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Technical report

Final Report

Upgrade of Auxiliary Seismic Station AS101, Hagfors, Sweden

Ref: CTBTO Contract 00/30/6037

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Final Report Upgrade of Auxiliary Seismic Station AS101, Hagfors, Sweden Ref: CTBTO Contract 00/30/6037

Abstract

This is the Final Report in a series of reports describing the upgrade of the Hagfors Array in 2001 and 2002. The report includes a history of the whole upgrade and the final technical installations. The report also summarizes maintenance and repair activities during a period of testing and evaluation. Finally the results from two consecutive calibrations are given as well as some statistics on observed data availability.

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Slutrapport Uppgradering av den svenska seismologiska array stationen AS101 i Hagfors

Sammanfattning

Föreliggande rapport är den sista i en serie av rapporter, som beskriver uppgraderingen av den seismologiska mätstationen i Hagfors under åren 2001 och 2002. I början ges en kort historik över uppgraderingen följt av en beskrivning av de sista tekniska installationerna. Rapporten redovisar också det tekniska underhåll som utfärdes under testperioden. Slutligen redovisas jämförande resultat från två kalibreringar samt statistik på observerad datatillgänglighet.

Nyckelord

Seismologi, provstoppsövervakning, mätstation, CTBTO

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Contents

1 Introduction **7**

2 History of the Upgrade **7**

3 Installation of pre-amplifiers **7**

4 Upgrade of UPS System **8**

5 Maintenance, Repair Activities and Software/Firmware Upgrade **9**

6 Calibration **12**

7 Data availability **13**

1 Introduction

This is the final report in a series of four reports, according to the Contract (00/30/6037) between the Swedish Defence Research Agency (FOI) and CTBTO, on the upgrade of Auxiliary Seismic Station AS101, Hagfors, Sweden. The first report mainly included the design and the specifications of equipment for the upgraded array station. The second report gave an almost full description of the new and upgraded array including the installation of the new data acquisition system.

This report, the Final Report, mainly describes the few items that remained to be done after the main installation phase in June-August 2001. It also summarizes the findings from a test period, including some calibration results.

2 History of the Upgrade

The Hagfors seismic array station has been designated as facility AS101 in the International Monitoring System (IMS) to be established under the Comprehensive Nuclear Test Ban Treaty (CTBT). Hagfors is an auxiliary station and thereby sending only segmented data to the IDC in Vienna but it has also been selected as back-up for primary stations (sending continuous data) in Europe and western Asia.

Due to the aging infrastructure and the inhomogeneous instrumentation FOI (former FOA) and CTBTO therefore in December 2000 reached an agreement on a major upgrade of the station including a new array configuration.

After a period of planning the actual field work started in April 2001 when the land owner started cutting trees to pave the way for the cable trenches. The site preparations could be started first in early June which was a month late compared to the plan and the delay was due to abnormally wet ground conditions. Although there were some delays caused by the delivery of defective equipment, almost all of the installation of the new array including the data acquisition system could be finished in late August only one week behind schedule. In parallel to the technical upgrade of the station both the exterior and the interior of the central facility building was also upgraded to a higher standard including a capability for housing a few people overnight.

On August 24 the first data from the new array started to flow to Vienna via a new and direct satellite link that had been set up just a week before. In January 2002 a new Uninterrupted Power Supply (UPS) system was installed. The installation of hardware was completed in early April 2002 when pre-amplifiers between the seismometer and the digitizer were installed at each recording site.

Since late August 2001 the new Hagfors array has been in continuous operation to gain experience on reliability and maintenance of equipment, data quality (spikes, gaps), data availability and the individual timing at each site from the GPS network. Such experience is necessary to see if the station meets the IMS requirements or if some hardware or software has to be shifted or upgraded before the forthcoming certification.

The experience gained during this testing period called for an upgrade of the software/firmware at each element and at the central facility. This upgrade was carried out by representatives both from CTBTO and Nanometrics (CTBTO equipment provider) during the first week of December 2002.

In the whole process of upgrading the Hagfors array station more than 10 different companies and organizations were directly involved. The work was done in close cooperation with NORSAR who delivered and installed part of the equipment. The main parts of the data acquisition system were delivered by Nanometrics who also assisted on-site with the installation.

3 Installation of pre-amplifiers

Only temporary (prototype) pre-amplifiers, to be installed between the seismometer GS-13 and the digitizer, were delivered by Nanometrics for the installation in August 2001. The background was that Nanometrics had developed pre-amplifiers with a new design and these were not ready and had to be tested to see that they did not significantly affect the system noise.

By January 2002 the new pre-amplifiers were delivered to the Hagfors station. However it turned out that an extra cable inside the Europa digitizer was needed to supply the amplifier with power. These extra cables were shipped to the site in March and on April 4 2002 the final pre-amplifiers could be properly installed (see Figure 1). The amplification factor in the current amplifiers is equal to 30.23.

Figure 1: The pre-amplifier installed in the vault

4 Upgrade of UPS System

A new Uninterrupted Power Supply (UPS) system was installed at the central facility in January 2002. The new UPS is capable of maintaining stable operation of the data acquisition system for 30 hours in the event of a power failure in the commercial power supply. The new system provides power conditioning/voltage regulation as required for all the equipment located at the central facility and the array element locations.

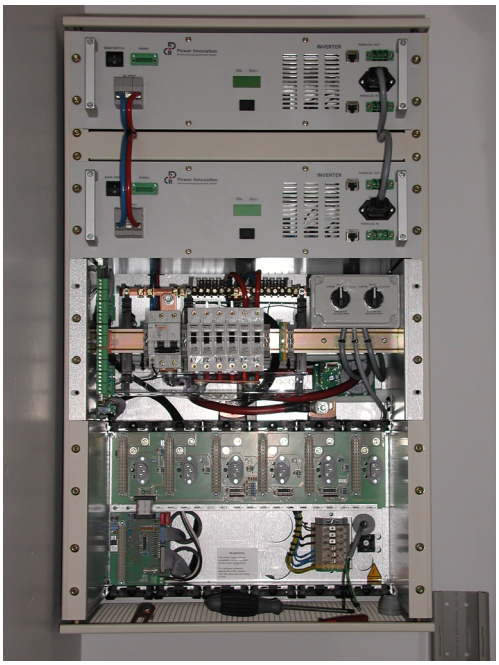

Figure 2: UPS mounted in the computer-room in central facility

The UPS also includes features that allows remote monitoring of the units status (SOH data). The new UPS is mounted in a wall cabinet (see Figure 2) in the computer room and has a bank of nickel cadmium batteries located in a separate battery room (see Figure 3).

Figure 3: Battery backup

5 Maintenance, Repair Activities and Software/Firmware Upgrade

This section summarizes the maintenance, repair activities and software/firmware upgrade carried out at AS101 during 15 months of operation since the start of the new array in late August 2001. Additional details are given in Table 1.

One of the main observations during this period was the occurrence of short gaps occasionally on all data channels but most frequently on a limited number of channels. So far the causes of these gaps are not fully understood. One explanation could be loss of communication with the GPS network typically a few times per day especially at the sites HFA0 and HFA1. Another explanation could be the so called "comms controller problem", a bug in the Nanometrics software, which severely effected the data from site HFC2 several times. It can be noted that the occurrence of gaps was reduced for a few days after power recycling on the digitizers and then they appeared again especially on HFA0, HFA1 and HFB2. An upgrade of the software, to make the GPS timing more robust and to get rid of the "comms controller problem", was carried out during the first week of December 2002. Although there has been occasional gaps on certain channels the data availability has been relatively high.

The communication link to Vienna has worked satisfactory except for one failure in June 2002. A HOT-engineer came and fixed the problem but a few hours after he left the link went down again. Three days later the local caretaker shifted to the spare PES (IDU) and since than the link has been working satisfactory.

During the summer of 2002 moisture was found on the floor of the sub-surface vault at almost all sites and especially HFB2. Therefore in October 2002 the HFB2 site was prepared with extra epoxy cement to get rid of this problem.

Instrument calibration have been carried out in January, August and December 2002.

One digitizer and one RM-4 multiplexer have been sent for repair to Nanometrics and both have returned ok.

Figure 4: Repair activities at site HFA0

Table 1: Maintenance and Repair activities AS101 August 2001-December 04 2002

Date	Description
010813 - 010817	Installation new equipment
010820 - 010824	Installation and testing new equipment
011007 - 011008	Power-cycling digitizers
011011	Power-cycling digitizers, RM4-problem
011017	Power-cycling digitizers, RM4-problem
011029	Power-cycling digitizers, RM4-problem
011207	Power-cycling digitizers, RM4-problem
020122 - 020124	RM4-channel HFA1 dead, fiber and power cable measurements, power-cycling HFB2
020123	Installation of new UPS
020123	Calibration of GS-13, 07:37, 2 Hz , 120 s, ampl 100
020123	Calibration of GS-13, 07:57, 2 Hz, 120 s, ampl 1000
020123	Receipt of two spare RM4:s
020123	Receipt of new seismometer cables
020123	Receipt of pre-amps and internal cables, not installed due to missing -12V DC on digitizer-signal connector
020325	Power-cycling HFC2

Date	Description
020403 - 020405	Digitizer modification, pre-amps and new seismometer cables installed
020405	Change of IP-addresses, Installation GCI router
020620	Maintenance activities, link to Vienna down, tried spare Out Door Unit-no success
020624	HOT-engineer repaired PES In Door Unit between 0800-1200 UTC
020624	Satellite link to Vienna down 1759 UTC
020627	Sven-Inge, Local Caretaker (LC) shifted to spare PES(IDU) about 0830-0845 UTC
020701	Maintenance activities
020702	Maintenance activities
020707	Round trip to all sites, moisture at all sites except for HFA2 and HFA3
020813	Round trip to all sites, water drops on the floor at all sites.
020813	Small fix on HFA2, HFB3 and HFC2 to tighten the lid.
020813	Calibration P Larsen, all GS-13, 2 Hz, ampl:100, 300, 500, 14:17, 14:20, 14:25
020813	Calibration of STS-2, 14:51
020813	HFA3 locked 15:30-15:50 to get data on system noise
021002	Start of gap on HFC2 due to "comms-controller problem"
021010	End of gap on HFC2 after power cycling on the power supply
021010	HFB2 and HFC2 visited and both totally dry on the floor.
021010	HFB2 disconnected from 10.00 due to epoxy preparation
021011	HFB2 up again 09.32 , epoxy preparation finished
021028	Long gap HFA2 and HFB3, power cycling by LC on all digitizers except HFC2
021121	Power cycling by LC 13:11 on HFA0, HFA1 and HFB2
021203 - 021204	Upgrade of digitizer/RM4 firmware/software to fix the GPS timing bug and the comms-controller bug
021204	Calibration of all GS-13 channels 09:59 4 Hz 320μm/s 0-peak amplitude 10:05 2 Hz 160μm/s 0-peak amplitude

6 Calibration

The Hagfors array has been calibrated several times during 2002. In this report the calibration on August 13 is compared with the calibration carried out on December 4. Specifically the sensitivities calculated from the observed amplitudes are compared. Table 2 shows that for each channel the observed sensitivity differ less than 2 % which is well below the upper limit of 5 % in the specifications. The small variations in sensitivity over the array is illustrated in Figure 5 where the traces from all GS-13 elements have been put on top of each other.

Table 2: Observed sensitivities for each channel and difference in percentage. The input parameters for the August 13 calibration were: amplitude 300 μm/s (0-peak), frequency 2 Hz. For the December 04 calibration the corresponding values were: amplitude 160 μm/s (0-peak), frequency 2 Hz. Observed sensitivity= No of counts (0-peak)/input amplitude (0-peak)

Channel	Observed sensitivity (counts/(nm/s)) August 13 2002	Observed sensitivity (counts/(nm/s)) December 4 2002	Difference (%)
HFA0	22.2766	22.5473	1.2
HFA1	22.8666	23.0162	0.7
HFA2	22.4732	22.6456	0.8
HFA3	22.4184	22.7362	1.4
HFB1	23.0122	23.1258	0.5
HFB2	22.8329	22.9285	0.4
HFB3	22.4134	22.6673	1.1
HFB4	23.3374	23.4736	0.6
HFB5	23.0125	23.0476	0.2

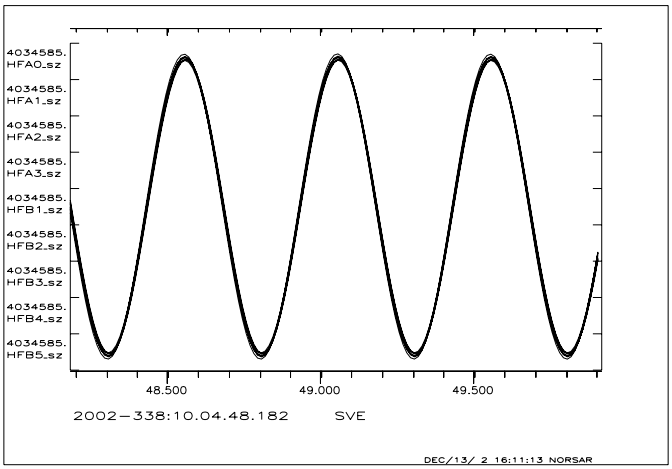

Figure 5: Traces from all GS-13 elements put on top of each other. The traces were generated by one calibration of all elements (amplitude: 160 μm/s, frequency: 2 Hz). The amplitude scale on the plot is the same for all traces.

7 Data availability

The following tables give the monthly data availability in 2002 for the Hagfors array. For the first 8 months the data availability is based on the data stored at NORSAR. From September 2002 the availability is calculated on data stored at FOI in Stockholm. The last table compares the data availability obtained before and after the software/firmware upgrade in the beginning of December 2002 .

For half of the channels the monthly data availability generally is above 98% for the whole time period. For certain channels especially HFA0 and HFA1 the figures are quite low for June-July (see Table 4 and 5). The reason for this drop in data availability is not fully understood but it is known that especially the sites HFA0 and HFA1 have occasional drop-outs in the communication with the GPS-network. The last table (Table 7) clearly indicates that the occurrence of gaps on these two sites has decreased after the software/firmware upgrade.

Table 3: Data availability for January-March 2002

	January		February		March	
Sta	Gaps (s)	Data availability (%)	Gaps (s)	Data availability (%)	Gaps (s)	Data availability (%)
HFA0_sz	7786	99.700	606	99.975	549	99.980
HFA1_sz	292233	88.726	267	99.989	685	99.974
HFA2_sz	9796	99.622	57	99.998	217	99.992
HFA3_sz	7972	99.692	153	99.994	193	99.993
HFB1_sz	8935	99.655	79	99.997	182	99.993
HFB2_sz	720976	72.185	333	99.986	338	99.987
HFB3_sz	9944	99.616	515	99.979	424	99.984
HFB4_sz	7120	99.725	481	99.980	120	99.996
HFB5_sz	28923	98.884	241	99.990	47	99.998
HFC2_be	145319	94.394	250	99.990	699093	73.899
HFC2_bn	145334	94.393	268	99.989	698157	73.934
HFC2_bz	145207	94.398	212	99.991	685739	74.397

Table 4: Data availability for April-June 2002

	April		May		June	
Sta	Gaps (s)	Data availability (%)	Gaps (s)	Data availability (%)	Gaps (s)	Data availability (%)
HFA0_sz	19169	99.260	848	99.968	1162515	55.150
HFA1_sz	6559	99.747	806	99.970	26186	98.990
HFA2_sz	7612	99.706	367	99.986	3115	99.880
HFA3_sz	7899	99.695	388	99.986	2658	99.897
HFB1_sz	7275	99.719	341	99.987	2722	99.895
HFB2_sz	20243	99.219	571	99.979	2894	99.888
HFB3_sz	7101	99.726	582	99.978	2847	99.890
HFB4_sz	6197	99.761	283	99.989	2655	99.898
HFB5_sz	4073	99.843	247	99.991	2733	99.895
HFC2_be	219798	91.520	175	99.993	2775	99.893
HFC2_bn	219780	91.521	88	99.997	2748	99.894
HFC2_bz	219801	91.520	79	99.997	2734	99.895

Table 5: Data availability for July-September 2002

	July		August		September	
Sta	Gaps (s)	Data availability (%)	Gaps (s)	Data availability (%)	Gaps (s)	Data availability (%)
HFA0_sz	763500	71.494	3249	99.879	1866	99.928
HFA1_sz	1256713	53.080	482675	81.979	4963	99.809
HFA2_sz	20342	99.241	7599	99.716	233	99.991
HFA3_sz	16907	99.369	972	99.964	67	99.997
HFB1_sz	16930	99.368	903	99.966	144	99.994
HFB2_sz	17283	99.355	1483	99.945	925	99.964
HFB3_sz	17216	99.357	986	99.963	147	99.994
HFB4_sz	16972	99.366	744761	72.194	148	99.994
HFB5_sz	17003	99.365	7342	99.726	89	99.997
HFC2_be	16840	99.371	1040	99.961	48	99.998
HFC2_bn	16858	99.371	1106	99.959	153	99.994
HFC2_bz	16899	99.369	1016	99.962	36	99.999

Table 6: Data availability for October-December 2002

	October		November		December	
Sta	Gaps (s)	Data availability (%)	Gaps (s)	Data availability (%)	Gaps (s)	Data availability (%)
HFA0_sz	12542	99.532	3284	99.873	67500	97.480
HFA1_sz	6292	99.765	3208	99.876	71983	97.312
HFA2_sz	339	99.987	982	99.962	85198	96.819
HFA3_sz	47553	98.225	905	99.965	85402	96.811
HFB1_sz	294	99.989	932	99.964	72599	97.289
HFB2_sz	81728	96.949	1607	99.938	82774	96.910
HFB3_sz	29760	98.889	913	99.965	87848	96.720
HFB4_sz	334	99.988	912	99.965	86071	96.786
HFB5_sz	260	99.990	978	99.962	67071	97.496
HFC2_be	692585	74.142	10591	99.591	5344	99.800
HFC2_bn	692714	74.137	10296	99.603	5396	99.799
HFC2_bz	685742	74.397	3195	99.877	5356	99.800

Table 7: Data availability before and after the Europa software upgrade on December 4 2002

	Day no. 314-324		Day no. 338-348	
Sta	Gaps (s)	Data availability (%)	Gaps (s)	Data availability (%)
HFA0_sz	1679	99.806	216	99.975
HFA1_sz	1273	99.853	190	99.978
HFA2_sz	258	99.970	219	99.975
HFA3_sz	227	99.974	210	99.976
HFB1_sz	217	99.975	205	99.976
HFB2_sz	497	99.942	211	99.976
HFB3_sz	223	99.974	275	99.968
HFB4_sz	258	99.970	205	99.976
HFB5_sz	296	99.966	214	99.975
HFC2_be	205	99.976	222	99.974
HFC2_bn	241	99.972	257	99.970
HFC2_bz	223	99.974	232	99.973