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Item Title BACS (Building Automation Control System) DFD - Integrated Architecture Description

Item Code 1G00PS250R789B

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Α	13.03.17	C. D'Apice	F. Nudo/R. Palma	G. Rizzi	I. Fulgieri	First issue.
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1 Introduction						

Introduction

1.1 **Context Description**

This document is relevant to the Building Automation Control System (BACS) and the Depot Building Automation Control System of Thessaloniki Metro Project. This description covers the main components of architecture of BACS and Depot-BACS.

The purpose of the BACS (in its complete architecture) is to control and monitor all Ventilation and HVAC systems and E&M systems within the stations, shafts and tunnels under all normal and emergency conditions. The building automation equipment managed by the BACS, can be grouped in the three below listed types:

- Electro-Mechanical (escalators, lifts, UPS, pumps, fire detection, etc...); ٠
- Heating, Ventilation and Air Conditioning (HVAC);
- Tunnel Ventilation (over-track exhaust fans, supply air fans, blast shaft fans, jet fans). •

Both subsystems, BACS and Depot-BACS, are composed by:

- The HMI Layer (CBACS and Depot-CBACS);
- The Field Layer (Local BACS) that is distributed in 13 (thirteen) stations, tunnel and depot area. ٠

The CBACS subsystem is composed of two parts:

- **CBACS No Safe**
- **CBACS Safe** _

They are two systems completely separated. The CBACS No Safe is composed of Server and Workstation component; the CBACS Safe is composed of Workstation, Safe Panel and Safe PLC. This difference is for maintain the segregation of the functionality managed.

The system allow monitoring and, where applicable, command building automation equipment in the stations, tunnels and along the railway. The BACS shall also be capable to perform other software functionality (like historical data storage and real-time trending) that will be described in specific technical documents (ID.05, ID.06).

The Depot-CBACS allows monitoring and, where applicable, command building automation equipment at the depot and is independent.

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1.2 Scope of the Document

The present document contains an architectural description for the realization of the BACS (Building Automation Control System) within the project "Thessaloniki Metro Project". The aim of this document is to define the description of integrated architecture of all subsystems that the BACS is composed, from HMI layer to field components, particularly in the safe aspect and describes the relevant safety architecture.

The scope of this document is to describe how to integrate (among them) the subsystems that comprise the BACS system. For the single subsystem are indicated the follows points:

- The HW architecture;
- The SW architecture;
- The interfaces with other BACS components and external systems;

CBACS No Safe and Depot-CBACS technical specifications are here defined to comply with:

• Subsystems' requirements (ID.02);

All safety requirements of CBACS Safe are specified in the safety requirements specification document (**ID.04**) and are compliant with the referenced standard (Table 1-7 – Reference Standards and Regulations) for the demonstration of SIL2.

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1.3 <u>Reference Documents</u>								
1.3.1	Inpu	t Documents						
	Table 1-	1 – Input Document	S					
	Item #	Code	Title The sector it i Mater	Date	Rev #			
	ID.01	1_DP15450	Design, Performance and Workmanship Specification. Building Automation Control System.	01.12.04	A			
	ID.02	1G00PS250G108	CBACS. Requirements' Compliance Matrix.		В			
	ID.03 1G00PS258G314		CBACS Safe. DFD Architecture Safety Analysis.		A			
	ID.04	1G00PS258G104	CBACS Safe. DFD Safety Requirements Specification.		A			
	ID.05	1G00PS250G105	CBACS Architecture Description (Technical Specification)		В			
	ID.06	1G00PS258G105	CBACS Safe Technical Specification	30.06.16	A			
	ID.07	1G00GE270B104	System & Subsystem Safety Requirements					
	ID.08 RFP-110/03		Design, Construction and Commissioning of Thessaloniki Metro System. Technical Description of the Project.					
	ID.09	05-724-TRA4-H1	CBACS - Review of DFD Specifications	12.2015	0			
	ID.10	05-724-TRA4-H2	CBACS - Review of Safety Analysis and Verification Report	12.2015	0			
	ID.11	1G00PS250G306	Local BACS. DFD – Interface Specification.					
	ID.12	1G00PS258G105	CBACS Safe. DFD Technical Specification		A			
	ID.11 ID.12	1G00PS250G306	Local BACS. DFD – Interface Specification. CBACS Safe. DFD Technical Specification		A			

1.3.2 **Applicable Documents**

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Table 1-2 – Applicable Documents

Item #	Code	Title	Date	Rev #
			BACS (Σύστομα Ελέννομ Αυτοματισμού Κτιοίων)	
17.11.2017	1G00PS250R789	в	BACS (Σύστημα Ελέγχου Αυτοματισμού Κτιρίων) ΜΕ – Περιγοριφό τος Ολοκλορωμένης Αργιτεκτονικός	1G00PS250R78

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1.3.3 Previous Stage Document

First issue of this document, then no Previous stage design review document referred.

Table 1-3 – Previous Documents

Item #	Code	Title	Date	Rev #
LD.01	None.	None.	None.	None.

1.3.4 Literature Documents

Table 1-4 – Literature Documents

Item #	Code	Title	Date	Rev #
LD.01	None.	None.	None.	None.

1.3.5 Customer's Design Review Documents

First issue of this document, then no Customer's design review document referred.

Table 1-5 – Customer's Design Review

Item #	Code	Title	Date	Rev #
DD.01	None.	None.	None.	None.

1.3.6 Verification Documents

Table 1-6 – Verification Documents

Item #	Code	Title	Date	Rev #
VD.01	1G00PS250G103	CBACS.		В
		Requirements' Compliance Matrix.		

В	17.11.2017	1G00PS250R789B	BACS (Σύστημα Ελέγχου Αυτοματισμού Κτιρίων)	1G00PS250R789

1.4	Referen	nce Standards and	Regulations		
	Table 1-	7 – Reference Stan	dards and Regulations		
	Item #	Code	Title	Date	Rev
	ST.01	EN 50126:2000	European Standard, EN 50126. Railway Applications: The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS).	2000	
	ST.02	EN 50128:2002	European Standard, EN 50128. Railway Applications: Communications, signalling and processing systems. Software for railway control and protection systems.	2002	
	ST.03	EN 50129:2009	European Standard, EN 50129 Railway applications. Communication, signaling and processiong systems. Safety related electronic system for signaling.	2009	
	ST.04	IEC 61508:2010	Functional safety of electrical/electronic/programmable electronic safety-related systems.	2010	

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	Κοινοπραξία	ΜΕΤΡΟ ΘΕΣΣ	ΔΑΟΝΙΚΗΣ		ЕРГО: СС	DN - 06 / 004

ΜΕΤΡΟ ΘΕΣΣΑΛΟΝΙΚΗΣ-THESSALONIKI METRO

EPFO: CON-06 / 004 - PROJECT: CON-06 / 004

1.5 **Glossary of Terms**

Term	Description
Fail-Operational	A characteristic of a system for which one failure is tolerated, i.e. the
	system stays operational after one failure.
	This is required if no safe state exists after the failure of a system
	component.
Fail-Safe	(or preferably de-energize to trip) A characteristic of a system which
	causes that system to move to a safe state when it loses electrical or
	pneumatic energy.
	After one (or several) failure(s) the system posses a safe state
	(passive fail-safe, without external power) or is brought to a safe state

	causes that system to move to a safe state when it loses electrical or				
	pneumatic energy.				
	After one (or several) failure(s) the system posses a safe state				
	(passive fail-safe, without external power) or is brought to a safe state,				
	by a special action (active fail-safe, with external power).				
	EN50128 defines it as "a concept which is incorporated into the design				
	of a product such that, in the event of a failure, it enters or remains in a				
	safe state".				
Safe State	Condition that the system reaches to preserve safety after internal				
	error. Thus, the state of the process after acting to remove the hazard				
	resulting in no significant harm.				
Fault Tolerance	Ability of a system to continue to perform a required function in the				
	presence of random faults or errors.				
	For example a 1002 voting system can tolerate one random component				
	failure and still perform its function.				
	Fault tolerance is one of the specific requirements for safety integrity				
	level (SIL) and is described in more detail in IEC61508-2:2010 Tables 2				
	and 3.				
Human-Machine	Refers to the software that the process operator "sees" the process				
Interface (HMI)	with.				

or	
Man-Machine	An example HMI / MMI screen may show a tank with levels and
Interface (MIMI)	temperatures displayed with bar graphs and values.
	Values and numps are often shown and the energies an "elick" on a

Valves and pumps are often shown and the operator can "click" on a device to turn it on, off or make a set point change.

Safety	Function	EN50128 defines a Safety Function as a "function that implements a
(SF)		part or whole of a safety requirement".
		IEC61508 defines a Safety Function as a "function to be implemented

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Αναθ. - Rev.	Hμ/vıα -Date	Αρχείο -Filename	BACS (Building Automation Control System) DFD – Integrated Architecture Description	Σελίδα -Page 13 / 61

КАТАДКЕУАДТІКН АЕ	Ansaldo STS A Hitachi Group Company SCEELI HITACHI SOCRETA' ESECUZIONE LAVORI IDBALLECE & A HITACHI HITACHI OHILIALI & A		
Κοινοπραξία	METPO ΘΕΣΣΑΛΟΝΙΚΗΣ ΕΡΓΟ: CON - 06 / 004		
ΜΕΤΡΟ ΘΕΣΣΑΛΟΝΙΚΗΣ-ΤΗ	IESSALONIKI METRO EPFO: CON-06 / 004 - PROJECT: CON-06 / 004		
Safety Requirements Specification	 by an E/E/PE safety-related system, other technology safety-related system or external risk reduction facilities, which is intended to achieve or maintain a safe state for the Equipment Under Control (EUC), in respect of a specific hazardous event". Specification containing all the requirements of the safety functions those have to be performed by the safety-related system. It includes 		
	It is often a contractual document between companies and is one of the most important documents in the safety lifecycle process.		
Safety Management Plan (SMP)	The Safety Plan or Safety Management Plan (SMP) is a key document in any IEC61508 / IEC61511 / EN50126 development project. It specifies how functional safety will be ensured throughout the entire development project and in production. The Safety Plan must identify the various roles and responsibilities as they apply to the development process. The Safety Plan lists the various techniques and measures that will be implemented as part of the development project to ensure that the targeted SIL is achieved. The deliverable of this task is the draft Safety Plan that the Customer must subsequently refine and implement in their development process.		

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	Ansaldo STS A Hitachi Group Company						
			SOCIPTA' ESECUZIONE LAVORI IDRAULICI S.p.A.	, @Hitachi Rail Italy, Spa			
Κοινοπραξία ΜΕΤΡΟ ΘΕΣΣΑΛΟΝΙΚΗΣ ΕΡΓΟ: CON - 06 / 004							
METPO	Ο ΘΕΣΣΑΛΟΝΙΚΙ	HΣ-THESSALONIKI METRO	EPFO: CON-06 / 004 - PROJECT: CON	√-06 / 004			
1.6	<u>Glossary o</u>	f Acronyms					
	Table 1-9 – 0	Glossary of Acronyms					
	Acronym Description BACS Building Automation Control System.						
	DOF						
	B/W	Black and White.					
	CBACS		nation Control System.				
	MCR	Main Control Room					
	DCR Depot	Depot Control Room.					
	BACS	Depot Building Autom	ation Control System.				
	Depot- CBACS	Depot Central Building	g Automation Control System.				
	DFD	Detailed Final Design.					
	E&M	Electro-Mechanical.					
	ECR	Emergency Control R	oom				
	EQP	Equipment Room					
	GUI	Graphic User Interface	е.				
	НМІ	Human Machine Inter	face.				
	H/W - HW	Hardware.					
	HVAC	Heating, Ventilation a	nd Air Conditioning.				
	IP	Internet Protocol.					
	IEC	International Electrote	chnical Commision				
	IPC	Industrial Personal Co	omputer				
	LAN	Local Area Network.					
	MNT	Maintenance Room					
	NIC	Network Interface Car	d.				
	occ	Operation Control Cer	ntre.				
	OTE	Over Track Exhaust.					
	PLC	Programmable Logic	Controller.				
	SAF	Supply Air Fan.					
SCADA Supervisory Control and Data Acquisition.							
	SIL	Safety Integrity Level.					
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		Societar Based	SELI ZZONE LAVDRE DBALTLES S.P.A @HITACHI Rail Italy, Spa					
	Κοινοπραξία ΜΕΤΡΟ ΘΕΣΣΑΛΟΝΙΚΗΣ ΕΡΓΟ: CON - 06 / 004							
ΜΕΤΡΟ ΘΕΣΣΑΛΟΝΙΚΗΣ-THESSALONIKI METRO ΕΡΓΟ: CON-06 / 004 - PROJECT: CON-06 / 004								
	SMR	Station Master Room.						
	SMS	Security Management System.						
	SPC	Statistical Process Control.						
	SQL	Structured Query Language.						
	sw	Software.						
	ТСР	Transmission Control Protocol.						
	UML	Unified Modelling Language						
	UPS	Uninterruptible Power Supply.						
	VDU	Visual Display Unit						
	WAN	Wide Area Network.						
	WS	Workstation.						

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	AEFEK impregilo Ansaldo) STS A Hitachi Group Company socartar Isaac	SELI Izone lavori idbalilici s _p a.,	HITACHI @Hitachi Rail Italy, Spa
	Κοινοπραξία ΜΕΤΡΟ ΘΕΣΣΑΛΟΝΙΚΗ	Σ	ЕРГО: СС	DN - 06 / 004
METPO	ΘΕΣΣΑΛΟΝΙΚΗΣ-THESSALONIKI METRO	ЕРГО: CON-06 / 004	- PROJECT: CON	-06 / 004
2	History of Revisions			

2.1 <u>Revision</u>

2.1.1 List of Changes

First issue of this document, then no list of changes is defined.

	ltem #	Reference	Rem	nark / Question / Deficiency	Response	Changed Sections
	RA.01	CON-06/004- AIASA- 10672/07.03.2017	Par give the com com the s syst the serv etc.	ticular attention should be n to the communication among PLCs (manner of munication, protocol of munication), the munication of the PLCs with servers of the em at local and central level, communication among the ers at local and central level,	We agreed. All requests are reported in the Changed Section.	§ 4.1
			More deta diffe will (Mic	eover, provide references as iled as possible to the two rent software programs that be used for the safe CBACS rosoft, Unix)	We are reported in the Changed Section.	§ 3.5.4
			as betw OCC SMF	regards the communication veen the safe CBACS of the c and the safe CBACS in the R and their cases of failure.	We agreed. All requests are reported in the Changed Section.	§ 4.1 § 4.2
			Dese failu serv PLC case OCC	cribe the operation in case of re between one of the two ers, as well as of the safe s inside the OCC, as well as in e of complete failure of the C or the SMR	We agreed. All requests are reported in the Changed Section.	§ 3.5.3.1 § 3.5.3.2 § 4.1
			Prov safe bette	vide more information on the PLCs and the safe panels for er understanding.	We agreed. All requests are reported in the Changed Section.	§3.5.3
			Mak BAC	e separate submittals for the S and for the Depot BACS.	There described in are different paragraphs. So the submission is only one.	
	RA.02	Internal Review	On p in t (Tur (1A1 six, The Fore Stati 1T0	bage 22/49 the Jet Fans PLCs the Track to Depot – 1A14 inel Nea Elvetia) are two (4/JFA & 1A14/JFB) and not according to the LBACS DFD. Jet Fans PLCs in the estation near New Railway ion- 1T01 will be named 1/JFA & 1T01/JFB.	Reported in the Changed Section.	§3.6.2
			On Field Elec	page 34/49 in the notice the d PLC will be Schneider tric products and not Rockwell	Reported in the Changed Section.	§ 3.5.2
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Hμ/	/ νια -Date	Αρχείο-Filename		BACS (Building Automatic DFD – Integrated Archite	on Control System)	Σελίδα -Page 17 / 61

Table 2-1 – Revision A – List of Changes

	KATAZKEYA	Salini Mpregilo	Ansaldo STS	A Hitachi Group Compan	SELI SELI	HITACHI @Hitachi Rail Italy, Spa
	к	οινοπραξία ΜΕΤΡΟ ΘΕΣΣ	AONIKHE		ЕРГО: СО	N - 06 / 004
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			Automation produ	ucts.	D	
			In page 41/49 in first sentence up to now are according to the L	h paragraph 3.6.2 the PLC cabinets 95 and not 85 _ocal BACS DFD.	Reported in the Changed Section.	§ 3.6.2
			On top of page 4 PLCs in the Fore Railway Station named 1T01/JFA the Jet Fans PLC Depot – 1A14 (Tu are two (1A14/J and not six. Corr 14 accordingly.	2/49 the Jet Fans estation near New - 1T01 will be & 1T01/JFB and Cs in the Track to unnel Nea Elvetia) FA & 1A14/JFB) ection of figure 3-	Reported in the Changed Section.	§ 3.6.2
			On page 49/, connection of t station TLC WAN the OTE/SAF PLC page 22/49 is r different PLC ca prefers.	49 the double he LAN to the N is realized from C cabinet while on ealized from two ibinets which AM	Reported in the Changed Section.	§ 3.6.2
	RA.03	Internal Review	Update the Overa	all to DFD Stage	Figure 3-3	§ 3.3.1
			Update the Archi equipment to DFI	tecture of LBACS D Stage	Pg. 35 Figure 3-9	§ 3.5.3
			Changes of ir clarification of tl Local BACS' PLC	mage for more he distribution of C in the station	Figure 3-14	§ 3.6
	RA.04	Internal Review	"The Field PLCs form local optic: two redundant separated conne LAN/WAN Swit 9907) with higi redundant archite TLC in the telex The BACS woo SMR (Safe and connected to a SMR (2.3), which via two redund same L3 LA (OmniSwitch 990 Room (3.4t). In case of communication (fault) or fault of the LAN part of 9907 continues the local comm BACS workstatio	are connected to al ring and have and physically ections to the L3 ch (OmniSwitch nly resilient and ecture supplied by com room (3.4t). rkstations in the d no Safe) are L2 Switch in the n in turn connects ant links to the N/WAN Switch 7) in the Telecom loss of WAN e.g. due to F.O. the OCC BACS, the OmniSwitch to operate, thus unnication of the ms with the Field	Reported in the Changed Section.	§ 3.1
Β Αναθ	17.11.2017	1G00PS250R789B	PLCs at station le independently of connection to the Further to this pr PLCs can be als the local switchbe in § 3.6.4." BACS (ME – RE BACS	Evel is maintained, of the gateway of the gateway e OCC via WAN. rovision, the Field so controlled from oard as described Σύστημα Ελέγχου Αυ constrained constrained S Cloud and an of the second and the sec	τοματισμού Κτιρίων) ωμένης Αρχιτεκτονικής το Control System)	1G00PS250R789 Σελίδα-Page
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		EK	salini 👘	Ansaldo	STS A Hitachi Group Comp	INY SELI	HITACHI
	KATAZKEYAS	TIKH A.E.			SOCI	ETA' ESECUZIONE LAVORI IDBAULICI 5.3.A.	. @Hitachi Rail Italy, Spa
	Ko	οινοπραξία	ΜΕΤΡΟ ΘΕΣΣ	AAONIKH	Σ	ЕРГО: С	ON - 06 / 004
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				Other parts Ch.3.3.1, updated acc	of the document (e.g. 3.5.1, 4.3,) to be cordingly.	Reported in the Changed Section.	§ 3.3.1 § 3.5.1 § 3.6.4 § 4.3
							§ 4.3
в	17.11.2017	10	G00PS250R789B	B	ACS (Σύστημα Ελέγχου Α Ε – Περιγραφή της Ολοκλη	υτοματισμού Κτιρίων) ρωμένης Αρχιτεκτονικής	1G00PS250R789
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		•				

2.1.2 List of Open Issues

First issue of this document, then no list of open issues is defined.

Table 2-2 – Revision A – List of Open Issues

Item #	Reference	Remark / Question / Deficiency	Response
OA.01	None.	None.	None.

в	17.11.2017	1G00PS250R789B	BACS (Σύστημα Ελέγχου Αυτοματισμού Κτιρίων) ΜΕ – Περινοαφή της Ολοκληρωμένης Αργιτεκτονικής	1G00PS250R789
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			An	Saldo STS A Hitachi Group Company	E LAVORI EDRAULICI S.P.A	HITACHI @Hitachi Rail Italy, Spa		
	Ko	υνοπραξία ΜΕΤΡΟ ΘΕΣ	ΣΑΛΟ	NIKHE	ЕРГО: СО	N - 06 / 004		
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3	3 BACS Architecture Description							
3.1	<u>General</u>	Description						
The I	BACS Syster	n, as showed in the " F	igure	3-1", is made of the:				
•	CBACS n	o Safe (OCC or SMR))					
	• T	o control and monitor	all Vei	ntilation, HVAC systems and E&	M systems wi	thin the		
	st	tations, shafts and tun	nels u	nder normal conditions;				
	о Т р	o perform real-time tre arameters.	ending	and Statistical Process Control	(SPC) for son	ne critical		
•	Depot-CB	BACS						
	• T	o control and monitor	all HV	AC systems and E&M systems	within the Adn	ninistration		
	B	uilding, the Operation onditions.	Contr	ol Centre (OCC) and the Depot	Area under no	ormal		
•	CBACS S	Safe (OCC or SMR)						
	o T st	o monitoring and cor tations, tunnels and ale	mman ong th	d equipment involved in <u>Tunne</u> e railway in emergency scenaric	Ventilation	located in the		
•	Local BA	CS (Field Components	s of the	e three previous listed subsysten	ns)			
	 To control and monitor all E&M, HVAC, Jet Fans, BSF, OTE and SAF equipment systems within the Administration Building, the Operation Control Centre (OCC) and the Depot. Area, stations, shefts, tupped, and responses under percent. 							
	e	mergency condition.						
The BACS System communicates with three External Systems (represented in the "Figure 3-1" by dashed lines): Time Server, for the clock synchronization, SMS and ATS for exchange of relevant alarms and events.								
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Figure 3-1 – Layer of Building Automation Control System (BACS)

The general architectures of the BACS is realized by integration of two levels:

- Human Machine Interface Layer (Central BACS).
- Field Layer (Local BACS);

The CBACS are based on the servers, workstations and printers installed at the OCC, in the SMRs, in the DCR and in the ECR.

The HMI Layer is a distributed Client-Server Architecture based on SCADA System Framework, including:

- SCADA System Server application that communicates with the PLCs of the Field Layer and collects, processes, stores, distributes data towards the SCADA System Client application.
- SCADA System Client application that collects the data distributed by the SCADA System Server and shows them by appropriately developed Graphic User Interface (GUI).
 The GUI allows also sending data towards the connected SCADA System Server.

Then, from the workstation where the SCADA System Client runs, the operator can interact either in monitoring or in control with the Field Layer and plant equipment through the connected SCADA System Server.

The Field PLCs are connected to form local optical ring and have two redundant and physically separated connections to the L3 LAN/WAN Switch (OmniSwitch 9907) with highly resilient and redundant

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salini impregilo	Ansaldo STS	A Hitachi Group Company	SECLEZONE LAVORI IDRAULICE S.p.A	HITACHI

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architecture supplied by TLC in the telecom room (3.4t). The BACS workstations in the SMR (Safe and no Safe) are connected to a L2 Switch in the SMR (2.3), which in turn connects via two redundant links to the same L3 LAN/WAN Switch (OmniSwitch 9907) in the Telecom Room (3.4t).

In case of loss of WAN communication (e.g. due to F.O. fault) or fault of the OCC BACS, the LAN part of the OmniSwitch 9907 continues to operate, thus the local communication of the BACS workstations with the Field PLCs at station level is maintained, independently of the gateway connection to the OCC via WAN. Further to this provision, the Field PLCs can be also controlled from the local switchboard as described in § 3.6.4."

The independency concept between the OCC and SMR allows the management of the Station by SMR if there isn't any communication with the OCC (OCC fault).

The Local BACS (represented in the "Figure 3-1" by dashed lines) it's constituted by the Field Layer PLCs and all related components (i.e. fiber optic LAN ring). The Local BACS is described in the next paragraph 3.6.



A block diagram that summarizes the limits of BACS components involved is shown in follow Figure 3-2:

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3.2 Interfaces components of BACS and other Subsystem

In the table below, the block diagram that summarizes the limits of BACS components involved (shown in Figure 3-2) and the external interfaces are combined for better shown the main component interface:

		Internal interfaces	External interfaces			
		DEPOT LBACS (administration and depot building)	LOCAL BACS (tunnel, station and shaft)	ATS	SMS	Time Server
CBACS	OCC		\checkmark	\checkmark	\checkmark	\checkmark
no Safe	SMR		 ✓ (only with the Local BACS of SMR) 			✓
CBACS	000		\checkmark	\checkmark	\checkmark	\checkmark
Safe	SMR		 ✓ (Local BACS required from the Tunnel Ventilation scenario) 			~
DEPOT-	000	✓			\checkmark	\checkmark
CBACS	Depot	\checkmark			\checkmark	\checkmark
1		Teble 2.4 Ma	in component interface			

Table 3-1 - Main component interface

3.3 Overall Architecture of BACS System Components

3.3.1 Integrated H/W solution

The general architecture of the entire BACS system, formed by components in Line Area (Technical Room, SMR) and Administration - Depot Building (OCC, DCC) are summary in the follow figure (refer to **"Figure 3-3**").

The "TLC" boxes and the "cloud" simbols represents the networking equipment and is out of scope of the BACS..

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3.4 <u>CBACS</u>	no Safe and Depot-CBAC	S H/W & S/W Arch	<u>nitecture</u>					
3.4.1 Subs The Building Auto	ystem's Overview mation Control System (BAC	CS), as showed in	the " Figure 3-1 ", is made c	of the:				
CBACS n	o Safe							
0 T	o control and monitor Ventila	ation, HVAC syster	ms and E&M systems withi	n the stations,				
sl	nafts and tunnels under norn	nal conditions;						
о Т р	o perform real-time trending arameters.	and Statistical Pro	ocess Control (SPC) for sor	ne critical				
Depot-CB	ACS							
• T	o control and monitor all HV	AC systems and E	&M systems within the Adr	ministration				
B	uilding, the Operation Contro onditions.	ol Centre (OCC) a	nd the Depot Area under no	ormal				
The BACS comm	unicates with three External	Systems (renrese	nted in the " Figure 3-4 " by	(dashed lines).				
Time Server, for t	ne clock synchronization. SN	/IS and ATS for ex	change of relevant alarms	and events (for				
more details, refe	to the ID.05 document).		J					
	Time Server	ATS	SMS					
BA	ACS System							
	CBACS NO SAFE		Depot-CBACS					
, L		ECR	ECR OCC					
FL	eld		LBACS					
	<u>Lananianan</u>		Contractionses;					
	Figure 3-4 - Building A	Automation Contr	ol System (BACS)					
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METP	ο Θεσσανοι	NIKHΣ-THESSALONIKI METRO	ЕРГО: CON-06 / 0	04 - PROJECT: CON	-06 / 004	
The two l	general archi evels:	itectures of the CBACS no	SAFE and the Depot-CBA	CS are realized by	integration of	
	Human MField-Leve	achine Interface-Level (HM el;	I-Level).			
The and	HMI-Level is in the DCR.	based on the servers, works	stations and printers installe	d at the OCC, ECI	R, in the SMRs	
More	e details abou	t Filed-Level are present in	the 3.6 paragraph			
3.4.2	2 CBAG	CS no Safe H/W Architectu	ıre			
The	OCC CBACS	no Safe H/W architecture (refer to " Figure 3-5 ") is base	ed on:		
•	 One coup Servers (I 	le of industrial grade Serve PWS room);	rs, in redundant hot-backup	configuration, act	ing as SCADA	
	• Two indus	strial grade Operator Works	tations, acting as SCADA C	lients (MCR);		
•	One indus	strial grade PC for Emergen	cy Room purpose (ECR);			
•	 Four Prin Laser Prir 	ters: one Line Printer (PSF nter (MCR).	R), two B/W Laser Printers	(MCR and ECR)	and one Color	
The	SMR CBACS	no Safe H/W architecture (refer to Figure 3-5), is base	d on:		
•	One indusTwo Print	strial grade Workstations, ac ers: one Line Printer and on	cting as stand-alone SCADA ne B/W Laser Printer.	Server and Client	t;	
For r	nore details r	egarding the mentioned con	nponents refer to ID.05 doc	uments.		
The other components in the "Figure 3-5", highlighted in yellow, are part of the BACS Safe						
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Figure 3-5 – CBACS H/W Architecture

The operator workstations act as SCADA Clients in the distributed Client-Server Architecture of the CBACS no Safe at the OCC. They are designed to carry out the main functions below listed:

- To collect in real-time the events/status/alarms distributed by the OCC CBACS no Safe Server application;
- To send data towards the OCC CBACS no Safe Server application;
- To provide the GUI for monitoring and control the Field Layer and plant equipment.

By default, the SCADA Client GUI act as client is configured to attach to either Primary server or Secondary server and will automatically switch to the Secondary server when the primary server fails. For detail of OCC CBACS no Safe and SMR CBACS no Safe refer the Technical Specification **ID.05**.

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The OCC CBACS S/W architectur	e is based on the cor	nponents listed in th	ne " Table 3-2 ":	
Computer		Installed S/	N	
Server 1-2 Operating System (OS): Server Operating System Database Management System (DBMS): SQL-based relational DBMS Server Edition SCADA Server application				
Server 1-2	DBMS Server Edition	ment System (DBl on Ilication	MŠ): SQL-based relational	
Operator Workstation 1-2	DBMS Server Editi SCADA Server app Operating System (SCADA Client appl	ment System (DB on lication (OS): Workstation C ication	MŠ): SQL-based relational	

The ECR CBACS S/W architecture is based on the components listed in the "Table 3-3":

Computer	Installed S/W			
Operator Workstation	Operating System (OS): Workstation Operating System			
Operator Workstation	SCADA Client application			
Table 3-3 – ECR CBACS S/W components				

The SMR CBACS S/W architecture is based on the components listed in the "Table 3-4":

Computer	Installed S/W				
	Operating System (OS): Workstation Operating System				
	Database Management System (DBMS): SQL-based relational				
Workstation	DBMS Workstation Edition				
	SCADA Server application				
	SCADA Client application				
Table 3-4 - SMR CBACS S/W components					

Table 3-4 – SMR CBACS S/W components

For more details regarding the mentioned components refer to the ID.05 documents.

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ΜΕΤΡΟ	ΘΕΣΣΑΛΟΝ	ΙΙΚΗΣ-ΙΙ	HESSALONIKI M	ETRO	ЕРГО: CON-06	/ 004 - PROJECT: CON	-06 / 004	
3.4.4 Depot-CBACS H/W Architecture								
The O	CC Depot-C	CBACS F	H/W architectu	re (refe	er to "Figure 3-5") is bas	sed on:		
•	One indus	strial gra	de Server acti	ng as S /orketa	SCADA Server (PSR);	Client (MCR)		
•		strial ara	de Operator M	orkata	tion, acting as SCADA	Client (MCR),		
•		strial gra	de Operator w	orksta	tion, acting as SCADA			
•	(MCR).	nters: on	e Line Printer	(PSR),	one B/W Laser Printer	(MCR) and one Cold	or Laser Printer	
The D	CR Depot-C	BACS F	H/W architectu	re (refe	er to " Figure 3-6 ") is ba	sed on:		
•	One indus	strial gra Printer (de workstation	acting	as stand-alone SCAD	A Server and Client (DCR);	
•	One B/W	laser pri	nter used for p	rinting	logs on-demand (DCR).		
For mo	ore details r	egarding	the mentione	d comp	oonents refer to the ID.	05 documents.		
The oth The "T through	her compor ʿLC" box re h WAN.	nents in t present f	he " Figure 3-6 the networking	6", are I equip	part of the field compor ment and mean that is	nent of the LBACS. a independent LAN	interconnected	
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Figure 3-6 – Depot CBACS H/W Architecture

There are two operator workstation acts as SCADA Client in the distributed Client-Server Architecture of the Depot-CBACS at the OCC. The Depot BACS is designed to carry out the main functions below listed:

- To collect in real-time the events/status/alarms distributed by the Depot-CBACS server application;
- To send data towards the OCC Depot-CBACS server application;
- To provide the GUI for monitoring and control the Field Layer and plant equipment.

For detail of DEPOT CBACS refer the Technical Specification ID.05.

3.4.5 Depot-CBACS S/W Architecture

The Depot-CBACS S/W architecture is represented in the "**Figure 3-6**", where the External Systems S/W and the components out of the scope of this technical description are highlighted by dashed lines.

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The I	The PC for maintenance purpose is not represented because it's not a part of the S/W architecture. The OCC Depot-BACS S/W architecture is based on the components listed in the " Table 3-5 ":							
	Computer Installed S/W							
	Se	rver	Operating Database DBMS W SCADA S	System (0 Managen Orkstation l Server appl	DS): Worksta nent System Edition cation	ition O ı (DBI	perating System MS): SQL-based	d relational
	Operator Wo	orkstation 1-2	Operating	System (C	DS): Worksta	tion O	perating System	
\vdash	PC for ma	aintenance	Operating	Svstem ((S): Worksta	tion O	perating System	
	pur	pose	Utility Pad	kage: Offici	ce Software S	Suite	peruting bystern	
	•	Table	3-5 – ÓCC	Depot-BA	CS S/W com	npone	nts	
The I	ECR Depot-E	BACS S/W archite	ecture is ba	sed on the	components	listed	I in the " Table 3-	6 ":
	Com	puter		<u> </u>		ed S/\	N	
	Operator V	Vorkstation	Operating	Derating System (OS): Workstation Operating System				
	Com	puter	Operating	System (Install	ed S/\	N Inerating System	
	Oper Data Workstation DBM SCA			Database Management System (DBMS): SQL-based relational DBMS Workstation Edition SCADA Server application				
		Table 3		Depot-CB	CS S/W con	nnon	onte	
				Јерог-СВА		пропе	ents	
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3.5 CBACS Safe H/W & S/W Architecture

3.5.1 Subsystem's Overview

The CBACS Safe subsystem is the safety-related HMI layer of the main Building Automation Control System (BACS).

Its purpose is to operate fire scenarios for tunnel ventilation, involving equipment, located in the stations, tunnels and along the railway.

The building automation equipment involved in safety functions is listed below:

• Tunnel ventilation (**TV**): over-track exhaust fans (OTE), supply air fans (SAF), blast shaft fans (BSF), jet fans (JF) and Motorized Fire Damper (MFD).

Operation and monitoring of equipment for purpose other than fire scenarios for tunnel ventilation is not through CBACS safe but from CBACS no Safe subsystem; this guarantees separation of safety-related subsystems and functions from non safety-related systems.

The "Figure 3-7" shows the main groups and layers of BACS, with its partitions in:

- Human Machine Interface layer (HMI layer), thus the CBACS Safe;
- Field Layer, composed by PLCs and all relevant components (Local BACS), directly controlling plant equipment.

The Field Layer (Local BACS) is described in the next paragraph **3.6**.

The CBACS Safe is composed of Workstation, Safe Panel and Safe PLC (boxes safe). The workstations is stand-alone client/server installed at the OCC and in the SMRs; in any case in every boxes safe runs the HMI application, which:

- Communicates data with Local BACS (is connected to the LAN's Field PLCs through Switch TLC in the SMR), in monitoring and command direction;
- Provides a set of interactive graphic screens (the GUI), which allows the operator to monitoring and command the scenarios of tunnel ventilation.

The HMI-Level safe is based on a stand-alone SCADA system (Server and Client), the boxes safe in OCC (WS, Safe Panel and Safe PLC) are able to communicate with the external systems: data are collected from Safe PLC. In SMR are able to communicate with server clock.

The CBACS Safe in OCC and SMR, in addition to communicating with Local BACS also communicates with some external systems (represented in the Figure 3-7 by dashed lines) like this schema:

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In case of detected non- correct working, CBACS Safe shall:

- Inhibit execution of incorrect commands by Safe PLC;
- Inform operators about malfunctioning by Safe Panel.

The following CBACS Safe components are to execute the safety functions:

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OCC boxes safe (WS, Safe Panel and Safe PLC) and Local BACS:					

• SMR boxes safe (WS, Safe Panel and Safe PLC) and Local BACS.

Dangerous states (undetected malfunctioning that leads to the inability of executing safety functions on demand) of CBACS Safe are:

• Inability to properly execute monitoring and command safety functions.

3.5.3 CBACS Safe H/W Architecture

The safety architecture (static view) of the CBACS Safe subsystems at the OCC and in the SMRs is shown in the **Figure 3-8** below:



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3.5.3.1 OCC Architecture

The OCC CBACS Safe architecture, shown in **Figure 3-8**, is based on **dual channel with diagnostic** architectural pattern (Fault Tolerance, 1002D).

Both channels can independently execute the same functions, then, both channels and peer components implement the same **safety requirements specification** (SRS) but, to reduce hardware common cause failures and systematic failures, diversity measures have been applied between corresponding hardware and software components.

For each channel, the main components and relevant functions are below described:

- WS. It provides the HMI which allows the operator to execute the safety monitoring and command functions. It's made up by one Industrial PC (IPC) equipped with network interface card, graphic card, audio card, visual display unit (VDU), keyboard and mouse (or touch-screen). The workstation alone is an "unsafe" component, which hardware faults and software errors need to be detected.
- Safe PLC. This section describes SafePLC<A> and SafePLC components, which are equal both channels. Both Safe PLCs are fail-safe and are based on Schneider Electric products series below listed:
 - BMEP584040S M580 SIL3 CPU
 - BMEP58CPROS3 M580 SIL3 COPROCESSOR
 - BMENOC0301 MODBUS TCP/IP ETHERNET/IP MODULE
 - PMXUCM0302 ETHERNET UNIVERSAL COMM TCPOPEN MODULE for communication with external system (no SIL).
 - BMXSDI1602 SAFETY DIG 16I 24VDC SINK
 - BMXSD00802 SAFETY DIG 8Q TRANS SOURCE 24VDC, 0.5A

These product series are certified for applications up to SIL 3, according to IEC61508 standard.

In **Figure 3-9** the UML diagram is showing the deployment of the software package OCC.SafePLC<k>.SW (the whole software to be executed) on the hardware node OCC.SafePLC<k>, where k = A or B. The UML diagram is also showing the main hardware features of the OCC.SafePLC<k> node.

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Figure 3-9 - Deployment of OCC SafePLC SW (OCC.SafePLC<k>.SW) on SafePLC Hardware

Notice: The choice of Schneider Electric products is justified to simplify interoperability with Field PLC, which use Schneider Electric products also, then TCP/IP communication protocol. It allows implementation of safety protocol over TCP/IP (SafeCommLayer). In particular the TLC system must ensure one NTP Server with 20 milliseconds tolerance to ensure the correct safety protocol working. For the communication (via peer to peer) between two PLCs in Safe modality it's necessary have an NTP synchronization. For this synchronization, the PLC's through Ethernet module (BMENOC0301) obtains the synchronization from the centralized NTP Server.

The Safe PLC is equipped with:

- One CPU, with safety diagnostic unit;
- One Coprocessor CPU with safety diagnostic unit;
- Two network interface cards (EtherNet Module BMENOC0301), one for data exchanging with workstation, and one for data exchanging with Field PLC
- One programmable module for external subsystems (ATS and SMS).
- One (or more depending on modularity) digital input card with total 16 channels;
- One (or more depending on modularity) digital output card with total 8 channels.

Using of two network interface cards guarantees "data filtering" function of Safe PLC; in fact, workstation is physically separated from Field PLC and external subsystems.

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It's the required "safe" component in the architecture. Executes three main functions:					
 Fault detection of workstation, which consists in comparison and data validation / integrity checks, applied to data exchanged with workstation; 					
 Fault reaction on workstation fault(s) detected which consists in enabling / disabling of workstation command functions (using fail-safe characteristic of PLC) and activation / de- activation of signalisations to subsystem's operator (through the Safe Panel); 					
 Communication mediator between workstation and Local BACS. Thus, acts as data filter which avoids (a) workstation command sending without data validation / integrity checks and (b) workstation visualization of incorrect data without error signalisation. 					
Safe Panel. This paragraph describes SafePanel's components and next Figure 3-10 shows the relevant layout. SafePanel					
Workstation diagnosis					
Workstation diagnosis Enabling Status Failed Run Failure Reset Photo-Resistors 8 1 8 1 1 1 1 1 1 1 1 1 1 1 1 1 1					
Figure 3-10 – SafePanel's Layout and Components					
It's composed by:					
 One red lamp IndLampFailed (see "Failed" in the figure above), which indicates that workstation fault / error has been detected from SafePLC, then commands have been automatically disabled. 					
• One key-switch KeySwEnablingDisabling, which have to be selected in "Disable" position					

by operator when workstation fault / error has been detected or maintenance procedures

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have to be initiated. When it's selected in "Disable" position workstation commands are disabled.
 One red lamp IndLampDisabled (see "Disable" in the figure above), which indicates that workstation fault / error has been detected from operator or maintenance procedures are progressing, then commands have been manually disabled by KeySwEnablingDisabling.
 One green lamp IndLampEnabled (see "Enable" in the figure above), which is complementary to IndLampDisabled, then KeySwEnablingDisabling is selected in "Enable" position.
 One green lamp IndLampRun (see "Run" in the figure above), active only when both IndLampFailed and IndLampDisabled are de-activated, which indicates that workstation is properly operating and then commands are enabled.
 One push-button PushBtnReset (see "Failure Reset" in the figure above), which have to be pressed to restore commands enabling after automatic or manual disabling, then IndLampRun lights-on.
 A number of photo-resistors (see "Photo-Resistors" in the figure above), each one connected to SafePLC's digital input module, for detection of incorrect alignment of data transmitted from SafePLC and data shown from workstation's VDU. In particular, SafePLC cyclically compares two counters, the first local of SafePLC's (e.g. the sequence number of data transmitted to the workstation) and the second local of workstation and shown on the GraphicUserInterface (e.g. the sequence number of data received from SafePLC). The GraphicUserInterface shows workstation's counter in binary format on eight adjacent little square where photo-resistors are positioned; e.g. white colour square indicates "on", whilst, black colour square indicates "off". When SafePLC compares the two counters, its local and feedback detected from photo-resistors, if they have the same value, then workstation is properly operating, else workstation fault / error is detected from SafePLC, then commands are automatically disabled and IndLampFailed lights-on.
To improve reliability of feedback, 3 lines of eight photo-resistors can be used and 2003 voting can be executed by SafePLC.
It's the auxiliary hardware component, directly controlled by Safe PLC (through I/O modules) which provides signalisations and control facilities, to subsystem's operator. It has to be used in combination with the HMI to support successful execution of safety monitoring and command functions. It's made up by set of LED-lamps, one key-switch, one push-button and a number of photo-resistors.

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In case of IPC fault(s) detected by Safe PLC, the operator realizes anomaly condition by SafePanel indications and moves the other workstation to continue execution of safety monitoring and command functions.

3.5.3.2 <u>SMR Architecture</u>

SMR CBACS Safe architecture, shown in **Figure 3-8**, is based on dual channel with diagnostic architectural pattern (1002D); similar to OCC, then the same components and measures (diversity, fault detection and reaction) are applied to the SMR.

Anyway, some details have to be described:

- Each SMR has a single WS, Safe PLC and Safe Panel, resulting alone 1oo1D architecture;
- Each SMR can monitor and command emergency scenario of adjacent station.

In case of workstation fault(s) detected by Safe PLC, the operator realizes anomaly condition by Safe Panel indication. Thus, it informs (by phone or other media) the SMR operator in the adjacent stations (<i-1> or <i+1>), so the other operator continue execution of safety monitoring and command functions by its own workstation.

Diversity measures between adjacent SMRs (both channels) are in workstations components, which have different IPC, VDU and software implementation. Whilst, both channels' D-components:

- Safe PLCs in SMR and OCC have the same hardware implementation (with exception of the programmable module that is present only in OCC);
- Safe Panel in SMR and OCC have the same hardware implementation.

The hardware of the WS of SMR<1> is the same of OCC WS<A>, whilst the hardware of the WS of SMR<2> is the same of OCC WS, and so on until SMR<13>.

For detail of safety protocol of CABS Safe, refer the Technical Specification ID.03.

3.5.4 CBACS Safe S/W Architecture

This paragraph describes WS<A> (first channel) and WS (second channel) components.

The workstations have different hardware (IPC and VDU), operating system and SW application framework but the graphics will be identical from the operational point of view. In term of HW reliability parameters, workstations has MTBF >= 60.000 hours.

In **Figure 3-11** the UML diagram is showing the deployment of the software package OCC.WS<k>.SW (the whole software to be executed) on the hardware node OCC.WS<k>, where k = A or B. The UML diagram is also showing the main hardware features of the OCC.WS<k> node.

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Figure 3-11 – Deployment of OCC Wo	orkstation SW (OCC.WS <k>.SW) on WS Hardware</k>
OCC.WS <k>.SW K = A,B</k>	
Wor - Vis	rkstation isual Display Unit;
- Ke	eyboard and Mouse (or touch-screen);
l - Gr	raphic Card /minimum resolution pixels 1.920 x 1.080;
- Au - Ne	udio Card; etwork Interface Card;
- M1	TBF >= 60.000 hours.
OCC.WS <k></k>	

On WS<A>'s Industrial PC basically runs:

- Linux SUSE operating system;
- Digia Qt SW application framework.

On WS's Industrial PC basically runs:

- Microsoft Windows 7 operating system;
- Microsoft .Net SW application framework.

The next Figure 3-12 shows the main architectural software packages of OCC Workstation<A>.

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Figure 3-13 – OCC Workstation SW Packages

Also here, over **Microsoft Windows 7** operating system and **Microsoft** .**Net** SW application framework there are two additional packages:

- GraphicUserInterface: It's the set of interactive graphic screens and related objects, which allows the operator to execute the safety monitoring and command functions. It includes an event handling module which defines, for a limited set of detectable events (e.g. mouse-clicked, keypressed), the specific behaviour of graphic objects (e.g. background colour change) or other actions to do.
- Safety Subsystem: is the group of all modules that guarantee the safety of OCC CBACS Safe.

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3.6 Local BACS H/W Architecture

3.6.1 Subsystem's Overview

This paragraph describes, for Local BACS, the HW components and relevant operating location.

Local BACS (LBACS) system consists of local substations cabinets equipped with necessary inputs and outputs for monitoring and control of electrical and mechanical CW sub systems

3.6.2 Local H/W Architecture

The system is composed by **95** (ninety five) PLC Racks distributed in the **13** (thirteen) stations, tunnel and shafts, at the depot and at the administration building.

The PLCs shall provide through the associated I/O modules the interface to the Tunnel Ventilation and HVAC switchboards as well as to the Station and Tunnel E&M equipment and shall perform local control logic, data manipulation and control of the plant equipment as listed hereafter:

Tunnel Ventilation equipment:

- Blast Shaft fans (BSF), and associated equipment
- Platform Over Track Exhaust fans(OTE) and associated equipment
- Platform Supply Air Fans (SAF) and associated equipment
- Tunnel ventilation Jet fans (JF);
- Shaft Roller Shutter Doors (RSD);
- Motorised Dampers (MOD);
- Fireman box (FB);

HVAC and E&M equipment

- Supply Air Fans for technical area (SAF);
- Exhaust fans (EXF);
- Motorised dampers (MOD);
- Chillers, their pumps and plant;
- Heat Pumps (HP);
- Fan coil units (FCU);
- Uninterruptible Power Supplies (UPS);
- Normal and Emergency Lighting;

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 Pumping and drainage systems; 	

- Hydrants, hose reel systems and deluge valves (DEV);
- Lifts;
- Escalators;

The whole Local BACS for technological systems consists of 13 LBACS installed in Stations; each of them will be composed of 5 fully cabled cabinet containing the PLC unit and relative I/O modules for hardwire interconnection to equipment and Modbus (RS485) Gateway modules (only for HVAC PLC). This unit will be connected to the WAN and consist in the following equipment:

- BSFE (Blast Shaft Fan East side) system;
- BSFW (Blast Shaft Fan West side) system;
- SAF/OTE (Supply Air Fan Over Track Exhaust) system;
- HVAC (Heating, Ventilation and Air Conditioning) system;
- E/M (Electro-Mechanical) system.

Therefore, each station includes 5 (five) PLC racks, as already described, and each PLC interacts and controls the equipment just mentioned.

In addition to PLCs mentioned before, there are 4 (four) JF PLCs (2 at the start of tunnel and 2 at the end of tunnel), 1 (one) MFD PLC, the Depot PLCs (EM and HVAC) and the 14 (fourteen) PCP PLCs subdivided between 6 (six) stations.

For more details, see Figure 3-14

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Figure 3-14 - Overall of PLC's Station

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	 BSF System, is related to Ventilation equipment of the Western and Eastern shaft, and shall comprise of appropriate power feeders. switchgear and automation for the blast shaft fans and 									
		relative eq	uipment	with that shal	l intera	act.				
	•	SAF/OTE shall comp supply air ducts at th	System, prise ap via the s e area c	is related to the propriate pow SAF ducts at the power/above t	the Ve ver fee the pla track	entilation e eders, swi atform side and relativ	quipment of t tchgear and es and the OT re equipment	he statio automa rE fans with tha	on platform a tion for the that extract a t shall interac	nd tunnel, and SAF fans that air via the OTE ct.
	•	HVAC Sy appropriate heating of	stem, is e power personr	s related to feeders, swit nel rooms, pas	HVAC chgea senge	equipme or and auto or rooms ar	nt and shall omation for th nd technical re	compri ne Venti coms of	se of and s lation, Air Co the station.	shall comprise anditioning and
	•	E/M Syste stand pipe	m shall system	comprise of e , normal and e	lectric emerge	control pa	anel of the eq 1g.	uipment	: escalator, li	fts, pumps, dry
	•	JF System switchgear	ı, is relat r and au	ted to Ventilat tomation for th	ion eq ne jet f	uipment, a ans and re	and shall com lative equipm	prise of ent with	appropriate that shall int	power feeders, eract.
	Tunnel I commai of 4 fan:	between fo nd the rele s.	restatior vant JF	n and "New Ra (Jet Fan) sub	ailway' systen	' station (S n (1T01/JF	01) includes : A, 1T01/JFB	2 (two) I). Each	PLC Racks th JF PLC man	at monitor and ageds a group
	Tunnel commai of 6 fan	between "N nd the rele s.	√ea Elve vant JF	etia" station (S (Jet Fan) sub	13) ar systen	nd East Sh n (1A14/JF	aft includes 2 A, 1A14/JFB	! (two) F). Each	'LC Racks th JF PLC man	at monitor and ageds a group
	The Eas Fire Dar	st Shaft ind mper) subs	cludes 1 system.	(one) PLC R	acks t	hat monito	ors and comm	nands th	ie relevant M	FD (Motorized
	The De comman	pot Buildir	ng & Aro vant HV /	eas (also nan AC and E/M si	ned C ubsyst	complex 1) tems.	includes 6	(six) PL	C Racks that	at monitor and
	The Ad comman	The Administration Building (also named Complex 2) includes 5 (five) PLC Racks that monitor and command the relevant HVAC and E/M subsystems.							at monitor and	
	The number and type of PLCs concerning Depot (Complex 1 and 2) could be different by the Figure 3-15									
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HVAC Heating, Ventila and Air Condition	HVAC Heating, Ventil and Air Condit	HVAC Heating, Ventilation and Air Conditionin	HVAC Heating, Ventilation and Air Conditionin	HVAC Heating, Ventilation and Air Conditioning	E/M Electro-Mechanical	Complex 1			
MFD Motorized Fire Dur	nper					East Shaft			
J F Jet Fan - A	JF Jet Fan - B					Tunnel between "Nea Elvetia" sti	ation (S13) and East Shaft		
JF Jet Fan - A	JF Jet Fan - B					Tunnel between forestation and	"New Railway" station		
OTESAF Over Track Exhau Supply Air Fan	BASE Blast Shaft Fan WEST	BIAST Shaft Fan EAST	HVAC Heating, Ventilation and Air Conditioning	E/M Electro-Mechanical		13 Stations			
РСР						6 Stations			
		F	igure 3-15	– Local BA	CS – PLC Type				
All PLC R	acks house	e all equipmer	nt necessar	y for monitor	ing and commar	nd; thus:			
 Power supply units for electronics devices and hardwired I/Os; 									
	Protection units against over-voltage, over-current, short-circuit circuits;								
 Ethernet switch(es) and electrical-to-optical media converter(s); 									
 Ethernet switch(es) and electrical-to-optical media converter(s); PLC components, which include housing chassis, CPU, communication modules, DI/DO modules. All the cabinets described earlier will be connect to the WAN through I/O card and network devices. 									
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Quar	ntity and typo	logy of equip	ment will be o	different from	site to site (and	d PLC to PLC) in	order to keep
into a	account, the r	elevant I/O sig	gnal to manag	je.			
The o	cabinets will I	be connected	to one UPS p	ower line.			
Impl	emented Pro	otocols:					
•	Modbus o	ver TCP/IP;					
•	Ethernet/I	P;					
•	Modbus o	ver Serial RS	485;				
•	SIL 2 Safe	e protocol (bas	sed on time s	ynchronizatio	n server master	clock).	
Inter	faces:						
•	Copper R	J45 Ethernet f	for DTN conne	ection;			
•	Copper ca	able for Power	rsupply				
•	Copper ca	able for earth o	connection				
•	Copper ca	able for Hard-v	wired I/O data	with field eq	uipment;		
•	Copper ca	able for Serial	I/O data with	field equipme	ent;		
•	Fiber Opti	ic cable for LA	N LBACS.				
For r	nore details,	see ID.11					
Hard	lwired conne	ection:					
•	According	to Figure 4-2	2, for each Sta	ation.			
Mod	Bus RS485 o	connection:					
•	According	g to Figure 4-2	2, for each Sta	ation in HVAC	cabinet.		
TCP	/IP using cop	oper connecti	ion and DTN	facilities:			
•	Communi	cation servers	at OCC				
Ethe	rnet using c	opper conne	ction and DT	N facilities:			
•	PLCs time	e Synchroniza	tion				
The	Figure 4-2 b	elow shows s	ystem's archit	tectural view,	including netwo	ork connections for	or Local BACS
of St	ation and De	pot. The "clou	d" symbol wit	h the equipm	ent inside, repre	esent the network	king equipment
(DTN	I) and is out o	of scope of BA	CS.				
	_						
3.6.3	5 Local	S/W Archite	cture				
The I	PLCs softwar	e architecture	will be based	l on:			
•	Real Time	e Operating Sy	ystem (RTOS) that ensures	s deterministic e	ngine features;	
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• Application Software that executes the raw data scaling in engineering units (field interface by means of hardwired or networked signals) and strategy execution.

Development software will provide the standard tools to configure, program, diagnose and maintain programs and devices (PLCs and RIOs).

All software shall be developed using appropriate techniques and measures to ensure that the software and firmware meets the systematic failure requirements of all specific safety functions at least at SIL 2. The application will be implemented using programming languages compliant to IEC 61131.

The software shall comprise a hierarchical structure which using techniques that functionally breaks down the requirement in to a few smaller, more manageable, comprehensible functions having well defined interfaces shall be used.

The PLC Software programming shall use industry standard programming languages like Ladder logic; however functional block or structured text can be used where required to reduce the complexity of the program code or to perform complex mathematical tasks or algorithms.

If more than one programming language is used, it shall be used in a consistent manner and shall be seamlessly integrated into the PLC system to avoid confusion in understanding the application.

The organization of the program data, data tables and program files within the PLC shall be structured and methodical in approach using different files for functions to allow ease of understanding.

Reuse of proven software in equivalent applications is to be encouraged.

All software shall be understandable, analyzable, testable, verifiable and maintainable, and shall be designed and fully documented so that it shall be managed from competent staff.

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3.6.4 Operation Mode and Control

There are different modes to control the local equipment.

Normally commands can initiate from OCC, Subsystem level (if present), and equipment level (if present) that is the highest priority level in the command execution. As well, a Fireman Box mimic panel that can be used as intermediate level in the command chain. Fireman Box can control only a subset of subsystems, those related to safety in critical conditions.

The choice of the control mode is performed by means of hardware selectors.

The Operators is able to initiate manually the control of all plant and equipment from:

- 1. OCC operator workstation;
- 2. SMR operator workstation;
- 3. Local switchboard via pushbuttons.

In manual mode all automatic control on the selected equipment is disabled.

On deselecting equipment from the Automatic to the Manual mode the equipment state shall remain unchanged. The operator shall perform all control actions after selection to the Manual mode.

Table 1 below summarises the control locations for manual operation of equipment.

E	quipment esignation	Equipme	ent use	Control available	Location
El	ectrical vitchboards	Motor Control Centre (MC This is the central motor of fans and MODs. Th electrical protection and equipment under contr enclosed PLC-panels wit Tunnel Ventilation and H Systems. Local control can be select this location	Remote/Local or Remote/ Local normal/ Local emergency	Blast shaft and station plant rooms	
FB	FB Fireman Box This is a pushbutton operated back up panel that is principally used in emergency situations			Remote / Scenario	Station concourse
SI Oj Wo	SMR Operator workstationComputer terminal with graphical interface within the station used by the operator for plant and equipment monitoring and control of the Tunnel Ventilation and HVAC Systems and E&M systems			Auto / Manual	SMR
	OCC Computer terminal with graphical interface within Operator the central Operations Control Centre used by the operator for plant and equipment monitoring and control and parameter adjustments of the Tunnel Ventilation and HVAC Systems and E&M systems.		Auto / Manual	OCC	
		Table 3-8 - E	quipment Control Sourc	e	
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EXAMPLE INFORMED A HILACHI Group Company SELI HITACHI BOCHETA' BERCIZIONE LAVORI EDBALTILEI SAA. HILACHI Rail Italy, Spa
Κοινοπραξία ΜΕΤΡΟ ΘΕΣΣΑΛΟΝΙΚΗΣ ΕΡΓΟ: CON - 06 / 004
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Starting from the highest command priority level (equipment) we have:
 Equipment Maintenance Switch : when activated, setting the hardware equipment selector in this position on the equipment, all other levels can only monitor the 'OFF' state of the equipment. A data point is transmitted to the BACS when the maintenance switch is in position for maintenance.
This modality affects only the equipment or, in case of partial local, the group of equipment involved. The activity on equipment MUST be carried out by a Equipment Operator.
• Fireman Box Control Mode (Remote/Scenario): when the local hardware selector is on Scenario position on Fireman Box, the control is taken by this last one and both OCC and SMR can only monitor the state of the equipment. In this modality no command or sequences coming from OCC or SMR can be performed if related to equipment controlled by the Fireman Box. The Fire-mans' Box (FB) operation is controlled by a switch (REMOTE - SCENARIOS) on its panel:
1) In position "remote", no intervention is possible from the FB
2) In position "scenarios", 4 scenarios can be executed from the FB: 1 - fire on concourse, 2 - fire on platform, 3 - fire on train at platform/track-1, 4 - fire on train at platform/track-2.
The execution of these 4 scenarios are executed directly from the switchboard at the station level and the PLC OTE/SAF is hard wired notified, and informs the CBACS. Note that from the FB, scenarios can be executed even if the switchboard is in condition LOCAL - EMERGENCY MODE or LOCAL – NORMAL also. This mean that only if the equipment maintenance switch is active mode the FB can't be executed the scenario.
• Switchboard selector switch (Switchboard Level in accordance to): two data points are produced by the same selector switch.
 Remote Mode. In this position, the equipment connected to the electric switchboard cannot be locally controlled. All control is handled by the others level.
 Local Mode. Note that when activated, the Central BACS (HMI) can only monitor the state of the subsystem and the control will be available only from the switchboard. To have total control from CBACS the related switchboard must be in remote mode. The activity on subsystem must be carried out by a Switchboard Operator (maintenance).
• Switchboard selector switch (Switchboard Level in accordance to): three data points are produced by the same selector switch.
o Remote Mode. In this position, the equipment connected to the electric switchboard

cannot be locally controlled. All control is handled by the others level.

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- Local Normal Mode. In this position the equipment connected to the electric switchboard can be locally controlled, by the corresponding pushbuttons on the switchboard, through the CBACS SAFE software. This position corresponds to the operation with active supervision through CBACS SAFE. In this position the equipment connected can be controlled from the FB or by scenarios from the SMR or OCC (FB has the highest priority). In this position, all equipment protections and damper positions are taken into account. In this position, local control of equipment is accomplished through the BACS functionality. Note that when activated, the Central BACS (HMI) can only monitor the state of the subsystem, to have total control from CBACS the related switchboard must be in remote mode. The activity on subsystem must be carried out by a Switchboard Operator (maintenance)
- Local Emergency Mode. In this position, the equipment connected to the electric panel can be locally controlled from the electric panel or from the local FB. All equipment protections (Temperature sensors, vibration sensors, differential pressure sensors) and damper positions are ignored even if this leads to equipment destruction. In this position, local control of equipment is accomplished from the electric panel internal circuitry without the BACS intervention other than monitoring.
- Central BACS (OCC and SMR): At the SMR and the OCC, CBACS SAFE can be activated to
 execute all fire scenarios. These scenarios are executed through the LOCAL BACS PLCs if the
 switchboards are in condition REMOTE or LOCAL NORMAL. If a switchboard is in condition
 LOCAL EMERGENCY it will not execute, the commanded by the corresponding PLC.

When all selectors are in Remote position, it will be possible to control the local equipment from the Central BACS.

The full control depends anyway on the selector position at FB, Switchboard and Equipment levels.

The Central BACS System logs the change of state and especially when a change of operational mode is performed.

The activation of the maintenance switch will be treated as a low level Alarm for upper levels.

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4 Network, BACS Network & Diagnostic Features

Concerning to traffic information between and inside stations, the TLC is opportunely configured to manage the traffic and routing, in high performance (millisecond order), without modify or/and filter the data's package between different LANs of the BACS. But, also the telecommunication infrastructure must warranty the compartmentation of data:

the real time data must have a different routing from the no real time data (i.e. printer)

- default denied must be applied for routing data from the external systems, so only some IPs address for each external systems must be connected to BACS.

4.1 <u>CBACS Connection</u>

The Central BACS is the HMI layer of the whole BACS. The communication between the Central BACS Server PCs at the OCC and Local BACS PLCs of a station "i", is physically supported by WAN infrastructure (DTN).

The couple of CBACS (**Figure 3-5**) servers are connected, by their dual Network Interface Cards (NIC), to the OCC Ethernet TCP/IP LAN, so that, they are able to directly communicate with the OCC Operator Workstations and the External Systems Servers (Time Server, SMS Server and ATS) connected on the same LAN.

The communication between the CBACS servers at the OCC and PLCs of a station "N", is physically supported by WAN infrastructure, independently to SMR server

The WAN supports the peer to peer communication between the PLCs of the station "N" with the PLCs of the adjacent stations "N-1" (previous station) and "N+1" (next station), independently to SMR.

The LAN that are present in each site (OCC LAN, station LANs, depot LAN, Local BACS LAN) are completely interconnected via WAN.

The CBACS workstation in the SMR is connected to the station LAN, so that, it's able to communicate with the PLCs, "independently" to the OCC CBACS; at last it can communicate, through the WAN, with the Time Server.

The independency concept between the OCC and SMR allows the management the faults in the OCC CBACS.

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The OCC CBACS servers operate in applicative redundant (hot-backup) configuration, that is, one server only (Master or Primary) performs the main functions, whilst, the second server (Slave or Secondary) is continuously aligned with the first one, by specific redundancy management application task included in the SCADA System Framework.

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In event of failure of the Primary server, the redundancy management application activates the Secondary server immediately to perform the main functions, previously provided by the Primary; this operation will be made in a transparent way.

4.2 CBACS Safe Connection

ΜΕΤΡΟ ΘΕΣΣΑΛΟΝΙΚΗΣ-THESSALONIKI METRO

The couple of CBACS Safe Boxes (each one composed by workstations, Safe Panel and Safe PLC) at the OCC are fed by different power supplies and are connected to the OCC LAN, so that, they are able to communicate with the three external systems (Time server, SMS server PC and ATS server PC).

The communication between the CBACS Safe Boxes at the OCC and the Field PLC LAN of a station <i> is physically supported by WAN infrastructure.

The CBACS Safe Boxes in the SMR is fed by local station power supply and is connected to the station LAN, so that, it's able to communicate with the Field PLC LAN, "independently" to the OCC CBACS Safe; at last it can communicate, through the WAN, with the external systems Time server.

The workstation in the SMR allows the operator to execute locally the monitoring and command functions of plant equipment in case of OCC failures.

The CBACS Safe Boxes in the SMR allows the operator to execute the monitoring and command functions of plant equipment of the two linked adjacent stations.

For more details about communication and protocol, see **ID.12**

Considering **Figure 4-1** (package "WS" mean CBACS Safe Boxes composed of Workstation, Safe Panel and Safe PLC and the package "Field PLC" mean Local BACS PLC and Fiber Optic LAN), we define the scope of the safety system being the CBACS Safe.

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4.3 LBACS Connection

Different segments of network are foreseen to connect Local BACS cabinets to WAN. Below a brief description of each segment:

WAN segment: this network connects the LAN's Field PLCs through L3 LAN/WAN Switch in the Telecom Room, to the central server at the OCC via the DTN Network. With this system, the PLCs shall communicate with the servers of near station, with the BACS servers at the OCC and, finally, each PLC shall communicate via peer to peer with the neighbouring station.

Local Optical Ring: this network connects the local PLCs. Is the LAN's Field PLCs. Each PLC shall communicate via peer to peer with the PLC in the LAN. To avoid single point of failure on the network, a ring topology protocol is implemented. This protocol is able to manage correctly the network reconfiguration in case of fault of a communicating element on the ring.

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The Figure 4-2 shows system's architectural view of the connection of each Station.

4.3.1 Diagnostic Features

The Local BACS Subsystem will provide self-diagnostic information. Diagnostic information is divided by function:

• Power supply, Communication, Acquisition Cards, PLC.

Each functional unit contains diagnostic information deriving from equipment that realizes the specific functionality. A brief explanation is depicted below:

Power Supply:

For Power Supply the following Diagnostic information is foreseen:

• Surge Protection Device failure:

In case an internal Surge Protection Device fails, a cumulative alarm at cabinet/RIO level will be generated.

 24VDC Power supply failure : In case a 24VDC power supply configuration fails, a cumulative alarm at cabinet/RIO level will be generated.

Communication:

For Communication unit the following Diagnostic information is foreseen:

• Network device Failure

This signal arises when there is failure on one or more Communication module. It is a cumulative signal.

• Connection to OCC Failure

This alarm arises in case the substation PLC cannot communicate with Central BACS server. It is generated at substation level.

Connection to LOCAL BACS PLC Failure
This alarm arises in case Central BACS server cannot communicate with F

This alarm arises in case Central BACS server cannot communicate with PLC. It is generated at Central BACS level.

Acquisition Cards

For Acquisition cards the following diagnostic information is foreseen:

• Card Failure

A failure occurrence on a DI, DO, AI card will be transferred as cumulative failure to Local HMI. This alarm does not identify the single channel, but it is a cumulative one related to a single Card. For Central BACS this alarm will be provided as cumulative at cabinet level.

PLC

For substation PLCs, the following Diagnostic information is foreseen:

PLC Failure

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A non balting failu	ire occurrence on a l		be transferred as	cumulative failu	re to both Local

A non-halting failure occurrence on a PLC will be transferred as cumulative failure to both Local HMI and Central BACS.

The PLC software shall include a 'watchdog' timer system to monitor and detect faults and to cause the equipment to enter a recovery state in the case of failure of the operational software. The case of Halt of PLC will generate a different alarm as already defined in Communication diagnostic ("Connection to CW PLC Failure" and "Connection to Central BACS Failure").

The following table summarizes the diagnostic information divided by cabinet substations will be provided.

Function	Diagnostic Alarm	CABINET
	Surge Protection Device failure	\checkmark
	Power supply line	\checkmark
24VDC Power Supply failure		\checkmark
	Network device Failure (cumulative)	\checkmark
	Network device Failure	al
Communication	(for each communication card)	v
	Connection to Central BACS Failure	\checkmark
	Connection to Local BACS PLC Failure	
Acquisition Cordo	Card failure (for each card)	
Acquisition Calus	Card failure (cumulative)	
PLC	PLC Failure (cumulative)	
-	Table 4.4.1 and DACC Diagnostic signals	

Table 4-1: Local BACS Diagnostic signals

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Figure 4-2 – Local BACS – Details Architectural of Station

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