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16611

DP/ID/SER.A/974
24 February 1988
ENGLISH

ASSISTANCE IN TESTING COMPONENTS
USED IN ELECTRICAL POWER DISTRIBUTION SYSTEM

DP/DRK/86/003

DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA

Technical Report: Establishment of a Short Circuit Laboratory *

Prepared for the Government of the Democratic People's Republic of Korea
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of T.S. Cesul
Expert in Power System Equipment Engineering

Backstopping Officer: J. Pürkus, Engineering Industries Branch

United Nations Industrial Development Organization
Vienna

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V.88-22234

ABSTRACT

The mission has been undertaken under preparatory assistance to the Project "Assistance in Testing Components Used in Electrical Power Distribution System", DP/DRK/86/003/11-51.

The immediate objective of the mission was to assess the possibility of and requirements for setting up a Central Industrial Testing Facility of the country. The mission's duration was one and half month, starting November 1987.

As the result, with the assistance of the UNIDO Backstopping Officer, a Draft Project Document was elaborated. Proposed duration of the Project will be 3 years; estimated starting date: April 1988.

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INTRODUCTION AND RECOMMENDATIONS

A. Introduction

The Government of DPRK accords high priority to quality of switchgear and other equipment delivered by national industry in order to improve electrical power distribution system.

The national industry is aware of the necessity that the types of switchgear presently produced and even to a greater extent those to be developed must be tested for short-circuit breaking and/or withstand capacities to achieve defined quality and reliability.

At the time, no national facilities exist to procure such testing. The Institute of Machine Industry has approached the testing problem by preparing a concept of a Short Circuit Laboratory/SCL/ with an option of using nationally produced power supplying machines, but there was a blank concerning associated control and measuring equipment.

The need of introducing a UNDP project was identified with the aim of assisting the country in elaborating a realistic SCL concept and advising on its accelerated construction. Preparatory assistance was, among others, provided to identify required technologies and formulate the scope of the project.

In 1987 a team of three national specialists made a study tour to three European laboratories to familiarize themselves with technological trends of testing techniques for switchgear and other power system components. As a follow up, this mission was arranged aimed at preparing a Project Document in line with UNDP/UNIDO guidelines on project formulation.

B. Recommendations

1. Following the outcome of the preparatory assistance assignment it is proposed that a generator supplied Short Circuit Laboratory be established as outlined in the respective draft project document.
2. The Ministry of Machine Industry should start without delay to specify the possibility of producing/reconstructing the special synchronous generator of 50 MVA capacity by the envisaged local manufacturer, The Dae-An Heavy Machine Combine. The required fellowship training of Korean design and production engineers from local industry should preferably be arranged in the USSR.
3. Both the National Project Co-ordinator and the Chief Technical Adviser should commence their assignments at short notice upon approval of the project document.

I. OBJECTIVE OF THE ACTIVITY AND DUTIES

A. Objective

The objective of the mission was to assess the possibility of and to formulate requirements for establishing a central industrial testing facility destined to contribute to the improvement of the quality of power distribution system components.

B. Duties

According to Job Description, the duties of the author were as follows:

1. fact finding/trouble shooting/identification of key problems/techno-economic assessment of the scope of the Project and related requirements to introduce appropriate testing facilities,
2. elaboration of the terms of reference for the subcontractor to be entrusted with project execution,
3. elaboration of a fully fledged Project Document with regard to the establishment of a Central Industrial Testing Facility to carry out testing and advisory services required, discussing, reviewing and defining in detail:
 - a. the tentative structure of the testing facility from the technical, managerial and organizational point of view, its functions and work programme as well as
 - b. project objectives, outputs, activities and modalities of implementation, project inputs /expertise, training, equipment, financial resources/ and work plan,
4. preparation of a final report on the course and results of the mission including specific conclusions for follow-up activities.

II. DESCRIPTION OF ACTIVITY

A. Visits to industry

Initial meeting establishing programme of visits and subsequent activities, was held with Mr. Ko Ju Chol, senior officer, Fifth Department of the Ministry of Foreign Trade. From the Ministry of Machine Industry, Dr. Kim Jong Ho, head of laboratory in the Institute of Machine Industry was present. The latter has been appointed partner to the author, responsible for delivering informations, explaining problems and organizing visits to factories.

Three large-scale factories of electrical distribution equipment have been appointed to be visited, part of products of each being relevant to authors activity. During the visits of each of these factories, chief engineers and other staff have presented actual products and outlined development problems. Specifically, types of switchgear supposed to be subject to short-circuit testing were pointed out and prospective values of short-circuit breaking/withstand currents were determined. Summary of them is attached as Annex I.

5th October Automation Combine in Pyongyang

Production programme of this multiplex combine is composed of a variety of measuring appliances and controlgear, of a serial production scale.

In addition to these, low-voltage switchgear is manufactured, significant in national scale, covering full demand of marked in certain products as: contactors, fuses, mechanic /automatic/ switches etc. Characteristics are given in Annex I.

Design of these apparatus has been made long time ago, and real short-circuit breaking capacities never have been confirmed in laboratory. Routine tests are being performed but they cannot include short-circuit testing.

It was acknowledged to have testing of making and breaking capacities performed according to standard requirements, in order to ascribe suitable utilization categories to contactors and mechanic switches.

The Combine is an unique manufacturer of low-voltage power fuse links of capacities from 30 A up to 630 A. Similarly as for switches, laboratory tests of breaking capacities and cut-off currents must be performed regularly, in order to assure proper protective characteristics of fuses.

In summary, actual demand for testing currently produced low-voltage switchgear concerns roughly 25 types, plus some in course of modernization/redesign. It is estimated that with these tests laboratory will be engaged during two years of steady service.

Another important product of the Combine, being unique construction and single type, is the current-limiting circuit-breaker for direct-current railway substations and locomotives, 4000 V, 2000 A. This circuit breaker also needs type and redesign testing. To do this, the short-circuit laboratory must be provided by one or two diode rectifiers of adequate nominal power and respective electrodynamic withstand. Such a test would be the test of the rectifier itself. This rectifier is also listed to be test-object in the Annex I.

5th October Combine is displaying vivid interest to have the SCL built in its territory. The Ministry's decision meets these aspirations.

The 5th June Electric Factory in Kyongsong

Originally a factory of insulators, it has been developed to be the largest high-voltage switchgear manufacturer of the country. The manufacturing program includes: circuit breakers from 10 kV up to 220 kV nominal voltage, isolators, lightning arresters, transformer bushings and others.

Research and development of products is made locally; a well equipped high-voltage laboratory delivering testing services, but no short-circuit testing facility exists there.

Each of the products actually produced as well as those which are in the process of being developed need regular short-circuit testing to confirm declared standard ratings.

An important trend in product development of the Factory, coherent with the world one, goes towards the use of sulphur-hexafluoride as insulating and arc-quenching medium. Studies are made and preliminary design is followed. For this new technique, there will be no success possible without an extensive prototype test program in a short-circuit laboratory.

The Factory's strong desire to convince the authorities to have the SCL built in Kyongsong seems be justified not by the needs only, but by dynamism of the staff also and by visible prosperity of extending new techniques and building new workshops, as well.

Whichever the location of the laboratory will be, the testing demand of the 5th June Factory will be serious in quantity /about 15 tests per year/, and more yet in required parameters /high voltages, heavy-type objects, complex programs of testing/.

The Dae-An Heavy Machine Complex

By the end of the mission, the visit to the transformer factory of the Complex could not be arranged despite of an insignificant distance from the capital.

According to informations received, the factory's manufacturing programme includes every kind of transformer, from distribution-type up to power station type 220 kV, 160 MVA.

Insufficient dynamic strength to short circuits has been reported for small and medium-size transformers. Short-circuit testing program would allow to help improve quality.

But in practice, short-circuit testing of transformers requires a powerful laboratory. Because of this, usually, transformer testing is limited to certain nominal rating of units only. For the Dae-An production, it is proposed to limit testing program with 1000 kVA units. This value was accepted for the SCL programme /see Annex I/.

B. Lecture

During the stay in the 5th June Electric Factory in Kyongsong, a lecture was given for the technical staff. The title was: "Electrotechnical Industry of Poland and Research Services Offered to them by the Electrotechnical Research Institute of Warsaw".

The discussion concerned detailed design and testing problems of: gas circuit-breakers, oxide lightning-arresters, transformer bushings etc. The staff displayed a high level of technical experience and a good information about actual development trends in switchgear building.

III. DEVELOPMENT PROGRAMME

A. Assessment of needs for the SCL

Enquiry made in industry about needs for short-circuit testing ascertained the necessity of establishing a short-circuit laboratory in the DPR of Korea.

There is no alternative since, at the time, no mathematical/computer models exist allowing complete design of switchgear. The only and typical measure promoting design and engineering of prototypes is, therefore, laboratory testing for short-circuit breaking capacity and/or withstand current. Even most advanced world manufacturers of switchgear are following the way of "trial and error" testing and that way will be adequate for the country as well.

Two levels of short-circuit testing can be distinguished:

- design/model testing, carried out to prove design, materials and technology when in prototype stage; generally, such test may be carried out many times in order to realize optimal construction; results of these remain at the discretion of manufacturer,
- type test; that is formal, as to prove evidence of standard characteristics declared by the manufacturer; an inspector from the quality-governing authority may take part in this test and an official certificate is issued.

Both levels must be performed by the SCL.

As for technical parameters of the SCL

it would be desirable to cover the requirements related to products of the visited factories listed in Annex I, but within the actual Project concerned, circuit-breaker testing must be limited up to nominal voltage of 10 kV. The limitation arises from power sources /generator and transformer/ possible to be delivered by the national industry; limited funds do not allow for import of other machines.

As the result of analysing needs and possibilities, i.e. considering human potential, financial resources and required period of realization, the SCL's realistic activity will cover the whole testing scope of the national production of switchgear except circuit-breakers above 10 kV. For transformers, the deliberate limit-rating is 1000 kVA.

The range of circuit-breakers above 10 kV, i.e., actually, for 60, 110 and 220 kV left behind this Project, can be reconsidered at any next approach to laboratory reinforcement/building. The best case would be if the Kyongsong Factory obtained its own unit built in site.

**B. Decision concerning a complex
Industrial Development Centre**

The task of the mission, according to Job Description, could also be understood with a wider scope: to assess possibility of establishment of a complex Industrial Development Centre. Activities of such a Centre could include, besides short-circuit testing, following exemplary services to industry:

- opportunity studies of products,
- preliminary design and prototype engineering,
- materials application reference,
- methodology of quality control, etc.

Some next services to the Ministry and/or Planning Commission could follow, e.g.:

- prognoses of development trends,
- updating of production programmes,
- survey of quality,
- standardization.

The substantial impact of such a Centre would be intellectual and based on own research & development activity mainly, as well as on experience accumulated from testing.

At the present stage however, the establishment of such a Centre cannot be decided positively because the factors named above are not sufficient. Instead, formation of a similar Centre would be quite possible in future, on the basis of SCL's activities and its staff's skills. These might be achieved beyond the time-schedule of the Project proposed.

C. Technical options of realization

Testing circuits of the SCL must be delivered with short circuit currents up to 40 kA at voltages up to 10 kV or with currents up to 100 kA at low voltages /up to 500 V/, see Annex I. For this, two options of power sources are possible:

- from national energy-network,
- from synchronous generator/s/ driven by motor/s/.

Both alternatives were discussed with national specialists. Considering local energy network conditions, preference to the second type of the SCL supply was given, more expensive in capital but assuring such more flexibility in operation. This option was accepted for realization.

Therefore, a special synchronous generator must be built in the country. Import seems not to be realistic due to the high cost. The producer of the generator will be the Dae-An Heavy Machine Combine. Production range of the works is reaching turbo-generators up to 125 MVA; for the SCL a reconstructed 50 MVA type is proposed. Reconstruction will consist mainly on reinforcement of windings against forces exerted during short-circuits.

As long as producers experience is not sufficient to perform this reconstruction promptly, training of design and engineering specialists abroad is foreseen within the Project's budget.

Another heavy equipment of special design for the SCL is the multi-tap transformer. An analogous training of engineering specialists abroad must be planned.

D. Location

By the decision of the Ministry, the new Laboratory will be located in the territory of the 5th October Automation Combine in Pyongyang, and for this, a part of an old production hall with 700 m² surface has been designated. At present, production of electric motors is continuing there but it will be transferred to another location by 1989.

After local visit to the site, observations to this location have been reported, namely:

- it is scarce to dispose the machinery rationally,
- location of control-room with measuring equipment in the common building is not permissible because of vibration from the machinery and electromagnetic interference from the test-circuit,

- test bay for oil circuit-breakers must be arranged in different way,
- as a matter of fact, the existing hall needs to be demolished and newly constructed; the impact of such reconstruction on foundations and remaining structure is unknown.

Discussion of these observations with the Korean counterparts did not bring change to original decision about location and it was understood that it must be accepted for general reasons.

It was however, accepted to change the disposition of test bays to outside and of the control room into a separate building. This disposition enables actual design of the Laboratory in a more rational manner. But in the future no further extension of the Laboratory's testing capacities seems to be possible.

E. Equipment/Facilities

To complete the SCL, two groups of facilities must be furnished. First group refers to the heavy equipment, from which power will be delivered, it is listed as Annex II. This equipment will be manufactured and delivered by the national industry or imported from the national budget.

The second group includes precision control and measuring equipment. Only a part of it is available on national market, and it is envisaged to have it delivered by specialized European manufacturers, from the UNDP budget. The list of required equipment of this group is given as Annex III, with descending order of necessity.

F. Mode of Project implementation

The final distribution of inputs and activities for the implementation of the Project was agreed with the Korean counterpart. The idea remained as follows:

- technical layouts and design of buildings and installations - to be made by the Government,
- rebuilding of premises and commodities - Government,
- heavy machines, equipment /see Annex II/ and installation - Government,
- control and measuring apparatus /see Annex III/ - UNDP,
- National Project Coordinator - from the staff of the Institute of Machine Industry,
- Chief Technical Adviser - recruited by UNDP and having a decisive role relative to designing, equipment-choice, installation and commissioning,
- Measuring Techniques Expert and Generator Expert - recruited by UNDP to discern problems associated with installing, commissioning and maintenance of relevant equipment,
- training of staff in the methodology of short-circuit testing, construction and maintenance of equipment - to be arranged by UNDP in Europe with the form of one study-tour and five fellowship-training groups; details are given as Annex IV,
- library and an archive of testing results will be essential to provide accumulation of knowledge necessary for the establishment of a complex Industrial Development Centre for Switchgear in future. The perspective of foundation of such a Centre is beyond the Project completion date, but it must be retained in every activity of the SCL, to approach the target.

As a completion to these items, in the opinion of author and following his Job Description, a subcontract had to be added, involved in design of the Laboratory, choice of equipment, assistance in installation and commissioning.

but following the government's views and bearing in mind the insufficiency of UNDP funds, the subcontractor's services/activities will be covered by the Government Implementing Agency as well as by the Chief Technical Adviser.

G. Draft Project Document

As a result of the mission, and with essential assistance of the UNIDO Backstopping Officer, Mr. J. FURKUS, a Draft Project Document has been elaborated.

This Draft Project Document was discussed in a final meeting held in the presence of the UNDP Resident Representative, Mr. Carl-Erik Wiberg and of the Government delegation under the guidance of the Head of the Fifth Department of the Ministry of Foreign Trade, Mr. Han Tae Hyok. Amendments were introduced reflecting this discussion.

The Project is supposed to start by April 1988 and to be implemented by April 1991. The UNDP inputs budget will amount to US\$648,000 and the Government inputs budget to Won 4,500,000 equivalent to US\$2,160,000.

The Project Proposal is issued as a separate document.

Apparatus to be tested by the SCL

Manu- factu- rer	Description	Nominal voltage	Nominal current	Required short-circuit currents		Remarks
				Brea- king capa- city	One second with- stand	
		kV	A	kA	kA	
5th June Fac- tory	Oil circuit breaker	60...220	630...1600	25	30	Testing not pos- sible in actual Project
	Oil circuit breaker	10	400...5000	40	50	
	Isolator	3...60	400...5000	-	50	
	Fuse link	3...10	6,3...100	10	-	
	Air contactor	1...6	63...250	15	-	
	Oil switch	3...10	100...200	-	0,5	
	Lightning arrester	3...10	-	10	-	
5th Octo- ber Com- bine	Automatic /mechanic/ circ.breaker	500	25...1000	100	100	
	A.C. Contactor	500	16...630	60	-	
	D.C. Contactor	440	100...1000	40	-	
	Non fused switch	500	1000...4000	4	-	
	Fuse link	500	30...630	100	-	
	Curr.-limiting circ. breaker	4000	2000	25	-	
	Diode rectifier	4000	10000	10	-	
Dae An	Power trans- former	kV	kVA	kA	kA	
		3...10	30...1000	-	5	

Equipment to be provided by the Government

Synchronous generator 50 MVA, 3000 rpm
Excitation device to generator
Asynchronous motor 1400 kVA, 3000 rpm
Starting device for motor
Roof crane or equivalent lifting device
Air compressor 12,5 m³/min
Short circuit transformer 50 MVA, 12/0,5 kV
High current transformer 1000 kVA
Diode rectifier 3 kV, 30 kA_m
Set of resistors
Set of reactors
Overvoltage protection device
High voltage distribution boards
Low voltage control and distribution panels
Set of voltage and current transformers.

Equipment to be provided by the UNDP

Multichannel sequency control device
Synchronizing device
Specialized oscillographs, one electromagnetic
and one cathode-ray
Set of measuring transducers /deviders, shunts, trans-
formers, portable instruments etc./
Voltage stabilisation device
Making switch
Security circuit breaker.

Annex IV

Training to be arranged by the UNDP

1. Study tour: Short Circuit Testing Techniques and Methodologies - with visiting of at last three laboratories of a type similar to SCL - 3 m/m
2. Fellowship training:
 - 2.1 Engineering of synchronous generators suitable to supply short circuit testing - 3 m/m
 - 2.2 Engineering of multi-tap transformers resistant to short circuit currents - 3 m/m
 - 2.3 Composition and calibration of short circuit testing circuits - 3 m/m
 - 2.4 Maintenance and repair of security circuit breakers, making switches, control and measuring devices etc. - 3 m/m
 - 2.5 Application of sequency control devices, oscillographs, measuring transducers; decoding of oscillograms, elaboration of test results and certificates - 3 m/m

Institutions proposed to grant study tour and fellowship training: 16 leading European testing laboratories and industrial works.