficient, to alert the abnormal condition in time and improve the pipeline safety pre-warning ability.

4) Strengthen the professional analysis and pipeline simulation.
   First, improve the simulation model and pay more attention to the application of pipeline simulation software, and promote the change of experiential decision-making to scientific decision-making. Second, develop a virtual platform of accident rehearsal by using online/offline simulation software to replace and upgrade the current “orally ask and answer” rehearsal training. Third, develop an authoritative and comprehensive virtual platform for various pipeline simulations and intelligent tests including commissioning/transport/shutdown test, staff training, accident rehearsal and decision support, by upgrading the pipeline simulation system and promoting the cooperative development of hydraulic/thermal simulation and automatic control simulation like virtual PLC. Fourth, on the basis of existing offline evaluation software, develop an online system for flow ability evaluation of waxy crude oil pipeline and periodically release the evaluation results, to replace the current work mode of “manual input + post assessment” with the advanced mode of “auto input + real-time assessment”.

5) Further improve the level of automatic control.
   First, improve the PID control logic and algorithm to realize the automatic distribution of natural gas pipeline [3-4]. Second, optimize the control process and logic based on the experience of manual regulation, to realize the function of one-click adjustment of download flow rate for product oil pipeline. Third, promote the reliability evaluation and establish the white list protection strategy of pipeline SCADA, to scientifically assess the control safety and network security of PetroChina Oil & Gas Pipeline Control Center.

3.2. Exploring the application of artificial intelligence
Intelligent development is the inevitable trend and senior stage of the informatization construction. The artificial intelligent techniques, represented by big data, deep learning and intensive learning, is developing rapidly with tremendous and promising futures. However, a blind application and following-up should be prevented due to the high technical threshold of artificial intelligence. It is suggested to explore the application of big data and machine learning to gradually advance the system abilities of “self-learning, self-adaption and self-decision” and boost the pipeline informatization construction to a higher level, on the basis of necessary foundation reinforcement and clear goal recognition.
The intelligent development of pipeline dispatch and control system can be carried out from the following three aspects of optimization, prediction and recognition/judgment problems.

1) Optimization problem.
Convert the complicated engineer problem to a mathematical optimization problem, through rational selection of optimization objectives and constraint conditions. Attempt to use intelligent optimization techniques such as genetic algorithm, simulated annealing algorithm and ant colony algorithm, to provide an optimal plan for pipeline operation [5]. For instance: First, use the dynamic programming algorithm to automatically figure out the maximum, minimum and optimal storage capacities of natural gas pipeline, to avoid the tedious manual trial calculations by using TGNET software. Second, strengthen the application of the existing steady state optimization software, to promote the optimization of large-scale natural gas pipeline network and improve the quality and efficiency of the monthly plan. Third, commence investigations on the transient optimization of natural gas pipeline network and develop the unsteady optimization software, to guide the condition transition and emergency disposal. Fourth, upgrade the planning software of product oil pipeline network by using optimization algorithms, to realize automatic planning instead of the current manual scheduling with fuzzy and tedious trial processes.

2) Prediction problem.
Attempt to build mathematical prediction models by using machine learning algorithms, to find the rules from the known or historical data, and improve the prediction accuracy. For instance: First, based on a bulk of historical sales data, set up a gas demand forecast model for terminal customer, by a comprehensive use of recursive neural network and time series algorithms, to provide timely and reliable decision support information for the peak load regulation of natural gas pipeline. Second, based on the historical data of oil pipeline shutdown temperature drop, set up a mathematical forecast model by using deep neural network or support vector regression algorithms, as a supplement to the traditional prediction means of Stoner Pipeline Simulator, to improve the prediction accuracy and promote the online prediction.

3) Recognition and judgment problem.
Explore the application of data mining technologies, to find links, clues and answers from known information, and even get access to some unconventional and insightful understandings. For instance: First, enrich the training samples by enlarging the applications of Optical Fiber Pipeline Security Pre-Warning System and Oil Pipeline Leak Monitoring System, and try to use deep learning and enhance learning algorithms, to improve their accuracy and pre-warning ability[6]. Second, develop the case study system for pipeline accidents with functions of classified retrieval, statistical analysis and similar-case reminding, and use logistic regression and correlation analysis to make up for the shortcomings of traditional paper case report and simple electronic document management, in order to give full play to the early warning education of the historical accidents in pipeline dispatch and control.

3.3. Expanding the technical service team
The intelligent development is not a pronoun of staff reduction, but a personnel structural optimization. The cultivation and reserve of high-skilled talents should be emphasized as well as persistent technical innovations, during the promotion of the pipeline intelligent dispatch and control. For example: Facing the heavy tasks of model reconciliation and maintenance for the scale-expanding natural gas pipeline network, more skilled technicians are needed to improve the performance and application of the existing online simulation software such as Gregg, Atmos and SPS, to better support and guide the dispatchers in their daily operation and control. Besides, more professional talents of industrial automation are needed to upgrade the pipeline SCADA system to a higher smart level, to further relieve the working pressure and labour intensity.

4. Conclusions
Through investigations on the demand and technical features of pipeline industry, the concept of Pipeline Intelligent Dispatch and Control is first put forward, of which the framework, service objects,
platforms and targets are established as well. Besides, the development strategy with 2 directions, 8 routes and 32 key points are proposed for the intelligent improvement of pipeline centralized dispatch and control, based on the experiences from power grid intelligent dispatch and petrochemical intelligent factory. In addition, the intelligent development is not a pronoun of staff reduction, but a personnel structural optimization. The cultivation and reserve of high-skilled talents should be emphasized as well as persistent technical innovations.

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