Abstract: This thesis introduces the way to increase safety by controlling the risk faced by Daya Bay Nuclear Power Operations and Management Co., Ltd (hereinafter referred to as DNMC) during the pre-operational of Ling’ao nuclear power station second phase (hereinafter referred to as LNPS-II). The way refers to methods include extending management system integration, effective safety culture construction, human performance tools developing and applying, and independent review.

1 Basic Information

Following Daya Bay Nuclear Power Station (GNPS) and Ling’ao Nuclear Power Station (LNPS-I), LNPS-II is the third large commercial nuclear power station constructed at Daya Bay Nuclear Power Base and the only nuclear power project constructed during the 10th Five-Year-Plan period of China and is a leading project under the national self-reliance program of the industry.

LNPS-II adopts the Chinese improved pressurized water reactor technology CPR1000 which is established by China Guangdong Nuclear Power Holding Co., Ltd (CGNPC) with its own nuclear power brand. In order to further improve safety and economical efficiency of power generation, on the basis of technological improvements of LNPS-I, LNPS-II adopts 15 major technological improvement items such as advanced fuel assembly, digital instrumentation and control, advanced main control room design and half-speed turbine generator, and more than 40 other technological improvement items. In addition, LNPS-II adopts digital operation procedures and status oriented accident procedures to improve the operation control under normal operation conditions and in the case of accident. The main structural work was started on December 15, 2005. On September 15, 2010, LNPS-II Unit 1 entered into commercial operations. On August 7, 2011, LNPS Phase II Unit 2 was put into commercial operations.

DNMC was established in March 2003 through the joint investment of Guangdong Nuclear Power Joint Venture Co., Ltd. (GNPJVC, GNPS owner) and Ling Ao Nuclear Power Co., Ltd. (LANPC, LNPS-I owner). After equity adjustment in September, 2009, CLP Nuclear Power Operation (China) Co. Ltd. and Guangdong Nuclear Power Investment Co. Ltd hold 12.5% and 87.5% equity of DNMC respectively. Entrusted by GNPJVC, LANPC and Ling Dong Nuclear Power Co., Ltd. (LDNPC), DNMC is responsible for the operations and management of the six 1000MWe PWR units of GNPS, LNPS-I and LNPS-II.

During the pre-operation period, China Guangdong Nuclear Power Engineering Company (CNPEC) is responsible for the design, construction, installation, start-up of LNPS-II and DNMC for the operations preparation.

Present organizational structure of DNMC is shown as below:
Figure 1: Organization Structure of DNMC

The departments directly related to safe operation of GNPS and LNPS-1 are Operations Department (OPS), Maintenance Department (MTD), Technical Department (TND), Safety & Quality Department (SQD) and Nuclear Training Center (NTC). The departments directly related to operation preparation of LNPS II are the Operation Preparation Department (DPR), OPS, MTD, TND, SQD and NTC. Human Resources Department (HRD) and other departments of the company provide support for safe operation and operation preparation within the scope of their respective responsibilities.

2 Main Function and Responsibility of DNMC in operation preparation

LNPS II is the extension project of LNPS. Operation preparation of LNPS-II depends on the existing capacity of DNMC. According to the Operation Preparation Consignment Agreement and the Operation Preparation Programme for LNPS-II approved jointly by the general managers of the Owner Company and DNMC, the operation preparation targets of LNPS-II are: to completely finish the tasks of operation preparation, train and develop an operation team with sufficient knowledge and skills, good at management, and high ethical work style so as to ensure safe, economical and steady operation after take-over of the units. The tasks of operation preparation include:

- Establish organizational structure for operation preparation, and appropriately allocate the human resources.
- Complete training and authorization of the operation preparation personnel, especially the licensed operators.
- Prepare the operation preparation management procedures, and regulate the responsibilities of each department for operation preparation and the interface relationship; prepare the various technical procedures such as operation and maintenance procedures to ensure successful implementation of operation preparation and take-over job and safe operation of the units after commercial operation.
- Participate in engineering design review, equipment procurement, surveillance during equipment manufacturing, as well as equipment installation and commissioning, and feed back the operation experiences to the engineering company.
- Complete take-over of systems, equipment, buildings and engineering documents. Push forward clearance of pending issues, and undertake the responsibilities of operation management and maintenance of the systems, equipment and buildings after take-over.
- Complete preparation of the first fuel loading (FFL) application documents and make preparation for the FFL together with CNPEC.
Establish and implement the Operation Preparation Quality Assurance Programme.

Prepare the Operating Technical Specifications (OTS) and the Surveillance Programme for Periodic Test, undertake the nuclear safety responsibilities after FFL.

Complete the preparation work for industrial safety management, fire protection, radiation protection, chemistry, environmental protection and emergency preparedness. And implement supervision and management of industrial safety, fire protection, environment and radiation safety on site together with the engineering parties.

Accept and manage the spare parts and various tools.

Make preparations for inspection and test, nuclear fuel management and complete engineering consignment projects.

Make preparations for the first refueling outage.

3. Main risks during operation preparation for DNMC

The purpose of operation preparation is to take over of the new unclear power station from engineering side by operation side and put it into commercial operation. The quality of engineering and operation preparation are the key factors affecting the performance of the units during the whole life cycle. Safe and stable operation could not be guaranteed if the risk is out of control.

The operation preparation of LNPS-II has its safety risk as the following:

- The quickly status change of unit and dilution of experienced operation staff
- Units from unloading to loading of nuclear fuel
- Complex site working conditions
- Complex interfaces between the owner, CNPEC and regulatory body
- New equipments with high failure rate both for abroad and localization items
- Black box of DCS and other modified technology
- Poor behavior and human performance of new staff
- Dilution of safety culture because of the drain of experienced and skilled staff

4. Methods to control the above risk

4.1 Extending DNMC’s integrated management system to LNPS-II

Based on HAF003 nuclear power quality assurance code since its founding, by continuous digesting, absorbing and integrating of ISO9001, ISO14001, OHSAS18001, rebuilding business process, on-loading ERP and introducing excellence performance model, DNMC has been forming its integrated management system.

During the operation preparation period, DNMC extended the management system to LNPS-II and made complete requirements for the activity for staff participating the operation preparation and interface with engineering side, along with a lot of special management innovation.

4.1.1 Management system for LNPS-II

4.1.1.1 Organization Aspects

- From August, 2004, DNMC set DPR and initiate the operation preparation before the main civil construction work. DPR is the department specifically responsible for operation preparation of LNPS-II, which is divided into 4 branches undertaking the operation preparation tasks according to the division of the responsibilities. The organizational structure of DPR is referred to the following chart.

- In order to coordinate and push forward operation preparation of LNPS-II, DNMC established
the interdepartmental Operation Preparation Committee. A member of the General Management (GMD) of DNMC assumed the chairman, and the members of the committee include the deputy managers of the six departments directly related to operation preparation, i.e. DPR, OPS, MTD, TND, SQD and NTC, and the manager of HRD as well as the branch heads of relevant implementation branches. The Operation Preparation Committee holds the weekly meetings, and monthly meetings, to follow up and push forward the operation preparation work, and coordinate to solve the difficulties and problems in practice.

Figure 2: Organization Structure of DPR

4.1.1.2 Procedure Management System

- An Operation Preparation Quality Assurance Programme was set up officially by the three parties and applicable to all the activities concerned with operation preparation related work, items and staff and contractors involved in the activities. These activities include organization management, design, procurement, manufacture, installation, construction, training, spare storage, procedure writing, engineering experience feedback, documents turn-over, follow-up of pending issue, first on-loading application, turn-over of equipment, system and building, cool and hot start-up, the first overall emergency exercise and first loading and trial operation.

- Under the program, DNMC wrote a series of management procedures and guidelines to describe more details of the requirement. And under these management procedures, a lot of operation, maintenance, technical working procedures were developed.

4.1.1.3 Main Management Innovation

- A Units Start-up Committee was established as the highest director organization for CNPEC and DNMC both appointing respectively one member from General Management Department
as chairman. They held meetings every month to discuss major issues affecting safety, quality and progress, and made important decisions mutually.

- Under the united commanding mode of the Committee, a three-level decision system was also established to effectively and efficiently deal with issues affecting safety, quality and progress. The three levels are engineer level, branch level and department level between CNPEC and DNMC. They held meetings daily and weekly and report to their line-manager.
- To assess safety and quality independently, a safety assessment committee was also established to give review opinions. They held meetings biweekly.
- Operation preparation staff was required to participate in the fields deeply as follows:
  - Attending the daily morning meeting, planning meeting, expert meeting.
  - Planning engineer and operators and STA worked at the same office, in order to control the activity risk as an united planning group.
  - Before significant test activity and high risk work, technical discussion meeting, pre-job briefing and briefing meetings were also required.
  - Managers were required to focus and patrol on site.
- Safety and quality surveillance were enhanced in the following aspects:
  - STA began to shift before fuel loading for on-line monitoring, sorted and analyzed DHP pending problems list, and followed-up and verification of GOR9 periodic test every day.
  - QA Branch set up a special section and allocate engineers to carry out audit and surveillance at the beginning of operation preparation.

4.2 Effective Safety Culture Construction

The safety culture development of DNMC is a multi-layer systematic project, whose general idea can be summarized as follows: international safety idea characteristic of in-depth defense, initiative prevention, and conservative decision-making; safety management idea characteristic of localized practices. Based on the theory of safety culture and supported by the theory of human error, the idea of acceleration of the safety culture development and the work of human performance, which is characteristic of “promise-making and example-setting of managers, influence radiation and penetration of the main force, participation and contribution of staff.

Figure 3: DNMC Multi-level Facilitation of Safety Culture Development

4.2.1 Safety Culture Development Practice

4.2.1.1 Safety Culture Lecture and Plant Patrol of Managers

In DNMC, managers of different levels are required to give various safety culture lectures to publicize the policies of safety culture to the staff and interpreting the idea of that. This mechanism has been institutionalized and incorporated into the annual training plan of the company and DPR for all the operation preparation staff.
All the managers, including every general manager, department manager, branch head, section head, are required to do plant patrol once every month. Managers from departments related to operation preparation are also required to patrol on LNPS-II site. This job can be divided into condition patrol and behavior inspection. The condition patrol is mainly a managerial inspection of the condition of various areas, workshops, equipment & facilities, and is a supplement to the site inspection and the inspection by technical personnel. The behavior inspection is mainly aimed at the process of operational action, and communication and discussion are also supplementary forms of the behavior inspection.

4.2.1.2 Safety Culture Construction

- A Special Facilitating Team For Safety Culture Construction and Human Performance

  This team constitutes a group of enthusiastic and experienced guys of different professions and ranks in the company including DPR. All members of the team come from important posts; they are representatives both in profession and in hierarchy. The team continuously learned knowledge and translated a series of books on INSAG safety culture reports, providing the basis and reference for the safety culture development and practice in DNMC. Meanwhile, it also actively exchanged ideas with such international organizations as IAEA and WANO, EDF, EPRI and RINPO.

- A Series of Shocking Training Courses and Flexible Training Types

  The “shocking training courses” is mainly lectured by members of General Management. In this educational activity, leaders together with the staff will review the achievements of the company and reveal deep rooted problems of the Company, through bench marking with international and national NPPs. The GMs will review and re-analyze previous significant safety-related events in production, and extended to the feedbacks of safety events happened in some high-risk industries. Through the retrospect of the past and the analysis of existing work-related problems at the present stage, the training may be ended with such a conclusion,” more often than not, an accident comes from a minor deviation and a consequential result comes from a minor error and the tolerance of the minor error”.

  In addition, DNMC pertinently and creatively carried out all sorts of practical activities concerning safety culture in various fields with many flexible types, such as the Special Activity Commemorating the 20th Anniversary of the Chernobyl Accident, the Safety Culture Sketch Contest, the Human Factor Tool Card DV Competition, the Debate on Safety Culture, the Safety Culture Cartoon and Story-telling Competition, the establishment of warning education exhibition room and the like. Via these activities, the staff including operation preparation staff can learn a lot from the shocking experiences of our own and world-wide.

4.3 Human Performance Improvement

4.3.1 Progress of DNMC Human Performance Project

  During the period from 2003 to 2006, the theory and method of human performance was introduced and popularized to personnel of various managing hierarchies.

  During the period from 2006 to 2008, six tools for human performance were developed and each branch formulated the “behavior standards” and some branches carried out pertinent
behavior trainings.

From 2009 to now, various human performance trainings and practices have been fully carried out and various measures like the management of minor deviation on the site and the setup of human clock have also been initiated.

4.3.2 Several Major Aspects of the HU Project

4.3.2.1 Development of Tool Cards for Human Performance

In order to standardize the operations of site personnel and reduce human errors, key behaviors or action standards of operation procedures that serve to provide general guidance were formulated, thus further putting the basic ideas and requirements of the safety culture into practice in the process of the site work. In 2006, DNMC initiated the development of the “tool cards for human performance”. So far, DNMC has issued and promoted six tool cards for human performance: “pre-job briefing”, “procedure use and adherence”, “self check (STAR)” “peer check”, “three-way communication”, “questioning attitude”, the tool card”1-min stop” is just under popularization.

Figure 4: Tool Cards for Human performance

4.3.2.2 Formulation of Behavior Standards

Based on the analysis of human factor of inner and outside events, and on the summarization of the modes of human error at typical posts, DNMC has been promoting the behavior standards in the operation and maintenance fields of the power station since 2006 and successively formulated the behavior standards of Operators in the Main Control Room, the behavior standards of Sampling Activities of Chemical Technicians, the Work Rules for Maintenance Workers, the behavior standards of Preparation Workers, the behavior standards of Persons in Charge of Work, and the behavior standards of Refueling Workers.

4.3.2.3 Human Performance Enhancement

In 2006, DNMC established the first human performance enhancement and research center. The centre provided training equipment and designed training scenes and selected and developed teachers according to the requirement of reducing human errors. On the other hand, the centre formed a team consisting of cross-branch trainees, and adopted methods like hands-on practice and video playback to enable the trainees master standard work procedures and methods and foster good conduct habits, and to improve the safety regarding
the trainees’ site implementation.

The most essential and also the most effective work content in the conduct training center is the training of human performance, which helps the trainees develop standardized conduct by means of simulation of the equipment or the site environment. The training is designed for all the staff, focusing mainly on the field-work engineers. DNMC has established a human performance enhancement system, which is made up of a set of training courses, aiming to correct the trainees’ false conduct habits and develop in them a good thinking mode. New staff of DPR and related to operation preparation is the main “customer” of the Human Performance Enhancement.

4.4 Self-Evaluation (Learning Organization)

DNMC has built self-evaluation system which evaluates the effectiveness of management system and finds the opportunity to improve. There are two parts of self-evaluation.

4.4.1 Internal Self-evaluation
- By indicators: the related indicators cover the human factor failures and equipment failures were classified by the execution branches and mainly concentrate on the situations of the operation preparation activities on LNPS-II site. There are other indicators to reflect the usual status of experience feedback in the whole power station, such as the number of abnormal events, distribution of abnormal events, event results and so on.
- By self-evaluation: according to the business planning of DNMC, all execution branches is required to conduct self-evaluation in their own fields including LNPS-II site every year.
- Management self-evaluation: GM is responsible for DNMC management self-evaluation which is planned, organized and conducted by SQD. The output of management self-evaluation is issued in memo signed by GM or the authorized person.

4.4.2 External Evaluation

WANO and IAEA are periodically and actively invited to conduct peer reviews. In 2010, IAEA conducted an official review on LNPS-II before its commercial operation. And all the findings were developed and improvement of business planning in DNMC were made.

5 Conclusion

Since the commercial operation of the two units of LNPS-II as schedule, LNPS-II keep its safe and stable operation without unplanned shutdown or scram during its first cycle.

In addition, through safety culture evaluation and monitoring of the safety culture indicator and index, it can be seen clearly that the staff’s including operation preparation staff’s awareness of safety has increased year by year. Meanwhile, the problems identified in the safety culture evaluation and correspondingly provoked thoughts pointed the direction for continuous improvement of the Company: the safety culture needs to be concretized so that ordinary employees can truly understand the nature of the safety culture and consciously apply their understanding to their behaviors, thus making contribution to the development of the safety culture.

These prove that the distinctive way to increase safety during pre-operational of LNPS-II by DNMC is effective and efficient and worthy of reference.