

## **7 Gleichrichtereinheiten ALRO S.A.**

Das aus den Firmen Siemens Deutschland, ABB Switzerland und INPEC ENGINEERING GmbH gebildete Konsortium schloss im Jahre 2006 einen Vertrag mit der Firma ALRO Slatina in Rumänien ab. Es ging um eine schlüsselfertige Investition über die Montage von sieben Einheiten von 66,8 MVA, jede Einheit bestehend aus Regeltransformator, Gleichrichtertransformator und den dazugehörigen Leistungsgleichrichtern. Die Einheiten versorgten die Elektrolysenhallen des Aluminiumwerks in Slatina, die im Zeitraum 1973 – 1975 in Betrieb gesetzt wurden und seitdem ununterbrochen funktionieren.

An der Ausschreibung nahmen mehrere Firmen teil. Das Konsortium Siemens-ABB-INPEC erhielt den Auftrag dank der technischen Qualität der angebotenen Einrichtungen und Leistungen, doch besonders wegen der kurzen Ausführungszeit einer jeden Einheit bzw. 24 Arbeitstage ab Abschaltung des Stroms in einer Einheit bis zur Inbetriebnahme unter Dauerlast (einschl. 72 Stunden Probe).

Innerhalb des Konsortiums lieferte die Firma SIEMENS die 66,8 MVA Regel- und Gleichrichtertransformatoren und die Firma ABB die 45 kA/1300 V Leistungsgleichrichter.

INPEC ENGINEERING stellte die Anschaffung, die technische und wirtschaftliche Koordinierung im Konsortium sicher. Zu den von INPEC erbrachten Leistungen zählen die Ausladung und der Transport auf rumänischem Gebiet der 14 Transformatoren (jeder von ca. 100 Tonnen), die planmäßige Anpassung der neuen eingeführten Einrichtungen an die bestehende Automatisierung der Einheiten, die ständige technische Betreuung bei der Abmontierung der bestehenden Einrichtungen und Freihaltung der Arbeitsfront sowie bei der Montage der rumänischen und der eingeführten Einrichtungen, die Teilnahme zusammen mit den ausländischen Fachleuten und die des Auftraggebers an allen bis zur Inbetriebnahme unter Dauerlast durchgeführten Proben. Es wurden keine Verzugsstrafen gezahlt.

Die Arbeiten vor Ort dauerten 9 Monate, von Oktober 2007 bis Juni 2008. Die vom Konsortium gewährleistete Garantie betrug 24 Monate ab Inbetriebsetzung.

## **IMPLEMENTATION MODE**

**Project ALRO „ 7 Rectifier groups DC 1300 V, 45 kA“**

**Turnkey project**

### **A. Introduction**

After a 32 year time period of practically uninterrupted operation of the rectifier groups delivered by Siemens, in which these showed a high operating security, and after extensive measurements of their wear and tear grade, ALRO S.A. decided it was time to replace the equipment of 7 rectifier groups of the electrolyse halls no. 5...8 with new equipment, which should ensure also the production increase in said halls.

Taking into account that one of the four groups from halls 7 – 8 was already replaced in the last years, ALRO wants now to replace the other three rectifier groups and to maintain the fourth group unchanged in operation.

Beside the equipment supplies, ALRO decided that INPEC/SIEMENS/ ABB should extend the scope of work to a full Turnkey Contract consisting of complete dismantling of the existing equipment, respectively erecting and commissioning the new rectifier groups.

### **B. Powers, voltages, comparison with existing rectifier groups of halls 5..8.**

In order to secure the production growth, ALRO decided to increase the voltage of the main DC busbars from 1150 V to 1300 V, to be able to increase the number of electrolytic baths, the 45 kA DC value of a rectifier group current remaining unchanged.

The INPEC/SIEMENS/ ABB offer contains essentially for each of the 7 offered rectifier groups:

- a) One regulating transformer and one rectifying transformer 66,8 MVA both transformers manufactured by Siemens Transformer factories in Germany.
- b) One rectifier with water- cooled diodes, produced by ABB Turgi /Switzerland.  
The diodes are mounted in two cubicles, corresponding to the 2 secondary coils of the rectifier transformer ( star and triangle).

The two cubicles are placed on the two sides of the transformer, on the existing platform of the rectifier, in the same way as by the existing installations.

The rectifier is delivered together with the pump unit for the rectifier cooling.

The rectifier devices are cooled with deionized water.

**Compared to the 59 MVA power of the existing transformers of actual DC 45 kA, 1150 V rectifier groups, calculations made by the installation manufacturers show that the power of 66,8 MVA for the INPEC/SIEMENS offered transformers was selected correctly.**

**This power is adequate to ensure the same operational security as that of the long time operated SIEMENS transformers :**

$$1300 \text{ V} / 1150 \text{ V} \times 59 \text{ MVA} = 66,695 \text{ MVA} = 66,8 \text{ MVA}$$

The tap changer of the rectifier transformer has 32 steps as compared to 27 steps of the existing tap changer, and the voltage increase is 63 V.

At the rectifier transformer, the transducers have a nominal regulating current of 6 A, as at the existing installations.

Due to the increase of the transformer power, the 6 current transformers of the rectifier transformer will have another transforming factor, in order to ensure the same value of the current reaction in the regulating system as presently for the 22,5 kA DC.

### **C. Peculiarities of the new rectifier groups**

The equipment to be supplied by the Supplier, in spite of being of higher power compared to the existing rectifier groups, is perfectly passing into the existing constructions, which thus do not need adaptations.

The resulting advantages are clear: low costs of the construction and mounting works, quick replacement of the old installations with new ones, short interruptions of operation.

#### **C1. Transformers.**

The rectifier transformer will be mounted in the existing niche and the regulating transformer will be positioned outside, next to it.

The Beneficiary puts at the Supplier's disposal designs of construction, foundation and placements of the installation part of all seven existing rectifier groups. The Supplier will verify the correspondence between the received designs and reality by each group.

The flexible connections between transformer and diode cubicles have the same dimensions and are positioned in space like at the existing rectifier groups, thus the existing connections can be again reused. Important is also that dimensions and drillings are identical.

**Transformer cooling** is assured with new oil-air heat-exchangers and oil pumps (Siemens supply), connected through pipes (Inpec supply).

The Beneficiary has to stipulate and fix the succession of the exchangeable aggregates at order granting, so that the necessary swing for the transformer being supplied is to be known.

## **C2. Rectifier**

The rectifier cubicles have modern, water-cooled diodes. There are 6 diodes mounted in parallel per branch, with 4000 V maximal blocking voltage (voltage security factor 2,7)

The rectifiers are set for an „ n- 1“ operation, respectively one diode of a branch can be missing without being necessary to reduce for this reason the nominal current on the DC busbar.

The current security factor at „ n- 1“ operation is 1.38.

The diode protection is ensured through the following devices:

- Over-temperature protection device for the diode busbars
- R-C damping circuits
- Fuse monitoring

The dimensions of the diode cubicles are very near to the existing cubicles.

**Rectifier cooling** is assured with deionized water + glycol in a closed circuit.

The water is recycled through a pump cabinet with two pumps of about 3,5 kW ( one active pump, the other as warm reserve). In its turn, the water is cooled through a separately mounted heat exchanger.

## **C3. Pulsation, losses, yield, power factor**

The pulsation of the DC current delivered by each rectifier group is 12 pulse pro AC current period.

The DC supply of a pair of electrolysis halls 5-6, respectively 7-8, will be done through 4 groups in parallel, whose transformers are supplying AC voltages, which are one to another dephased successively with 7,5 electrical degrees, to produce on the DC collecting busbars a resulting pulsation of 48 pulses. At these pulsations one can obtain optimal values for efficiency and power factor.

As resulting from the operational experience of the Beneficiary installations, for a future working current in the collecting busbars of 120 kA, the optimal operation is obtained with 4 groups, coupled

in parallel on the current busbars of one pair of halls, each group being charged with DC 30 kA, respectively 66,7% of the nominal current of a rectifier group.

**The maximal losses** , in nominal operation conditions of 1300 V, 45 kA, for one of the rectifier groups delivered by us ( excluding the auxiliary devices of the cooling, control and regulation, ) were stated in our offer and in subsequent letters, being 728 kW.

The losses are much smaller in the case of an operation with 4 groups coupled in parallel and 66,7% charge on the groups ( 120 kA on the DC collecting busbars).

**The yield of a group, calculated for transformers + rectifiers, including transducers but excluding auxiliary devices (as exception towards IEC) in nominal operation conditions, is of 98,8 %.**

#### **Power factor**

The power factor calculated by ABB by a feeder voltage of 220 kV for a total current DC 120 kA is:

- a) with 4 parallel working rectifier groups by 1220 V/120 kA :  $\cos \phi = 0,929$
- b) with 3 parallel working rectifier groups by 1220V/120 kA :  $\cos \phi = 0,912$

#### **C4. Control and regulation**

The existing installations for the current control, regulation and signalization will be maintained with minimal changes, taking into account the fact that these were previously modernized, when one passed to the free programmable control, both for the series control as for the group control.

Because the new transducers are similar to the ones in operation, the saturation and control currents are remaining unchanged.

Differences are in principle only in the increase of the tap numbers of the tap changer, from 27 to 32 taps, fact which needs the addition of several signalization lamps for the signalization of supplementary taps on the panel in the control room, with corresponding wiring.

The command/control equipment for a rectifier group will include:

- a) Existing cubicle with programmable logic, delivered by ALSTOM, supplying the command currents of the transducers;
- b) According to the ALRO request, the existing control cubicle Siemens will be maintained in operation.
- c) One new device cubicle for auxiliary services will be supplied

The Beneficiary will have to put at the disposal of the Supplier successively all the existing operating series and group control and regulation installations of groups no. 400 ... 403 and 501 ...503, in a perfect operational status.

The Beneficiary will also put at the disposal of the Supplier the updated design documentations of the electrical circuits of the existing 59 MVA rectifier groups (up to date circuits diagrams, part lists, cable lists with free conductors and clamp connection plans, external wiring plans, mounting plans, documentation for hardware and software of the regulation cubicles).

A collaboration of the technical personnel of ALRO and of the electrical mounting company is necessary for optional clarifications of circuits and execution of changes/adaptations thereof and of the software.

## **D. Engineering**

For the timely elaboration of the documentations for the turn-key integration, the Beneficiary will submit no later than 2 weeks after contract signing all necessary documentation in order to enable the Supplier to make the engineering for the turn-key contract.

The Supplier will deliver to the Beneficiary 3 sets of erection project before the beginning of the erection works for each rectifier group and 3 sets as-built drawings latest 3 months after the Final Acceptance Protocol for each group including schematic diagrams, parts lists, terminal diagrams, etc.

Operating and maintenance manuals will be delivered together with the equipment.

## **E. Existing premises, works and supply of ALRO**

The existing premises, works and supply of the Beneficiary are stipulated in Annex no. 4.1.B

## **F. Inspections and tests on the test bench of the factories**

The tests will be effected as follows :

- for the Trafo Rectifier in the Siemens factory in Nuernberg
- for the Regulating Trafo in the Siemens factory in Dresden
- for rectifiers in the ABB factory in Turgi, Switzerland
- for the cabinet of auxiliary services in Celule Băilești

The tests to be performed are given in the Annex 10 and are corresponding to the IEC Norms, and a respective protocol shall be issued.

## **G. Dismantling of the existing equipment and mounting of the new equipment**

According to the contract, the dismantling of the existing equipment and the mounting of the equipment being object of the present contract will be executed by the Supplier (Turn Key) by means of specialized companies, for which scope corresponding contracts will be concluded.

### G.1 Dismantling of the existing equipment

One week after the arrival of the delivered equipment of a rectifier group, at the request of the Supplier, the Beneficiary will uncouple a rectifier group from voltage, which group will be given in the care of the Supplier based on a protocol .

Dismantling of the equipment by the mounting company will develop according to the Annex no. 8, which is valid for each of the 7 rectifier groups.

First of all occurs dismantling of the heat exchangers and regulating transformer cooling pipes, to make place for transformer dismantling.

The dismantled trafos will be transported by the erection company up to the common line of the rectifier groups, to create conditions for moving and mounting the new delivered transformers.

Parallel occurs dismantling of existing auxiliary cubicle (except by group 400) and of non re-used cables according to erection project.

The rectifiers, trafos and auxiliaries will be given to the Beneficiary for warehousing, based on a protocol.

## G.2 Mounting of the new equipment

The equipment delivered by the Supplier will be taken over by Beneficiary based on a over- reception protocol, and the Beneficiary will give the equipment to the erection company 5 days before erection start.

The equipment mounting will be effected according the enclosed schedule (see annex no. 8). According to the provisions of Annex 4.1B Beneficiary has to fulfil its obligations during the dismantling / mounting time period.

After erection end a protocol signed by both parties.

## **H. Commissioning**

As the dismantling and mounting activities, the commissioning will be made separately for each rectifier group.

Due to the technological process of erection, the mounting cannot be terminated completely for a rectifier group, and then immediately execute the commissioning .

First it is necessary to terminate the mounting of the trafos , after which the commissioning of the trafos allone will be effected witout AC connection to the rectifier cubicles, under technical assistance Siemens.

After successful termination of the transformer commissioning, a protocol will be concluded, wherein the obtained results of measurements and respective conclusions will be stated.

After successful termination of the trafos commissioning, one can connect the flexible AC busbars between rectifier transformer and rectifier cubicles, and the mounting works at the rectifiers will be continued.

After the end of these works, the commissioning of the rectifiers, first in a “ cool” regime and then “under load” will be effected, with technical assistance from Supplier.

During the whole mounting- and commissioning period the Beneficiary specialists who will take over the installations, will have to give technical assistance and being present.

After successful warm test of the recitifiers, ALRO will ensure the conditions specified by the supplier’s specialists to be able to execute the 72 hour test .

## **I. Guarantees**

Terms: see the commercial part of the contract

## **J. Training**

Basically the training of the operational personnel takes place during the commissioning of the new rectifier groups on site.

## **K. Technical assistance at erection and commissioning.**

Services of technical assistance with the Supplier's specialists to this end shall be provided acc to Appendix 8.

**TURN –KEY SUPPLY OF 7 RECTIFIER GROUP of 1300 V,  
45 kA DC CURRENT**

No	Subject in question	INPEC - SIEMENS - ABB Split unit
1	Power	<b>Regulating transformer power 66,8 MVA Typ TFFJ7854</b> Rectifying transformer power 66,8 MVA Typ TFAJ7846 + 2x CBMB1624
2	Power factor by DC 1220 V, 120 kA	4 groups parallel: 0.929 3 groups parallel: 0.912
3	Output, calculated for transformers + rectifiers, including transducers but excluding auxiliary devices	98.8 %
4	Losses (guaranteed maximum values)	<b>Regulating transformer : 255 kW (Tol. +15%)</b> Rectifying transformer + Transducers: 343 kW (Tol. +15%)  <b>Rectifying cabinet : 130 kW ±15%</b> <b>TOTAL 728 kW (Tol. +15%)</b>
5	Connection groups	7 groups of connections with displacements that allow 48 pulses
6	$U_{\text{short-circuit}}$	Regulating transformer: 6.5% (Tol. ±10%) Rectifying transformer: 6% (Tol. ±10%)
7	Tap changer	On load 32 positions, no-load 2 ranges

8	Constructive solution	Regulating transformer+Rectifying transformer 2 rectifying cabinets (each with 2 outputs +,-)
9	Dimensions, Weights	Regulating transf.: 7,300 x 3,450 x 6,650 mm, 126 t out of which 28 t oil Rectifying transf.: 6,000 x 3,700 x 6,650 mm, 100 t out of which 28 t oil Rectifying cabinet: 4,400 x 1,150 x 2,500 mm, 2 x 3,8 t Dimensions almost identical with those of the existing Siemens groups
10	Cooling	Regulating transformer, rectifying transformer, rectifying cabinets: new coolers supply
11	Protections	Existing protections on 220 kV side are reused; in addition overtemperature protection and fuse burning are implemented by the rectifying cubicles
12	Regulation	INPEC offer keeps the existing regulating devices for group current as well as for series current, units upgraded by ALSTOM 3 years ago. Current measurement is made by current transformers within the rectifying transformers.
13	Remote control	The existing panels for signaling, commands etc. are reused with minimal adaptations
14	Adjustment, possibilities of erection instead of existing groups	Equipments offered can be mounted on the actual positions without additional works. Existing electric circuits remain operational, with minimal adaptation. Complete protection is provided
15	Designing for achieving the groups	Regulating transformer self-contained, rectifying transformer self-contained, rectifying cabinets self- contained, supply 220 kV reused, outlet voltage 1300 V DC, outlet current 45 kA

16	Auxiliary command and control devices and circuits needed for each rectifying group	A new cabinet for auxiliary services will be supplied. Existing auxiliary command and control cables except auxiliary cables between transformers, rectifier and the new cabinet are used
17	Delivery terms	<p>Lot 1 – 2 rectifier groups – 31.07.2007</p> <p>Lot 2 – 2 rectifier groups – 31.09.2007</p> <p>Lot 3 – 3 rectifier groups – 31.12.2007</p>
18	Standard fittings, oil, tests	<p>There are provided in the transformer price: oil, standard fittings, oil pumps, as well as routine tests, with no special tests.</p> <p>The existing arresters on the 220 kV are used.</p> <p>Oil filling, erection and PIO are included in the scope of supply only in the turn-key variant of the contract.</p>
19	Technical assistance on erection and PIO	<p>Technical assistance on erection and PIO with specialists Siemens, ABB and INPEC is offered.</p> <p>If erection will be in charge of customer, good erection guarantee will be in charge of ALRO.</p> <p>Siemens / ABB personnel will perform a visual inspection of erection, without being able however to determine possible hidden flaws. Qualified personnel of ALRO shall participate at the PIO beside of specialists Siemens, ABB and INPEC, according to the conditions stipulated in “Implementation mode” of the contract, chap. H and I.</p>
20	Guarantee	24 months from PIO, max. 30 months from Ex Works delivery.

21	<b>Civil works – erection works</b>	<p>INPEC offer also keeps besides the current regulation units the auxiliary circuits units with little adaptations, changing consisting only in the replacement of existing transformers and diode cabinets to be adjusted to the existing bars, as well as new and auxiliary services cabinets.</p> <p>INPEC can carry out dismantling, mounting and connecting the equipment comprised in the Scope of supply, through a specialized firm engaged by INPEC to this purpose. The works will be carried out with technical assistance Siemens, ABB and INPEC for the period of dismantling, mounting and PIO, whereas ALRO will assure premises, works and supplies according to <b>“Implementation mode for the turn-key variant of the contract, chap. H and I”</b>.</p>
22	Erection duration	<p>In the turn-key variant of the contract, 3 weeks for a rectifying transformer group (see annexed time schedule).</p> <p>In the variant of supply only of equipment, this time schedule must be performed by ALRO, since the period of technical assistance according to contract is determined through this time schedule.</p>

**ERECTION AND COMMISSIONING SCHEDULE FOR ONE RECTIFIER GROUP 66,8 MVA**

**Appendix 8**

ACTIVITY	Dismantling Mounting	1	2	3	4	5	St	Sn	8	9	10	11	12	St	Sn	15	16	17	18	19	St	Sn	22	23	24	25	26	St	Sn	29	30			
1	2 pcs. transformer	Dismantling	Orange																															
		Mounting		Blue	Yellow																													
2	2 pcs heat changer oil/air	Dismantling	Orange																															
		Mounting		Blue	Yellow																													
3	2 set transformer cooling oil pipes	Dismantling	Orange																															
		Mounting		Blue	Yellow																													
4	Secondary circuits of the transformers	Dismantling	Orange																															
		Mounting		Blue	Yellow																													
5	AC flexible connection Alu bars	Dismantling	Orange																															
		Mounting		Blue	Yellow											Green	Green	Green	Green	Green	Green													
6	2 pcs. diode cubicles	Dismantling	Orange																															
		Mounting								Blue	Green	Green	Green	Green	Green																			
7	1 pc. pump unit for rectifier cooling	Dismantling	Orange																															
		Mounting								Blue	Green	Green	Green	Green																				
8	1 pc. heat exchanger water / air	Dismantling	Orange																															
		Mounting								Blue	Green	Green	Green	Green																				
9	2 set rectifier cooling water pipes	Dismantling		Orange																														
		Mounting								Blue	Green	Green	Green	Green																				
10	DC current Alu bars	Dismantling	Orange																															
		Mounting														Green	Green	Green	Green	Green	Green													
11	Secondary circuits	Dismantling	Orange																															
		Mounting		Blue	Yellow											Green	Green	Green	Green	Green	Green													
12	Auxiliaries cubicle	Dismantling	Orange																															
		Mounting		Blue	Yellow											Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	
13	Transformers commissioning															Yellow	Yellow	Yellow	Yellow	Yellow	Yellow													
14	Rectifier commissioning without charge																Green	Green	Green	Green	Green	Green												
15	Rectifier commissioning with charge																																	
16	Equipment testing																																	
17	Acceptance test																																	
	Supervision INPEC		Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	

Legend :

	Dismantling without supervision Siemens , ABB
	Mounting with supervision Siemens , ABB
	Mounting supervision ABB
	Commissioning supervision ABB (PIO)
	Mounting supervision Siemens
	Commissioning supervision Siemens (PIO)
	Commissioning supervision INPEC (PIO)
	Supervision INPEC to dismantling and mounting